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An Assessment of the Resilience of Hospitals to Environmental Impacts in Los Angeles County

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An Assessment of the Resilience of Hospitals to Environmental Impacts in Los Angeles County

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Environmental Health Sciences

by

Sabrina A. Adelaine

2016
ABSTRACT OF DISSERTATION

An Assessment of the Resilience of Hospitals to Environmental Impacts in Los Angeles County

by

Sabrina A. Adelaine

Doctor of Philosophy in Environmental Health Sciences
University of California, Los Angeles, 2016
Professor Hilary Godwin, Chair

ABSTRACT

This study assesses the vulnerability of hospitals in Los Angeles County to environmental impacts, with the goal of providing guidance on how resiliency to these impacts could be built for hospitals across the LA basin. This study specifically focused the ability of LA hospitals to work collaboratively with other response agencies during disasters and the vulnerability of hospitals in Los Angeles to water outages and climate change. First, we performed a survey of hospitals across the United States to evaluate their current level of preparedness, partnerships with other agencies and best practices or barriers they experienced when coordinating during disasters. The results indicated that a top priority is to build tools that enable hospitals to feel connected to people in other organizations, but that does not entirely rely on an individual
personal connection during a disaster. Second, we assessed the ability of Los Angeles hospitals to remain operational during a major water outage using their current stored water and rationing strategies. The results of the survey showed that hospitals in Los Angeles County are grossly underprepared to remain at full operational capacity during a water outage event. Nearly 95% hospitals responding to the survey did not have the recommended amount of water, and further analysis of the recommendations showed that even that amount of water did not reflect the demands of the hospital. Third, we assessed what the impact of climate change will be on hospitals in Los Angeles County. Impacts on hospitals related to extreme heat events, wildfires, sea level rise, allergies and asthma were considered. Although hospital infrastructure is expected to be at greater risk due to flooding and wildfires, the actual healthcare visit rate is anticipated to remain at levels that are within the current fluctuations seen during seasonal influenza.
The dissertation of Sabrina A. Adelaine is approved.

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University of California, Los Angeles

2016
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<tr>
<td>EMS</td>
<td>Emergency Medical Services</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilating, Air Condition</td>
</tr>
<tr>
<td>HHS</td>
<td>Health and Human Services</td>
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<tr>
<td>ASPR</td>
<td>Assistant Secretary for Preparedness and Response</td>
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<td>AHA</td>
<td>American Hospital Association</td>
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<tr>
<td>TJC</td>
<td>The Joint Commission</td>
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<tr>
<td>HPP</td>
<td>Hospital Preparedness Program</td>
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<tr>
<td>LADWP</td>
<td>Los Angeles Department of Water and Power</td>
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<tr>
<td>OSHPD</td>
<td>Office of Statewide Healthcare Planning and Design</td>
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<tr>
<td>LACEMSA</td>
<td>Los Angeles County Emergency Medical Services Agency</td>
</tr>
<tr>
<td>MOU</td>
<td>Memorandum of Understanding</td>
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<tr>
<td>ED</td>
<td>Emergency Department</td>
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<tr>
<td>HPSA</td>
<td>Healthcare Provider Shortage Area</td>
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<tr>
<td>MUA</td>
<td>Medically Underserved Area</td>
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<tr>
<td>MUP</td>
<td>Medically Underserved Population</td>
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<tr>
<td>RNSA</td>
<td>Registered Nurse Shortage Area</td>
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<tr>
<td>PCSA</td>
<td>Primary Care Shortage Area</td>
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<tr>
<td>DSH</td>
<td>Disproportionate Share Hospital</td>
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<tr>
<td>VHFHSZ</td>
<td>Very High Fire Hazard Severity Zone</td>
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<tr>
<td>SRA</td>
<td>State Resource Area</td>
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<tr>
<td>FRAP</td>
<td>Fire and Resource Assessment Program</td>
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<td>NPS</td>
<td>National Park Service</td>
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ACKNOWLEDGEMENTS

Chapter 2 is a version of a previous publication which appeared in *Prehospital and Disaster Medicine* online on February 3rd, 2016 (Adelaine, S. A., Shoaf, K., & Harvey, C. (2016). An Assessment of Collaboration and Disasters: A Hospital Perspective. *Prehospital and Disaster Medicine, 31*(02), 121–125). I would like to thank the co-authors for their contributions. Specifically, I would like to thank Caitlin Harvey, former staff member with the Centers for Public Health and Disasters for performing the statistical analysis of the major data sets, and contributing to the writing and editing of the manuscript. I would also like to thank Dr. Kimberly Shoaf (Associate Professor Emerita in the Department of Community Health Sciences in the UCLA Fielding School of Public Health) for the grant that funded the project, and setting the framework for the study, as well as providing guidance on the paper’s direction. Dr. Shoaf continued to provide support after her transition to Utah University, where is currently an Associate Professor in Family and Preventive Medicine.

Chapter 3 is adapted from a report that I submitted to Los Angeles County Emergency Medical Services Agency in December 2015. I would like to thank my collaborator on this report, Caitlin Harvey, former staff member for the Center of Public Health and Disasters, for her contributions: Caitlin Harvey for ensuring the completion of the data, and compiled the hospital profiles for each hospital in Los Angeles County. I would also like to Los Angeles County Emergency Medical Services Agency for their support in sending out the survey to the hospitals in Los Angeles, and giving me a platform to speak about my work.
I plan to submit a modified version of Chapter 4 will to *Prehospital and Disaster Medicine*. I would like to thank my collaborators on this project for their contributions. Specifically, Mizuki Sato, student at Columbia University for aiding the GIS analysis of the data. Dr. Yufang Jin (Assistant Professor in the UC Davis College of Agricultural and Environmental Sciences) for providing the mapping and historical wildfire data. I would also like to thank Dr. Godwin for steering me towards an investigation of climate change, reviewing and refining the study, and contributing to the writing and editing of the manuscript.

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CHAPTER ONE

Introduction and Overview of the Organization of the Thesis

Hospitals are the cornerstone of the healthcare system and when they are threatened, the health of our communities are put at risk. During Superstorm Sandy in 2012, hospitals in New York found themselves in a major environmental disaster. There were over 7,000 patients transferred during that time, including patients being transferred from facility to facility due to flooding in the hospital itself. Superstorm Sandy exposed the vulnerability of hospitals in New York to an environmental event, and many efforts have been put in place subsequently to make those hospitals more resilient. Similar to the hospitals in New York, California hospitals use an all-hazards approach based on historical data to planning that is designed to be effective in all scenarios, with specific adaptations made as needed. It is very unlikely that hospitals in California will face a Hurricane like Superstorm Sandy, but there are unique challenges for which they need to plan. This study identified specific challenges facing Los Angeles hospitals. Both prior to and during disaster events, hospitals in Los Angeles need to interact with a variety of local, state, and federal agencies. Because these interactions are central to hospital preparedness and response and because readers of this dissertation may not be familiar with all of the agencies and their relationships to hospital emergency planning, a diagram showing both the responsibilities of the organizations involved in hospital preparedness and response and how they interact with each other is provided in Figure 1.1. Likely challenges for LA hospitals include climate related healthcare impacts, water outage events and the coordination of care during a large disaster event. The overarching goal of the work presented in this dissertation was to assess the vulnerability of hospitals to the specific challenges that Los Angeles County hospitals are...
anticipated to face in the future, and make recommendations for how to increase their resilience and support the care of patients in the Los Angeles community.

Chapter 2 describes successful strategies that hospitals can use to develop healthcare coalitions that will provide them with greater resiliency in the event of new stresses and outages. Effective collaboration is critical to a robust response to potentially catastrophic events. Emergency Medical Services (EMS), Public Health, and hospitals all have active roles in providing for the health of the public during events but have not always worked together effectively. Recently, efforts have been made at a federal level to encourage the development of healthcare coalitions which hope to establish a framework that agencies can use to increase coordination between these agencies. Using a survey to collect factors that contribute to a successful collaboration between public health and EMS, as well as what barriers exist to collaboration, we assessed the results to provide guidance to hospitals. We found that resources need to be devoted to the development of both personal and technological solutions for keeping hospitals informed and connected during a disaster. The results of the survey included the identification of people as both a barrier and successful strategy to collaboration. Hospitals want to know that the information they are receiving is credible and reflective of the current state of the organization; however, relying on the personal abilities of each organization to connect and share during a disaster is impractical.

Chapter 3 highlights the vulnerability of the hospitals in Los Angeles county to a major water outage. Hospitals are large users of water for both potable and operational needs such as heating ventilation air condition (HVAC), medical air & vacuum, sterilization, and dialysis. An average hospital uses more water in one day than the average household in the U.S. does in a year. The potential for a major water outage event in Los Angeles is high due to our aging water
infrastructure. In addition, there is a 99% likelihood that a catastrophic earthquake on the San Andreas Fault line would disrupt incoming water supplies to region. As a result, hospitals must learn to conserve water and become more water independent. In Chapter 3, we report the results of a survey of hospitals across Los Angeles. We found that the current level of emergency water available to most hospitals in LA is severely lower than the amount of water that would be required to keep a hospital running in a major water outage event. Greater than 80% of the hospitals surveyed would not be able to maintain operations for longer than 12 hours.

Chapter 4 delineates the anticipated impacts of the climate change on hospitals in Los Angeles County. We know that climate change will have a significant impact on public health in Los Angeles County. Prior studies have focused primarily on direct and indirect impacts of climate change on the health of individuals. For instance, as a result of climate change, we anticipate increases in the incidence of allergies, asthma, and heat exhaustion. Indirect health impacts from climate change include impacts associated with flooding, sea level rise, water scarcity, and forest fires. Each of these direct and indirect impacts on health could result in increased numbers of clinic visits and would in turn affect hospitals in Los Angeles County and their ability to provide basic services to our population. Our assessment of the potential impacts that climate related events could have on hospitals in Los Angeles reveals that biggest challenge that the LA hospital system will likely face results from hospitals being in proximity to hazard areas such as wildfire zones and sea coastal flooding. By contrast, we found that the amount of emergency department visits anticipated to be generated from extreme heat events is likely to substantially lower than what is expected during annual seasonal influenza surges, even by mid-century.
Hospitals must remain open in any disaster event so they can take care of their surrounding community. In Los Angeles, hospitals are going to be impacted by environmental events. While climate-related visits are not a high percentage of the total number of ED visits, the potential for a hospital to be caught in a water outage, wildfire, or coastal flooding are high. The consequences of these events could be catastrophic and require evacuation, putting patients in potential harm. The work outlined here provides critical guidance for hospitals that demonstrates how they can be more resilient through the development of better communication, a stronger redundancy plan for water, and clear priorities for planning adaptation to climate change.
**Figure 1.1 Organizational Oversight Network and Relationships to Hospitals for Medical Emergencies.** Hospitals in Los Angeles County have a variety of agencies that they are accountable to and must coordinate with during a disaster. **Federal oversight.** At the federal level, Health and Human Services (HHS) oversees the coordination of public health infrastructure; the Public Health Service (PHS) is the uniformed branch of HHS that provides oversight for preparation for public health emergencies. The Assistant Secretary of Preparedness and Response (ASPR) develops the federal strategic plan for preparing the United States Healthcare Sector for disasters. The Hospital Preparedness Program (HPP) was developed following the events of September 2011, as a way to ensure national preparedness, and provide federal funding and oversight to preparedness of hospitals. The Centers for Medicare and Medicaid Services (CMS), which are located in a separate area of the Federal government, provide hospitals with reimbursement funding to support the care of patients who use Medicare and Medicaid as their primary insurance. The federal reimbursement program requires adherence to a comprehensive set of requirements, and hospitals are required to submit data on a variety of areas as well as undergo a triennial inspection by a contracted vendor of CMS. This contracted vendor is the Joint Commission (TJC), which provides the inspection and reporting services for CMS. TJC emergency requirements are mainly focused on ensuring the hospitals have plans that address all hazards. These plans must incorporate management of staff, management of patients, utilities, safety and security, resources and assets as well as overall hospital coordination. TJC does not evaluate the effectiveness of the plans. Reports are requested by TJC following large events to evaluate the hospitals response and responsibility to their patients. **State Oversight.** The California Department of Public Health (CDPH) has overall jurisdiction for assessing penalties
on hospitals for activities that put patients at risk or lack of adherence to regulatory standards. However, CDPH does not provide support to hospitals and is not specifically involved during disasters. If there is a large enough public health related concern, CDPH will coordinate with Los Angeles County Department of Public Health (LACDPH; see below). California’s Office of Healthcare Planning Design & Construction (OSHPD) ensures hospitals are built to state codes requirements. OSHPD has the authority to prevent the approval construction or renovation of hospitals based on the building code requirements. Hospitals are held to the standards that were enacted at the point when construction took place. OSHPD only enforces standards enacted after original hospital construction if significant additional construction takes place at the facility. OSHPD does not respond during emergencies or provide oversight, but would require hospitals to meet the latest standards if renovations were required following a large disaster. County oversight. Los Angeles County has a population of approximately 10 million people. Due to the large population, the county functions similarly to a state and that is reflected in the organizational structure. HPP funding in Los Angeles County is provided to Los Angeles County Emergency Medical Services (LACEMSA) in addition to funding provided to the entire state of California. LACEMSA is responsible for ensuring grant compliance to HPP and providing support and coordination of the hospitals in the county. During a disaster participating hospitals are allowed access to the resources outlined in the grant terms and are incorporated into a larger network of hospitals across the county. Reports are requested by HPP through LACEMSA following any incidents to demonstrate how the hospital used the resources provided by the funding and any opportunities for improvement or gaps in their response. The county department of public health, LACDPH, also works with hospitals on a regular basis to plan for public health emergencies and provides support to individual hospitals during outbreaks,
highly infectious patient visits, and disaster events. LACDPH does not serve as a penalizing agency for hospital responses to disaster events.
CHAPTER TWO

An Assessment of Collaboration & Disasters, A Hospital Perspective

This manuscript has been published in Prehospital and Disaster Medicine. Adelaine, S. A., Shoaf, K., & Harvey, C. (2016). An Assessment of Collaboration and Disasters: A Hospital Perspective. Prehospital and Disaster Medicine, 31(02), 121–125

ABSTRACT

Introduction: There is no standard guidance for strategies for hospitals to use to coordinate with other agencies during a disaster.

Hypothesis/Problem: This study analyzes successful strategies and barriers encountered by hospitals across the nation in coordinating and collaborating with other response agencies.

Methods: Quantitative and qualitative data were collected from a web-based study from 577 acute care hospitals sampled from the 2013 American Hospital Association database. The results were analyzed using descriptive statistics.

Results: The most common barriers to collaboration are related to finances, ability to communicate, and personnel.

INTRODUCTION

Hospitals’ ability to provide the best patient care during an emergency is dependent upon their ability to coordinate effectively with other agencies and service providers.1-3 In the past, hospital emergency management programs focused on building resilience to disasters by ensuring that their facilities were self-sufficient and well-prepared.4-5 However, experiences in recent disasters
have shown that an ability to work effectively with other agencies and service providers is equal- ly important to the ability of hospitals to provide safe patient care during emergencies. Prior to Superstorm Sandy, many hospitals on the East Coast had basic preparedness plans that were developed based on their experiences during Hurricane Irene, but these plans focused on taking a small surge of patients and sheltering in place with their employees. During Superstorm Sandy, the Healthcare Facility Evacuation Center in New York was used to coordinate the dispersal of patients from the storm and coordinate with the hospitals. Total patient transports were near 7,000. Through interviews with hospitals, Toner et. al identified significant challenges with the process. The overriding problems fell into three categories: command, control, and communication. The hospitals were unable to communicate due to technology failures, and used cell phones, text messages, radios and news broadcasts. The inability to communicate caused a subsequent shift in command of the evacuation process from the centralized Healthcare Evacuation Center to the hospitals themselves. The lack of command prevented the process from being controlled and instead caused a large amount of patients to be evacuated to a small number of hospitals and other hospitals received very few. This experience highlighted the need for hospitals to coordinate with a wide range of agencies -- including Emergency Medical Services Agency (EMS), Public Health, and Governmental Emergency Managers to plan appropriately before disasters, respond appropriately during disasters and make corrections and adjustments after disasters. Currently, there isn't clear guidance on how hospitals should work with other response agencies.

The U.S. Department of Health & Human Services (HHS) through the Office of the Assistant Secretary for Preparedness and Response (ASPR) developed fifteen emergency support functions, which organize governmental, and private sector resources to most effectively support
critical infrastructure including medical services. ASPR developed the hospital preparedness program, and uses it to attempt to facilitate collaborations between hospitals and other response agencies by requiring Health Care Coalitions. These coalitions include hospitals, local EMS agencies, long-term care facilities, and specialty care clinics and urgent care centers. However, the U.S. federal guidance developed for Health Care Coalitions does not outline specific strategies that should be implemented for better outcomes during a disaster. A study conducted by Walsh et. al found that this lack of detailed guidance is a significant challenge to effectiveness of Health Care Coalitions.

This study provides specific factors that need to be address for more successful collaboration with hospitals during a disaster. This report includes a survey of hospitals nationwide that was conducted to elucidate best practices for coordinating and collaborating with other agencies including public health, emergency management, and emergency medical services during disasters. This study also includes assembled gaps and challenges hospitals faced when attempting to collaborate with other agencies. Recommendations are made based on these findings for how individual hospitals, healthcare coalitions, and U.S. federal agencies can support focused efforts to help hospitals coordinate with other response agencies.

METHODS

The survey was designed using the emergency management sections of The Joint Commission, and previous studies regarding hospital preparedness. The survey contained 132 multiple choice, scaled, and open-ended questions. The questions evaluated the current state of preparedness at hospitals, their perspective on the preparedness of the other agencies, and the hospital
experiences collaborating with those agencies. West Los Angeles hospital emergency planners piloted the survey in order to ascertain internal validity of the questionnaire.

A random sample of 1,982 U.S. acute care facilities was obtained from the 2013 American Hospital Association database (AHA), which contains approximately 6,500 hospitals. The sample was stratified by HHS region; 200 hospitals were selected from each region, with the exception of Region 1, which contained a universe. 577 hospitals responded, yielding a response rate of 29.7%, after accounting for 13 unreachable hospitals.

In order to reach each facility, the standard Dillman method of survey research was utilized; this used a mailed invitation addressed to the hospital executive listed in the AHA database, with instructions that the letter be forwarded to the facility Emergency Manager or most appropriate staff member. In order to complete the survey, the participant logged onto to a web-based questionnaire hosted by Snap Survey with a unique identifier included in the initial letter. Two weeks after the letter was sent, a postcard was sent to all hospitals that had not yet completed the survey. Two weeks later, a second letter was sent to all remaining non-participants. SPSS version 21.0 was used to analyze data; preliminary analyses included simple univariate descriptive statistics. The open ended questions were coded based on functional categories of personnel, financial, and technology.

The study was reviewed and approved by the Institutional Review Board at both affiliated Universities.

RESULTS
Hospitals have a basic level of preparedness, and no longer need guidance on how to internally prepare for disasters. When asked questions related to The Joint Commission standards for the
basic components of an Emergency Operations Plan, most hospitals (>90%) responded that they have all the fundamentals including communications, surge planning, and utility failure plans (Table 2.1). Hospitals are actively participating in coalitions, at a high rate. An overwhelming 85% of hospitals belong to healthcare coalitions. These two areas were primary foci for previous efforts to build hospital resilience, and are the building blocks for preparedness. However, individual preparation of a hospital and participation in a healthcare coalition alone are not enough to ensure a successful partnership and safe patient care during a disaster. Hospitals identified barriers to successful collaboration in the areas of physical distance between collaborating entities, emergency management staffing, funding, communication, and reliance on personal relationships.

Physical Distance Between Collaborating Entities

The distance between neighboring hospitals and their collaborators creates one of the most basic described barriers to collaboration. As stated by one of the hospitals

“We are beyond Rural. Considered Frontier. The next closest Hospital to us is another Critical Access, 25 bed Facility. Larger Facilities are 2 to 3 hours away.”

A majority of the hospitals that responded identified themselves as being in a rural area, and about one third were categorized as Urban (Table 2.2). Less than one third of the hospitals belonged to a larger system. One hospital identified this as a major barrier

“Distance. We are located above the Arctic Circle in Kotzebue, Alaska. No road systems to other hospitals that are about 500 miles or greater distances away.”

The mean number of licensed beds was 193 and the median was 120 beds. The number of staffed beds was lower with a mean of 156 and median of 85.
Emergency Management Staffing

Having staffing with multiple responsibilities creates a larger barrier to being able to dedicate the time needed to participate in collaborative meetings. Approximately one third of the hospitals have less than one full time employee working in emergency management (Figure 2.1). This creates a significant barrier as stated by this hospital

“In critical access hospitals the person assigned to work on disaster planning has many other roles in the hospital. There is not enough money to hire someone full time to do this work. This is not a full time position. It is hard for hospitals to send someone to all the planning meetings. Therefore the hospitals are not fully represented on the coalition board.”

Slightly less than half of the hospitals had only one person working full time in emergency management. Sixty percent (60%) of hospitals with fewer than 50 licensed patient beds do not have a full time person working in emergency management. This prevents the employee from having the amount of time they need as stated by this hospital

“Lack of time, all of our coalition members are performing as Emergency Preparedness Coordinators part time while trying to fulfill their main roles within the hospital system.”

Very few hospitals had more than one person working in Emergency Management. The survey asked the total number of Full Time Employees, and this study speculates that for those that identified more than five FTE’s they were a part of health system and answer for the whole system instead of an individual hospital.
Funding

Funding was mentioned as both a barrier to preparedness and collaboration and as something that ensured success. 71% of hospitals stated their local jurisdiction received Hospital Preparedness Program (HPP) funding from the Assistant Secretary of Preparedness and Response (ASPR), and 69% stated that the hospital itself received such funding. Of note, 13% of the hospitals did not know if they received HPP funding. The funding from HPP was fairly distributed with hospitals citing amounts of less than $10,000, $10,000-$24,000 and $25,000-$49,000. Less than 5% received more than $49,000 annually, and nearly 32% left this question blank. The median amount was $19,000 and the mean was $32,999. Hospitals with more beds received more funding, but the average amount per bed is approximately $155, with hospitals that are smaller than 50 beds having a slightly higher average of $188. Fifty-five percent (55%) of the hospitals stated that they felt more funding would be useful for their emergency management program. Most hospitals stated a funding level roughly one third to twice as much as they currently have would be ideal for preparedness. Hospitals with 50 beds or less stated that the funding they would require was approximately $200.00 per licensed bed. The larger hospitals stated $235 per bed (Figure 2.2).

“Our Mutual Aid Coalition is reliant on individual hospital support and does NOT receive HPP funding. We continue to ask New York State for funding and are denied yearly; this severely hinders our ability to provide training, exercise support, and actual response efforts.”
“ASPR funding has decreased significantly to hospitals. Many hospitals are considering dropping out of the ASPR program as the deliverables are more time consuming than the funding provided.”

“Grant funding. That is it. If we didn't get money, we wouldn't meet (with other hospitals or agencies).”

Communications

Communication barriers included technology, accessing the right information, and having the correct contact. Hospitals used a variety of communication strategies. The effectiveness was strongest with interoperability with EMS at 89% and the lowest with Skilled Nursing Facilities at 11.40% (Figure 2.3). The barriers noted were both from being able to get the information they needed from communications, and having the right technology.

“In a perfect world receiving real time, accurate, concise information from an incident scene would be ideal. However, the reality is that we usually get information through EMS, Emergency Mgt or Law Enforcement that is incomplete.”

“The county is working to implement a new radio system, but at present the ‘old’ and ‘new’ systems don't communicate well so we have fragmentation.”

“The ability to communicate with someone within another organization that has the ability and understanding of their organization’s readiness and resources and has the authority to either make decisions or work with leadership that can.”
“Through the coalition we build relationships and contacts over time. One is able to respond quickly and more efficiently knowing these processes and contacts ahead of time. There is a level of trust and support when calls or request made etc.”

Collaboration

Overall, the factor that most contributed most to a successful collaboration with other hospitals was related to personnel, and that paralleled with the greatest barrier also being personnel (Figures 2.4 & 2.5). A majority of the other barriers that were specifically mentioned are related to personnel. The overall process mentioned in various ways by the hospitals begins with knowing the correct contact person. Once a contact person is established, having a relationship of shared expectations during a disaster was stated as required for success. Lastly, having organizational and logistical support to make that connection during a disaster was required. Any break in those components prevents successful collaboration between agencies.

DISCUSSION

These results indicate that hospitals are struggling to make connections needed for collaboration. The major factor contributing to both facilitation of collaboration and barriers to collaboration centered on personnel. Traditionally, emergency managers have relied extensively on relationships. The value of personal relationships is reiterated with the demonstration of it being both barrier and successful strategy. However, when that relationship strategy for collaboration breaks down through a variety of means including physical distance, staffing, funding, and communication, it can prevent any further course of action.
U.S. Federal and Regional agencies need to refocus funding and guidance on the establishment of partnerships across hospitals and other agencies. A two-part approach may be necessary for addressing the concerns about personal connections. The first approach may be to provide opportunities to increase the development of relationships by tying them to funding. U.S. Federal funding may need to include annual requirements to attend meetings, participating in exercises, collecting and distributing contact information. A second approach to address the need for personal relationships is to work towards removing the need to have specific relationships to be effective collaborating. It would include establishing processes that require you not to know an individual, but an assigned position for standard forms and requests.

LIMITATIONS
Due to the small amount of respondents to the hospital survey needs, the results may not be applicable to all hospitals. There may have been a participation biased by hospitals who are in need of additional funding. Participants were allowed to answer open-ended questions, the analysis of which included the identification of themes which is biased by the interpretation of the answers.

CONCLUSION
Collaboration with hospitals and other agencies is crucial to being able to effectively manage patients in a disaster. Alignment of funding, identification of barriers, and addressing gaps in the ability of hospitals to collaborate is required. This study begins to address funding needs, identify gaps and propose strategies for better collaboration. It will be necessary for U.S. federal funding
agencies to ensure that hospitals are using funds to address gaps and increase the ability of hospitals to collaborate effectively.

Relying on relationships during a time of crisis is not practical. It can be incredibly effective, but unreliable. Individuals who are collaborative may be affected by the disaster and be unable to respond at the time of the event. Conversely, if a hospital is unable to establish a strong relationship with other agencies the public suffers.
Figure 2.1. Percentage of Hospitals Surveyed With 0-1, 2-4, 11-50, 50 Full-Time Employees Dedicated to Emergency Management.
Figure 2.2. Financial Provisions for Hospital Emergency Management Use. Blue bars represent the amount of federal funding provided to hospitals for emergency management use; red bars represent the amount of federal funding responding hospitals perceived as being sufficient to support emergency
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Figure 2.5. Distribution of Factors That Inhibit the Hospitals Ability to Collaborate with Other Agencies.
Table 2.1. Demographic Description of Hospitals in the Survey.

<table>
<thead>
<tr>
<th>Hospital Setting</th>
<th>N</th>
<th>%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>175</td>
<td>0.303</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>297</td>
<td>0.515</td>
<td></td>
</tr>
<tr>
<td>Suburban</td>
<td>103</td>
<td>0.179</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>2</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>577</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
**Table 2.2.** Hospital Incorporation of Categories Into Emergency Operations Plan

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical supplies</td>
<td>566</td>
<td>98.40%</td>
</tr>
<tr>
<td>Staffing</td>
<td>538</td>
<td>93.60%</td>
</tr>
<tr>
<td>Support supplies</td>
<td>538</td>
<td>93.60%</td>
</tr>
<tr>
<td>Equipment</td>
<td>539</td>
<td>93.70%</td>
</tr>
</tbody>
</table>
CHAPTER THREE

Vulnerability of Hospitals in Los Angeles County in a Water Outage Event

This chapter is adapted from a report submitted by S. Adelaine and C. Harvey to Los Angeles County Emergency Medical Services Agency On December 15th, 2016.

EXECUTIVE SUMMARY

The water infrastructure in Los Angeles County faces many challenges. Many portions of the infrastructure are nearly 100 years old. The Los Angeles Department of Water and Power (LADWP) recently catalogued the system and gave ratings according to the likelihood of failure providing a grade on a scale from A to F. 44.5% of the piping in Los Angeles received a grading of C or lower. 40% of the piping that received a grade of D or F was installed in 1930 or earlier.¹ The fragility of the piping can be exacerbated by even minor earthquakes causing imperceptible damage until further damage causes an outage. This strong likelihood of failure is combined with a 99% likelihood of an earthquake on the San Andreas Fault, which could have catastrophic effects on the water infrastructure in Los Angeles according to LADWP evaluation of an earthquake model.² The Los Angeles Aqueduct was designed and built by 1913, at which time there wasn’t an ability to map earthquake fault lines. Both the Los Angeles Aqueduct and California Aqueduct cross over the San Andreas Fault Line. Both lines intersect the San Andreas Fault at a single point, the Elizabeth Tunnel, which if severely damaged would cut off Los Angeles from its two primary water supplies.
These vulnerabilities in the Los Angeles water infrastructure in turn pose a considerable risk to area hospitals, which use a large quantity of water to meet a variety of critical needs. Water is, of course, used by hospitals for sanitation services, including toilets, sinks and showers. Water is also used by hospitals as part of heating, ventilation and air conditioning for buildings and also to cool rooms that contain critical information technology hardware, which house essential data for electronic health records. The increase in new technology that uses water-cooling in hospitals has resulted in hospitals being even more dependent on access to large quantities of water. Many hospitals may also use water to provide their facilities with medical air and vacuum by using water-cooled air compressors. Finally, steam produced from water is used to sterilize equipment and to humidify operating rooms to a level of functional safety.

Two different regulatory groups provide guidance for hospitals to identify the amount of water they need to have stored to provide for resiliency to outage events (see Figure 1.1). The Office of Statewide Healthcare Planning & Design (OSHPD) sets forth specific requirements which are necessary to be licensed to take care of patients. Although these requirements are applied when a hospital is first built, or during major renovations or reconstruction, the requirements are not pushed retroactively. As a result, many hospitals which were built prior to the regulation are not required to meet these requirements. In 2013, OSHPD specified that hospitals must have access to sufficient emergency water to provide 50 gallons per licensed bed for three days (72 hours). OSHPD only requires hospitals to store 5,000 gallons on site, as long as the hospital has a protocol in place to use an outside contract vendor to provide additional water directly to the hospital in the case of an outage. The second requirement about emergency water resources for hospitals comes from The Joint Commission. The Joint Commission requirement focuses primarily on potable water. The Joint Commission requirements state: “As
part of its Emergency Operations Plan, the hospital identifies alternative means of providing the following: Water needed for consumption and essential care activities.” This requirement is often interpreted as solely requiring that hospitals only have sufficient drinking water to last 96 hours for people who may be in the hospital during a disaster. The Joint Commission’s only requirement for emergency operational water planning is that hospitals must have a plan written in place that addresses what will be done in the case of a utilities outage. The Joint Commission does not specify that hospitals must be able to operate at a level commiserate with what was provided before the event occurred.⁶

Neither the OSPHD or The Joint Commission requirements specify that hospitals have planning in place to address the possibility of a catastrophic water outage event such as might result from a break in a main water source that provides water to multiple hospitals (e.g., if a major earthquake were to occur in Los Angeles region or along one of the aqueducts that deliver water to Southern California). OSPHD regulations also do not take into consideration the possibility that one vendor may be contracted to provide water supply services to multiple hospitals and might be unable to meet the considerable demand that would result if multiple hospitals were simultaneously affected by a water outage. Unfortunately, the aging water infrastructure and high risk of major earthquakes in Los Angeles make catastrophic water outages a real possibility for our region.

To more fully elucidate current vulnerabilities of LA hospitals to major water outages and to provide guidance into how greater resiliency could be built, we conducted a survey of 38 Los Angeles County hospitals that are dependent upon municipal water for normal operations. This survey included 4 Level I trauma centers and Children’s Hospital Los Angeles.
This study provides critical insight into how hospitals could be better supported in their emergency water planning activities. When asked what specific barriers were preventing hospitals from being able to meet the water requirement, a majority (90%) of respondents indicated that space was an issue, and 67% of respondents noted a lack of funding as a barrier. The results of this survey also suggest that the vague nature of regulatory requirements may contribute to confusion on the parts of the hospitals regarding what constitutes an adequate water supply to be able to maintain critical services. Based on regulatory requirements, the target many hospitals are aiming for will only provide bottled water to the occupants of the building for 96 hours. Hospitals are not currently required to demonstrate which services (operative services, sanitation, basic medical care, etc.) they could sustain during a major water outage. This leaves open critical questions about the level of care hospitals will be able to provide during a major water outage event, even though this may be (e.g., in the case of a catastrophic earthquake) when their services are needed most.

In addition to providing critical data about how prepared area hospitals are for major water outages, this study also points to a need to build capacity in the ability of Los Angeles hospitals to conduct water emergency planning. One of the most critical aspects to building resilience within hospitals is to establish an accurate representation of the current state of each hospital’s water capacity. Unfortunately, a majority of the hospitals surveyed struggled to identify how much water they have stored, how the distribution of their supply is used, and the impact of an outage. For instance, when we asked hospitals to calculate how long they would be able to continue taking care of patients under a fictitious major water outage scenario, approximately 61% of the hospitals reported a timeframe that conflicted with (and were significantly more optimistic than) the results that we calculated based on the detailed
information they provided. As a result, we recommend that resources be provided to area hospitals to assist them with their water vulnerability assessments and outage planning activities.

**METHODOLOGY**

**Survey Design and Administration**

Prior to designing our survey, we obtained data from the Los Angeles County Emergency Medical Agency (LACEMA) from a previous survey conducted in 2012 California Hospital Association on preparedness for utility outages more broadly. 70 hospitals in Los Angeles County at least partially responded to the survey in 2012. We conducted a gap analysis to identify what additional data would be needed to characterize the state of preparedness of hospitals in Los Angeles County for a major water outage. This analysis revealed that additional data were needed in the following areas: basic hospital demographics, amount of water used daily by each hospital, what the water is used for within each hospital, what hospitals use as criteria for activation of water outage response plans, what mechanisms each hospitals uses to storage water and how much water they store on site, which hospitals have MOUs established with outside water vendors that can be activated in case of a water outage, and whether these hospitals have conducted tests of how they would connect to water delivery trucks in case of an outage. We then designed a second online survey to address these data gaps. The resulting survey was sent out by our partners at LACEMSA to emergency managers or appropriate staff to all 80 Hospital Preparedness Program participating LA County hospital facilities in March 2015. Emergency manager(s) completed the survey for each responding hospital; each manager provided data for their entire hospital.
Analysis of Survey Data

The response rate to the 2015 survey was 61% (i.e., 49 out of the 80 hospitals that were surveyed responded), even though LACEMSA indicated to area hospitals that participation in the survey was mandatory. The 2015 survey included some of the same questions as the original 2012 survey, so that data for hospitals that did not provide complete responses in 2012 could be gathered in 2015. Data from both the 2012 and 2015 surveys were included in the final analysis. In cases where the data provided by an individual hospital in 2012 and 2015 for the daily amount of water used were not consistent, the contact person for the hospital was asked to verify whether the data from 2015 were the more accurate. In cases where we were unable to verify if the 2015 data were more accurate, an average of the data provided in 2012 and 2015 was used to provide an estimate for further calculations.

Calculation of Amount of Emergency Water Required by OSPHD. We used the number of beds reported by each hospital to calculate how much emergency water each hospital would need to have available to be in compliance with the OSPHD requirement that they have enough water to provide 50 gallons per licensed bed for three days (72 hours).

Calculation of Amount of Time that Hospitals Could Remain Open and Fully Operational in Case of a Major Water Outage. We used three different scenarios to determine the amount of time that hospitals could remain fully operational in the event of a major water outage. In all cases, we used the daily water actually used by each hospital (as reported by the hospitals in the survey) to calculate how long that particular hospital could remain open. In Scenario 1, we assumed that each hospital actually had the amount of emergency water available that is
mandated by OSPHD. In Scenario 2, we used the data provided by each hospital about how much emergency water they actually have available. In Scenario 2, we assumed that hospitals would have ready access to all of the “emergency water” that they reported in the survey in the event of a major water outage, and did not distinguish between what emergency water sources could realistically be used for operations. In Scenario 2, stores of bottled drinking water reported by hospitals were included in the total available emergency water that each hospital could potentially use to maintain operations in the event of a major water outage. In Scenario 3, we also used the data provided by each hospital about the amount of emergency water they actually have available, but we assumed that there is not a mechanism by which hospitals could use bottled drinking water to maintain operations (e.g., to cool servers and humidify operating rooms), because the logistical challenge of pouring water out of bottles to maintain the building systems was deemed too impractical to consider. Hence, in Scenario 3, we did not include stored bottled drinking water in the total amount of emergency water that each of the hospitals has available to maintain operations. Instead, only water stored in large storage tanks that were directly connected to hospital infrastructure and for hospitals with MOU agreements, the amount of water that they contracted company would provide were included in the total amount of emergency water that each hospital had available for operations in case of a major water outage in Scenario 3. Once the water storage amount was determined for each scenario, the amount of time the hospital could remain operational was calculated by dividing the stored amount, by the amount of water used by the hospital in a 24 hour period, as provided by the hospital.

RESULTS & DISCUSSION

Many Los Angeles Hospitals are Dependent on the Same Water Sources
Los Angeles County derives all of its above ground water from two main sources: The Los Angeles Aqueduct and Colorado Aqueduct. The former is controlled by Los Angeles Department of Water and Power (LADWP), while the latter is controlled by the Metropolitan Water District. 44% of respondent hospitals listed LADWP as their primary source of water. (Figure 3.1.) These hospitals represent a capacity of 7,496 licensed beds. A large portion of the remaining hospitals indicated they receive their water from their local city provider, of which 37% are a part of the metropolitan water district and would be disrupted if that source was impacted. A disruption of the metropolitan water district would impact hospitals with a combined capacity of 6,898 licensed beds.

**OSPHD Emergency Water Requirements are Much Lower than Normal Daily Water Use by Los Angeles Hospitals**

Comparison the OSHPD requirements for emergency water for hospitals to the actual daily water use reported by individual hospitals reveals that that the amount of water required by OSPHD much lower than actual hospital water use. OSHPD calculates the amount water that should be stored at hospitals based on an average of 50 gallons per licensed bed for three days (72 hours). (Figure 3.2) This amount of water is intended to provide the basic support for hospitals in the event of a water outage. Not all hospitals surveyed provided information about their daily water consumption. However, the average daily water consumption was 48,727 gallons of water per day for those hospitals that did provide these data (n = 60). Given that the average hospital bed size for the hospitals surveyed was 256, if an average sized hospital used an average amount of water, the average water consumption by bed for hospitals in Los Angeles would be190 gallons per day per hospital bed. However, the amount of water that hospitals reported that they
consumed daily varied tremendously, from 10 g/day to 334,247 g/day. When divided by the number of beds that each specific hospital had, the reported daily water use ranged from 2 g per day per bed to 1752 g per day per bed. It is highly unlikely that the lower end results in this survey (10g/day and 2g/bed) are accurate. As a comparison the average amount of water that a single person uses flushing a single toilet is 9gal/day. The variability in the results of this survey demonstrate the need to provide hospitals with training and resources to more accurately measure their water use.

Most Los Angeles Hospitals Do Not Currently Meet OSPHD Emergency Water Requirements With Onsite Water Storage

The survey revealed that very few of Los Angeles Area hospitals currently meet even the relatively modest (and probably inadequate) emergency water requirements that are set by OSHPD with onsite water, as opposed to through an outside contract for emergency water. (Figure 3.3.) Many hospitals have some water stored on site: 62% of hospital respondents indicated that they had water tanks, and 36% maintained their tanks with full water. The amount of water stored in the tanks was an average of 27,003 gallons with a median of 2,125 gallons. Only 5 of the 72 of the hospitals (6.9%) that responded to the surveys indicated they had the OSHPD required amount of water stored for an outage disaster. For all but 3 hospitals surveyed, this stored water accounts for fewer than 12% of the average recommended OSHPD amount. The remaining 3 hospitals averaged 439% of stored water, strongly indicating that they may be outliers. (Figure 3.3) Hospitals were asked what major barriers have prevented their ability to store sufficient amount of water. 41% of responding hospitals indicated that space was a contributing factor, and money as the second most stated barrier. (Figure 3.7)
Multiple hospitals are relying on outside vendors to supplement their emergency water

Many hospitals reported that they supplement onsite emergency water storage with a Memorandum of Understanding (MOU) with a commercial water vendor to meet the OSHPD requirements for emergency water. 61 of the hospitals that responded to this question in either the 2012 or 2015 survey indicated that they had a MOU in place with an emergency water provider in Los Angeles County. Responses to the 2015 survey (n = 36), in which we asked what specific vendor the hospital was using indicated that multiple hospitals rely on the same outside vendors for service. 53% (19) of hospitals that have a MOU in place, and provided a vendor, indicated that they had an agreement in place with Arrowhead, having Arrowhead as their sole emergency water vendor. The vendor that has the next largest number of hospitals relying upon it as a source of external emergency water is Sparkletts, with whom 27% (n = 10) of the hospitals indicated that they have a MOU (Figure 3.4)

To assess whether hospitals would likely be effective at executing the contract with vendors, they were asked if they had tested the connection with the water provider trucks. This is important because 40% of hospitals that indicated that they had an MOU for water indicated that they intended to use this water to provide water to the entire building. (Figure 3.5) Only 36% of hospitals that have MOUs in place for external emergency water indicated that they had previously tested the hose connection to their facility. (48% of hospitals that indicated that they had MOUs in place did not respond to this question.).

An additional concern is that the likelihood of the water vendors being able to deliver the amount of water required to keep multiple hospitals open is small. An average tanker truck holds approximately 9,000 gallons, and to keep one hospital operating at the average of 48,000 gallons per day, it would require 5 trucks every 24 hours. This also requires that local infrastructure in
the county is functional enough to drive trucks across the county, which might not be the case in the event of a catastrophic earthquake or other major outage scenario.

**Most Los Angeles Hospitals Would Struggle to Remain Open for > 12 Hours in the Event of a Major Water Outage**

Finally, we calculated how long Los Angeles hospitals could realistically remain open (with 100% operation) in case of a major water outage under three scenarios. In all cases, we assumed that hospitals require the amount of water that they currently use daily to remain fully operational. In Scenario 1, we assumed that hospitals actually have the amount of emergency that is required per OSPHD (50gal/per licensed bed/day). In Scenario 2, we assumed that each hospital has the amount of emergency water that the indicated in the survey and that they would be able to use all of that water for operations. In Scenario 3, we assumed each hospital has the amount of emergency water that the indicated in the survey, minus the amount of bottled drinking water they have stored, since we felt that this water could not realistically be used for operations. The results of these calculations are shown in **Figure 3.6**.

**Scenario 1:** When we calculated the amount of time hospitals could remain operational if they had the OSHPD recommended amount of stored water, and found that 62 hospitals would remain operational for less than 12 hours. A comparison to the hospitals’ own estimates indicated that hospitals are over estimating the amount of time they can remain operational. Hospitals without storage data may be in this category.

**Scenario 2:** We found that when we calculated the amount of time hospitals can remain 100% operational based on dividing the daily water use by the total storage provided at each hospital
40 hospitals would remain fully operational for less than 12 hours, and that only 5 would be viable for longer than 72 hours.

**Scenario 3:** When we calculated the amount of time hospitals can remain 100% operational based on dividing the reported daily water use by amount of water stored not included bottled water we found that 48 hospitals would be fully operational for less than 12 hours. This indicates that 8 hospitals required the use of bottled water to remain operational longer.

**Scenario 4:** We asked hospitals themselves to report the amount of time they could remain operational with current storage, and 13 stated that they could remain operational for less than 12 hours, and 13 stated they could remain open for longer than 72 hours.

Particularly disconcerting was how much our estimates differed from the time that the hospitals themselves estimated that they would be able to remain operational in the event of a major water outage. (The hospitals’ own estimates are shown in the purple columns in Figure 3.6) 61% of hospitals’ self-reported estimates differed from those we calculated. For instance, whereas we calculated that 42 hospitals would remain viable for less than 12 hours, only 6 emergency managers estimated this for their own facilities. In all cases where there was discordance between our calculations and the estimated provided by hospitals, the emergency managers were more optimistic about how long they could remain operational than our calculations suggest are realistic.

Responses to other questions on the survey suggest that the many area hospitals plan to ration water in the event of a major water outage so that they can remain open longer, but that those water rationing strategies will probably not allow the hospitals to remain fully operational. Just under half (49%) of responding hospitals indicated that they were preparing for a water
outage by developing a water rationing plan that would reduce the overall amount of water the
hospital required to function during a disaster or major event. 91% of the hospitals that plan to
ration water have identified specific services that would be adjusted with the activation of a
water rationing strategy. The most commonly identified strategies were the reduction in
sanitation services such as toilets and showers, and the second most indicated was to cancel
elective surgeries. 70% of hospitals with water rationing plans (n = 23) were able to correlate the
water saved with a specific amount of time for which the hospital could remain viable. Hospitals
were then asked to provide an estimate for the amount of time they determined their hospital
would remain open if they used their water rationing strategy. Assuming the water rationing
strategies could be executed at time zero of the incident, 29% of these hospitals (n = 6)
calculated they would be able to maintain 100% operations for 0-12 hours. 0% stated 13-24
hours, 10% (n = 2) stated 24-36hours, 24% (n = 5) stated 36-72, 14% (n = 3) stated 72-96 hours
and 24% (n = 5) stated 96+ hours. 61% of the estimated timeframes provided by hospitals were
inconsistent with our estimation of the amount of time hospitals could remain 100% operational.

LIMITATIONS
This study was subject to several limitations. First, although combining data from the 2012 and
2015 surveys provided a more complete data set, doing so may have contributed to inaccuracies.
Secondly, self-reported data are, as previously mentioned, generally problematic. Inaccuracies
and outliers are likely in self-reported data, suggesting that standardized reporting mechanisms
for these data would help going forward. Thirdly, although completion of the 2015 survey was
mandated by the LAECSMA, only 49 of the 80 facilities surveyed responded (61%), indicating a
potential response bias. Furthermore, of the facilities that did reply, many completed the survey
more than once, changing their responses, or did not complete key portions. Again, this highlights the critical need for standardized reporting practices and procedures as noted earlier in the report.

CONCLUSIONS

Hospitals in Los Angeles are very vulnerable to major water outages. Hospitals use a large amount of water for both potable and non-potable means. The risk of a water outage event in Los Angeles is high due to both our aging water infrastructure and the high probability of a catastrophic earthquake occurring either in Los Angeles or along one or more of the aqueducts that provide water to the region. Oversight of planning for hospitals to prepare for a potential major water outage events is minimal, and hospitals across Los Angeles County are struggling to store enough water to be adequately prepared for a major water outage event.

Regulatory agencies do not currently provide clear guidance on how much emergency water hospitals should have to remain viable. The regulations only stipulate that a hospital needs to have plans for providing water alternatives in the event of a water utility outage, and that these plans should include consumption, sanitation, equipment, and care. Because it is challenging to fully assess the amount of water that is being used by a hospital are complex, many hospitals that responded to this survey struggled to quantify the daily amount of water they currently use, let alone how that water is used. The low response rate to the survey may be indicative of the inability of hospitals to answer questions regarding their water use.

Hospitals require support to be able to effectively plan for a water outage event. Water metering and professional consultation services may be necessary for each hospital to develop a clear picture of their normal water use. Once hospitals have identified their regular water usage
rates, and for what it is used, more accurate estimations can be made regarding timeframes for hospital viability during a water outage event, and what specific reductions in functions within in a hospital would impact patients the least while providing the biggest gains in water savings. Additionally, a standard expectation for what information hospitals should be able to provide in regards to the level of care they will be providing following a water outage event would aid hospitals in gaining leadership support.

Once a clear measurement of water use on a daily basis is established, and an expectation for the amount of water required to be available during a large event is set, alternative sources of water should be explored beyond water storage. Alternative water sources may include wells or aquifers. Most hospitals will require financial, engineering and regulatory support to efficiently access alternate water resources. In cases where hospitals want, in cases of emergency, to be able to access water sources that they are not currently using (e.g., aquifers), appropriate use contracts would need to be developed ahead of time with the required regulatory agencies. Beyond the addition of alternate water resources, the inclusion of recycled water protocols and infrastructure would allow for maximum flexibility and help to ensure that hospitals could remain operational for longer – and with a safer water supply -- during outage events. Statewide initiatives to increase recycled water use and to expand the use of recycled water (e.g., beyond irrigation and landscaping) also has the potential to greatly improve the water resiliency of hospitals.

RECOMMENDATIONS

1. Resource support should be provided to hospitals to enable them to make realistic calculations about their water. This may include water meters or hiring a consulting company to assist hospitals in these efforts.
2. The goals for water storage should be clarified and expanded to include expectations for storing sufficient water for operational use.

3. Local and regional plans should be made incorporating water storage information, so that evacuation plans will be effective during this type of event.

4. Exercise scenarios should be conducted that establish the effect that a multi-day water outage would have on the hospitals in Los Angeles County, including planning for critically ill patients in hospitals with only water bottle stored. Alternate water source provisions should be established for hospitals that are dependent on external emergency water and hospitals should work with providers to practice delivery and hookup of external emergency water on a regular basis so that they are ready for outage events.
Figure 3.1. Distribution of Primary Water Providers for Los Angeles County Hospitals. Data presented as the percentage of hospitals that is dependent on each water provider in the region for their primary source of water.
**Figure 3.2. Daily Gallons of Water Used by Hospitals.** Data provided by the survey respondents. No data indicates those hospitals that responded to the survey in general but did not provide data in response to this question.
Figure 3.3. Amount of Emergency Water Stored by Hospitals Onsite Compared to the Amount of Water Required by OSHPD. Amount of water stored by hospitals onsite (self-reported) is shown in blue; OSHPD calculated storage amount (50 gallons x licensed bed x 3 days) is shown in red. Hospitals are grouped by size (number of beds).
Figure 3.4. Distribution of Hospital Memorandums of Understanding with Water Provider. Data shown as the percentage of Los Angeles Hospitals (n = 36) that have memorandums of understanding with outside water vendors to supply water in case of outages.
Figure 3.5. Ways That Hospitals Indicated That They Plan to Use Water Provided by the Independent Water Vendors in Case of Water Outage.
Figure 3.6. The Amount of Time Los Angeles Hospitals Can Remain 100% Operational. Comparison of how long Los Angeles hospitals could realistically remain open (with 100% operation) in case of a major water outage to how long hospitals self-reported that they could remain open. Blue columns represent Scenario 1, in which hospitals actually have the amount of emergency that is required per OSPHD. Green columns represent Scenario 2, in which each hospital has the amount of emergency water that they indicated in the survey. Red columns represent Scenario 3, in which each hospital has the amount of emergency water that they indicated in the survey, minus the amount of bottled drinking water they have stored. Purple columns represent what the hospitals reported themselves as the timeframe they think that they could remain open.
Money 28%

Engineering 10%

Space 41%

Leadership 11%

Regulations 3%

N/A 7%

Figure 3.7. Barriers to Storing Water Reported by Hospitals.
CHAPTER FOUR

Climate Change Impact Assessment: Hospitals in Los Angeles County

We are planning to submit a modified version of this chapter as a manuscript for publication in Prehospital and Disaster Medicine. Authors: Sabrina Adelaine, Mizuki Sato, Yufang Jin, and Hilary Godwin.

ABSTRACT

Introduction: Although many studies have delineated the variety and magnitude of impacts that climate change is likely to have on health, very little is known about how well hospitals are poised to respond to these impacts.

Hypothesis/Problem: We hypothesized that most modern hospitals in urban areas in the United States need to augment their current disaster planning to include climate-related impacts.

Methods: Using Los Angeles County as a case study, historical data for emergency department (ED) visits and projections for extreme heat events were used to determine how much climate change is likely increase ED visits by mid-century for each hospital. In addition, historical data about the location of wildfires in Los Angeles County and projections for increased frequency of
both wildfires and flooding related to sea-level rise were used to identify which area hospitals will have an increased risk of climate-related wildfires or flooding at mid-century.

Results: Only a small fraction of the total number of predicted ED visits at midcentury are likely to be due to climate change. By contrast, a significant portion of hospitals in Los Angeles County are in close proximity to very high fire hazard severity zones and will be at greater risk to wildfire impacts as a result of climate change by mid-century. One hospital in Los Angeles County is anticipated to be a greater risk due to flooding by mid-century as a result of climate-related sea level rise.

Conclusion: This analysis suggests that several Los Angeles County hospitals should focus their climate-change related planning on building resiliency to wildfires.

INTRODUCTION
Mediterranean climates, like the American Southwest, are projected to experience severe impacts due to climate change that will have a wide variety of impacts on the health of local populations. The American Southwest region is home to about 56 million people, about 90% of whom live in cities, which is the highest percentage of urban dwellers for any U.S. Region. The population of the Southwest is expected to increase by nearly 70% by mid-century, which will further exacerbate the region’s ability to build resiliency to the impacts of climate change.

Of particular concern is how Los Angeles County, home to 10.1 million people, will withstand the challenges posed by both population growth and climate change. Downscale modeling of
projected climate change for Los Angeles County has revealed that the region is likely to experience a significant increase in the number of extreme heat event days, with some inland areas experiencing more than 100 days per year of temperatures over 95 degrees by midcentury. As heat waves increase in number, length, and intensity, morbidity and mortality associated with heat stress is expected to increase significantly. A primary focus of prior work on the projected impacts of climate change on health in Southern California has been to assess risks to vulnerable populations. Extreme heat is anticipated to have a large impact on elderly, outdoor workers, and those with underlying medical problems. Vulnerability to extreme heat events includes access to cooling through air conditioning or cooling centers. In addition to additional extreme heat events, Southern California is anticipated to experience water scarcity, as climate change will result in less precipitation will be captured as the snow pack. The reduction in snowpack will strain water resources statewide. Water scarcity is also expected to impact food production as alternate models as current adaptive strategies are exhausted. Drier conditions combined with the extreme heat due to climate change is predicted to generate conditions that will result in increased wildfire events and more acres burned per fire. The impact of wildfires in Southern California has been increasing and expected to continue into the future. Wildfires in Southern California fall into two types, those driven by Santa Ana winds, and those that coincide with the hot and dry weather of June through September. Both types of fires are expected to increase with climate change. Santa Ana fires have historically placed more structures and human lives at risk. The overall areas burned by Santa Ana driven fires in Southern California are anticipated to increase by an average of 64% by 2041-2060 relative to 1981-2000. Overall area burned by non-Santa Ana fires are anticipated to increase by an average of 77%, due to increases in the fire size from a warmer drier climate. Vulnerability to wildfires parallels extreme heat with low
income, and populations with preexisting medical conditions, especially respiratory disease.\textsuperscript{18} In response to these climate-related events, a wide range of individuals will seek additional medical care, and a majority of lower socioeconomic populations are more likely to visit emergency departments than other types of ambulatory healthcare settings.\textsuperscript{19}

Surprisingly, no detailed studies to date have assessed if hospitals are prepared to take on the increase in emergency department and hospital visits that are expected to result from climate change. The resiliency of communities to these impacts is dependent upon the ability of hospitals to continue to meet the needs of their local population under climate change. Currently, all of Los Angeles area hospitals are at or over capacity some portion of the year, with eight hospital systems accounting for 40\% of hospitals and beds in California.\textsuperscript{20} The cost of uncompensated care in California increased between 2004 and 2013 from \$1.95 to \$2.8 billion. Preventable adverse events reported at California hospitals have also increased each year from 2009 to 2013.\textsuperscript{20} Taken together, these factors put hospitals at risk for not being capable of taking on additional surges of patients.

To adequately prepare for and build resiliency to the impacts of climate change, a thorough assessment of the projected impacts on hospitals is needed. The ways in which climate change will impact the ability of hospitals to respond to those impacts is not well known, even though recent downscale studies have provided great insights into how climate change will manifest itself at the local level for specific regions and what the resulting impacts of those changes will be on the health of the communities living in those regions.\textsuperscript{21-22} As a result, hospitals are unclear whether they need to conduct additional planning (i.e., beyond current disaster planning) to build resiliency to the impacts of climate change. A better understanding of hospital planning needs related to climate change would also be very beneficial to public health...
and other agencies that support hospitals. Here, using Los Angeles County as a case study, we projected increases in surges in Emergency Department visits due to climate-related events at mid-century. In addition, we used historical data and climate-related projections to predict which hospitals in Los Angeles County will experience greater risks due to wildfires and sea coastal rise resulting from climate change at mid-century.

**METHODS**

**Demographic Descriptions of Los Angeles Area Hospitals**

The list of hospitals compiled for this study was acquired from California’s Office of Statewide Healthcare Planning & Design Hospitals (OSHPD). Only those hospitals licensed as of June 2015 were included. Data obtained from OSPHD included: hospital address, number of beds, emergency department status, and level of care provided. In addition, data regarding whether each hospital was located in a geographic area that qualifies as a healthcare shortage areas (i.e., geographic areas lacking sufficient healthcare professionals or providers per federal or state criteria) were obtained from OSHPD. The Federally-mandated workforce shortages designations used included: Health Professional Shortage Area (HPSA), Medically Underserved Area (MUA), and Medically Underserved Population (MUP). Primary Care Shortage Areas (PCSA) and Registered Nurse Shortage areas (RNSA), and disproportionate share hospitals (DSH).

**Current and Projected Emergency Department Visits for Los Angeles Area Hospitals**

Hospitals that did not have an emergency department were excluded in the assessment for patient volume. The number of beds for each hospital was also obtained from OSHPD. Heat-related emergency department visits (combined visits and admissions) from 2009-2014 were obtained
from OSPHD. Heat-related visits were defined as those for which heat-related ICD-9 codes were provided (see Appendix 1). The average number of annual ED visits related to heat from 2009-2014 for each hospital was used as a baseline for that hospital. The baseline number of heat-related ED visits per extreme heat day was calculated by dividing the total number of annual heat visits by the number of extreme heat days indicated in work by Alex Hall and co-workers, which uses averages from 1981-2000.3

The projected number of heat-related emergency room visits for 2050 was calculated by multiplying the current rate of extreme-heat related ED visits per extreme heat day by the number of extreme heat days for a specific subarea of Los Angeles in 2050 predicted by Hall and co-workers and by the predicted increase in population (approximately 13%) for Los Angeles County by 2050.3,23 The predicted total number of ED visits in 2050 was calculated by multiplying the average annual total number of ED visits from 2009-2014 by the predicted increase in population for Los Angeles County between 2015 and 2050.23

**Historical and Current Impacts of Seasonal Influenza on Capacity of Los Angeles Area Hospitals**

ICD-9 codes for Seasonal Influenza related ED visits were obtained from OSHPD (see Appendix 1). Data for seasonal influenza-related ED visits were examined for each hospital for two different years (2009 and 2015) and used to provide a reference for the volume of surges in ED visits area hospitals already experience and prepare for on a regular basis. 2009 was picked as a high volume reference year due to the H1N1 pandemic, and 2015 represents the most recent year for which regular seasonal influenza data were available. These data, along with total ED visit data for 2015, were used to calculate the percentage of total ED visits that were due to
seasonal influenza in 2009 and 2015 for each hospital. 2050 seasonal influenza ED visits were not calculated, as the only projected increase is that due to population increases, and as a result the ratio to the total number of emergency department visits is projected to stay the same.

**Proximity of Los Angeles Area Hospitals to Coastal Flooding Zones**

The facility listing address for each hospital that was included in the OSHPD data set was used to map the hospital locations. Maps of one foot, three feet, and six feet projected increases in sea coast level rise were obtained from the National Oceanic and Atmospheric Administration. The distances between hospitals and the sea coastal flood zones were determined using the line measurement tool in ArcGIS, rounded to the nearest tenth of a mile.

**Proximity of Los Angeles Area Hospitals to Fire Hazard Zones.**

Geospatially encoded data for fire hazard zones Very High Fire Hazard Severity Zones (VHFHSZ) and State Responsibility Areas (SRA) were obtained from Cal Fire. VHFHSZ are determined by Cal Fire, and indicated that the area has the physical conditions that create likelihood the area will burn over a 30-50 year period without considering mitigation modifications. The model incorporates propriety characteristics that affect the probability of the area burning and the fire behavior in the area. The characteristics include but are not limited to fire history, existing and potential fuel, flame length, blowing embers, terrain, weather and likelihood of buildings igniting. Distances between hospitals and fire hazard zones were measured using the line measurement tool in ArcGIS, rounded to the nearest tenth of a kilometer. If the distance from a hospital to the VHFHSZ exceeded the distance from the hospital to a State Responsibility Area (SRA) zone, then the distance to the nearest SRA distance was used. SRAs
fall into three hazard categories (1 = Moderate; 2 = High; 3 = Very High). The spatial query of fire zones included a 2 mile radius, and 5 mile radius to calculate the proximity to hospitals.

In addition, historical fire data mapping was developed using the statewide GIS layer of historical fire perimeters from 1959 to 2012 http://frap.cdf.ca.gov/projects/fire_data/fire_perimeters/) to derive the spatial distribution and frequency of wildland fires in Los Angeles county. The number of fires that occurred in a specific region during 1959 – 2012 was based on the FRAP (Fire and Resource Assessment Program) historical fire database. Only fires that consumed more than 100 acres were included for the analysis. The annual fire perimeter database, jointly developed by FRAP, the USDA Forest Service Region 5 Remote Sensing Lab, the Bureau of Land Management, and the National Park Service (NPS), represents the most complete digital record of historical fires on public and private lands throughout California. The data are stored as an ArcGIS Feature Class, which provides effective tools for handling overlapping polygons (e.g., areas that burn more than once). A vector map of historical fire frequency was created by calculating number of fires (greater than 100 acres) during 1959-2012 using ArcGIS spatial analysis tools.

RESULTS

Seventy-nine hospitals in Los Angeles were included in this study. The majority of these hospitals are mid-size with an average bed size of 235, and a range of 12-1265. (Figure 4.1) 61% of the hospitals studied represent more than one healthcare service shortage area, and 33% are disproportionate share facilities. (Figure 4.2)

Current and Projected Emergency Department Visits for Los Angeles Area Hospitals
Based on projected increases in extreme heat events and population for the region, we calculated that the average number of annual extreme-heat related ED visits for hospitals in Los Angeles County will increase over 65% (from 13 visits per hospital per year at the present time to 21 visit per year) by 2050. However, it is important to note that the percentage of ED visits that received ICD-9 codes related to heat in 2009-2014 in Los Angeles constituted less than 0.2% of the total ED visits for the area. By comparison, the average number of ED visits in 2009 due to seasonal influenza for each hospital in Los Angeles was 784 (3% of total ED visits), and 2015 was 856 (5% of total ED visits). Thus, even if the number of ED visits that are heat-related is underestimated by a factor of 10 (e.g., because we only used those ED visits that received heat-related ICD-9 codes and not secondary illnesses), seasonal flu still represents a greater percentage of the total ED visits for LA county currently. (Figure 4.3a, Figure 4.3b)

**Proximity of Los Angeles Area Hospitals to Sea Coastal Flood Zones**

Very few hospitals in Los Angeles County are predicted to be at risk due to sea coastal rise. There were a total of 5 that were within a one mile proximity to a 500 year flood event and 6 feet of sea level rise. Three of the five hospitals in Los Angeles County are located within one mile of a 500 flood event and only one foot of sea level rise.

**Proximity of Los Angeles Area Hospitals to Fire Hazard Zones**

Proximity to wildfire areas was found to be a significant potential impact for several hospitals in Los Angeles County. 34% (n = 25) of hospitals in Los Angeles County are located within 1 mile of an area that either had a wildfire between 1959 – 2012 or is at high risk for a future wildfire. The Los Angeles County hospitals located within 1 mile of a wildfire area represent 37% of
patient beds (n= 8,294). 24% (n = 6) of the affected hospitals are disproportionate share hospitals, with 12% (n = 3) being both disproportionate share and having more than four healthcare shortages. (Figure 4.4)

DISCUSSION

This analysis suggests that the single largest threat to Los Angeles County Hospitals related to climate change is direct impacts resulting from an anticipated increase in wildfire frequency. In Los Angeles County, 34% of hospitals are within 1 mile of a very high fire hazard severity zone, and 24% of these hospitals are disproportionate share with 12% being both disproportionate share and having greater than four healthcare staffing shortages. In addition, one Los Angeles hospital was found to be at risk from sea coastal flooding as a result of climate change related sea level rise. By contrast, our projections suggest that surges emergency department visits due to extreme heat will not exceed what is already experienced as a result of seasonal influenza. The total impact of climate change on public health in Los Angeles will be significant; the majority of that impact will be focused in the community instead of emergency departments at hospitals. This data suggests that hospitals are prepared to handle any acute surges of patients that may be generated from climate events, and arrive at emergency departments. Climate change preparedness efforts should be focused on plans for hospitals that are impacted anticipated to be affected by wildfires. As Los Angeles continues to prepare for climate impacts hospitals should partner to ensure their communities are aware of the possible impacts to their systems.
LIMITATIONS

One limitation of this study is that we use “business as usual” projections for the number of extreme heat event days for 2050 to calculate the anticipated volume of emergency department visits in 2050. Because greenhouse gas emissions may continue to rise in the near future, these projections may underestimate the actual number of extreme heat days in 2050.

Another limitation of this study is that we only considered emergency department visits that were explicitly linked to heat based on their ICD-9 Codes. The complexity of heat-related illness may be such that this underestimates the amount of emergency department visits that will occur during an extreme heat event. While our study projected an estimated 1-3% increase in the number of patients who are coded as heat related by mid-century, other types of patients are likely to visit during extreme heat days. Patients with chronic conditions such as heart disease who take medications that exacerbate the body’s response to heat may be more likely to visit the emergency department. That being said, other studies which have included a more expanded definition of “heat-related illnesses” (e.g., have included increased numbers of ED visits with respiratory and cardiac ICD-9 codes and/or have incorporated other heat-related primary and secondary diagnosis in their analyses) have also found less than a 5% increase overall ED patient volume. These studies did identify significant increases in patients with specific disease states: people with chronic conditions such as diabetes, acute renal failure and cardiovascular disease were more likely to visit the emergency department during extreme heat events. While ED visits from these patient populations did not contribute significantly to overall ED volume from a surge capacity perspective, hospitals may wish to explore whether they need to put in
place additional specialized surge capacity to deal with these subpopulations (e.g., whether they have sufficient dialysis units in their ER to be able to handle additional surges in acute renal failure ED visits).

Another limitation of this study is that we did not look directly at potential impacts of climate change on the number of ED visits related to asthma and respiratory disease or vector-borne disease. Although it is generally assumed that climate change in Los Angeles will result in increased air pollution which will in turn increase the number of patients with asthma and allergies, and the volume of ED visits due to acute respiratory problems, no data are currently available that allow the fold increase in individuals with asthma and allergies in Los Angeles by 2050 to be estimated.30-31 Likewise, several authors have suggested that the incidence of vector-borne diseases will increase in Los Angeles due to climate change, and it would be reasonable to assume that this would result in increased numbers of ED visits.32 Although data on vector-borne disease related ED visits is currently not available on a hospital level, the current case volumes county-wide are low when considered as a function of total ED volume. For instance, Los Angeles County is considered to be a hotspot for West Nile Virus (WNV), and concerns have been raised about the possibility of WNV increases in prevalence as a result of climate change.32-33 However, the total number of cases in LA County (n = 165 for 2013) is very small compared to total volume of ED visits (n = 3.4 million for 2013) in the entire county.34-35 There is a possibility that new vector-borne disease (e.g., Dengue and Chikungunya) may become endemic in LA County as a result of climate change.33 It is important to note that none of these vector-borne diseases are communicable and therefore they are unlikely to result in dramatic surges in the number of ED visits.
CONCLUSION

We conducted a regional assessment of the projected impacts of climate change in Los Angeles County on area hospitals to help them determine whether they need to incorporate additional preparedness measures to plan for these impacts beyond what they are already doing. This assessment suggests that surge planning that Los Angeles hospitals currently engage in for seasonal influenza should allow them to plan effectively for expected heat-related ED visits due to climate change in 2050. However, the assessment also suggests that wildfires will pose an increasing risk to many hospitals in Los Angeles County as a result of climate change and that hospitals located near wildfire risk zones should prioritize planning for wildfire impacts going forward.
**Figure 4.1. Demographic Description of Hospitals in Los Angeles County.** Percentage of Los Angeles County hospitals with different numbers of beds in 2014.
Figure 4.2. Shortage Area Description of Hospitals in Los Angeles County. Shown are the number of hospitals that qualify as being (in) a Registered Nurse Shortage Area (RNSA, dark blue), more than one shortage area (red), Disproportionate Share Hospital (DSH, dark green), Primary Care Shortage Area (PCSA, dark purple), Healthcare Provider Shortage Area - Primary Care (HPSA-PC, aqua), Medically Underserved Area (MUA, orange) Medically Underserved Population (MUP, light blue), Healthcare Provider Shortage Area -Mental Health (HPSA-MH, pink), rural hospital (light green), or Critical Access Hospital (CAH, light purple).
Figure 4.3a. Emergency Department Visits from Extreme Heat and Seasonal in Los Angeles County. The predicted number of ED visits per year in 2050 due to heat (blue bars) for each hospital in Los Angeles County, compared to the total number of emergency department visits per year for each hospital 2009-2014 (red bars) visits, and total number of seasonal influenza ED visits in 2009 (green bars) and 2015 (purple bars) for the same hospitals.
Figure 4.3b. Logarithmic Scale Plot of Emergency Department Visits From Extreme Heat and Seasonal in Los Angeles County. Shown on a log scale (so that small numbers can be seen more easily, the predicted number of ED visits per year in 2050 due to heat (blue bars) for each hospital in Los Angeles County, compared to the total number of emergency department visits per year for each hospital 2009-2014 (red bars) visits, and total number of seasonal influenza ED visits in 2009 (green bars) and 2015 (purple bars) for the same hospitals.
Figure 4.4. Map of Los Angeles County Hospitals, Historical Wildfire Sites (1959-2012), and Fire Severity Zones. Hospitals are depicted as black dots with 1km circle around them. The locations of historical wildfires are in red, yellow, and green; where dark red indicates locations that have experiences seven wildfires and green indicates zones that have indicated only one wildfire during the period 1959-2012. Fire severity zones are show in gray. Figure courtesy of Yufang Jin (UC Davis).
CHAPTER FIVE

Future Directions and Applications of This Work

OVERALL

The work presented in this dissertation explores the impacts that environmental events can have on hospitals in Los Angeles County. It provides recommendations for making hospital in Los Angeles more resilient, and areas of focus for further study.

CHAPTER TWO

The work presented in Chapter 2 demonstrates that human beings rely on one another during a time of crisis; unfortunately, humans are not always reliable. One of the respondents to the survey presented in Chapter 2 summarized this well: “The ability to communicate with someone within another organization that has the ability and understanding of their organization’s readiness and resources and has the authority to either make decisions or work with leadership that can.” To address this, emergency management must look at ways to effectively use technology that do not completely removing the human connections that are so critical to creating trust. A possible area of exploration would be to investigate the ways in which tools such as social media can help to combine the consistent use of technology for real-time information, and maintain a human element which lets the participants know the information is coming from someone who "has the authority to either make decisions or work with leadership who that can". A more focused survey of hospital emergency managers to determine what
specific factors they are using to decide whether an individual or specific tool is reliable during a disaster would help to inform future programmatic development and emergency management policy.

CHAPTER THREE

The work presented in Chapter 3 demonstrates that the impact a water outage would have on hospitals across Los Angeles County could be catastrophic. Combined with the ongoing water security issues that Los Angeles County is facing from climate change, the results of this study provide increasing pressure to develop better local water management systems in Los Angeles generally and to improve hospital water conservation strategies specifically. A successful strategy for addressing the hospital and water challenges will likely require investment in alternate water infrastructure. Future efforts should be made to inform policy makers and engineering innovators of the potential public health crisis if hospitals lose their water. Alternate means to large storage tanks for water need to be developed. A potential area for further study should include how solutions like recycled water could help hospitals to improve their resiliency.

This study also revealed that Los Angeles area hospital emergency managers (and likely hospital facilities departments as well) do not have the knowledge or tools to successfully conduct a comprehensive assessment of their water use. Future studies should be accompanied by initiatives aimed at providing hospitals with the training and tools they need to accurately assess how much water they use. Hospitals may require specific meters or other measuring devices that would allow them to calculate which systems are using the greatest amounts of water. Such an initiative would allow hospitals to determine how much emergency water they realistically need to have available to be able to provide critical patient care in the event of a
water outage. Developing more specific plans for water outages and developing redundant emergency water supplies would greatly improve the resiliency of our hospitals to a major a water outage event.

CHAPTER FOUR

The climate impact study described in Chapter 4 suggests that the projected increase in volume of heat-related ED visits due to climate change is well within the current surge capacity of Los Angeles hospitals. However, this analysis also suggests that hospitals in Los Angeles should focus additional planning efforts on the impacts associated with wildfires. Increased communication to hospitals about their proximity to wildfire areas, and the associated risk will be necessary to ensuring response plans are in place. Specific guidelines for how to plan for a wildfire as well as regional plans will increase the resiliency of hospitals across Los Angeles.

Future study could include a more extended evaluation of the potential patient volume and the types of patients generated during extreme heat events. Some studies have shown an increase in morbidity and mortality associated with specific disease states such as heart disease, respiratory illness and neurologic conditions. The overall volume of these types of visits is within the current capacity of hospitals to absorb. However, more specific resource assessment of the available of cardiology response staff and equipment may provide a more nuanced picture to hospitals for day to day operational planning. Likewise, efforts to quantify the impacts of climate change on asthma-related ED visits and ED visits related to vector-borne disease would help to further elucidate the projected impacts of climate change on Los Angeles area hospitals.
APPENDIX 1

Supporting Information for Chapter 4
Primary and secondary diagnosis codes (ICD-9 Codes) that were included in this assessment.

Heat-Related ICD-9 Codes Used Herein

9920 9921 9922 9923 9924 9925 9926 9927 9928 9929 E9000 E9009

Seasonal Influenza ICD-9 Codes Used Herein

46400, 46401, 46410, 46411, 46420, 4642, 46430, 46431, 4644, 46450, 46451, 4650, 4658, 4659, 4660, 46611, 4661, 4780, 47811, 47819, 47820, 47821, 47822, 47824, 47825, 47829, 47830, 47831, 47832, 47833, 47834, 4784, 4785, 4786, 47870, 47871, 47874, 47875, 47879, 4788, 4789, 4870, 4871, 4878, 48801, 48802, 48809, 48811, 48812, 48819, 48881, 48882, 48889
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