Cross-sector Infrastructure Planning for Water Purveyors and Critical Care Facilities

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ABSTRACT

Water supply interruptions from a major catastrophic event can severely compromise the operations of a medical facility during a time when the facility's services are most needed by society. For example, in a magnitude 7 earthquake, the East Bay Municipal Utility District (EBMUD) is expected to experience 4,000 to 6,000 main breaks, which could impact one or more of the sixteen hospitals in EBMUD's service area. To better assess and support emergency water supply planning for these critical customers, EBMUD launched a hospital outreach program to discuss its water system capabilities, limitations, and emergency preparedness measures. The twofold purpose of this program is to survey and better understand hospitals' emergency water supply readiness and expectations, and to facilitate coordinated planning efforts to enhance water supply resilience.

This paper summarizes findings from recent outreach efforts to six of the sixteen hospitals in EBMUD's service area that have recently completed seismic retrofits and upgrades to their facilities. While most hospitals have a general awareness of water supply disruptions resulting from emergencies, few were prepared for the severity and lengths of possible water service impacts, and some were overly optimistic about the quantity of water required to sustain operations. During recent seismic retrofits and hospital upgrades, the hospitals addressed critical infrastructure needs, but some did not incorporate adequate on-site storage for a 72-hour water outage or build sufficient redundancy to strengthen emergency water supply reliability. In fact, only two out of the six hospitals is currently in compliance with the California Office of Statewide Health Planning and Development (OSHPD) 2030 requirements for on-site storage.

EBMUD's outreach experience suggests that improvements in four areas – awareness of water infrastructure vulnerabilities, understanding of emergency water supply needs, implementation of on-site water storage or alternative water supply, and coordinated planning – could greatly enhance emergency planning for water purveyors and medical facilities, leading to better performance across both infrastructure sectors.

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INTRODUCTION

The East Bay Municipal Utility District (EBMUD) is a water/wastewater utility located in the San Francisco East Bay Area of California, USA providing water service to approximately 1.4 million customers in a seismically active area. As the owner and operator of important lifelines, EBMUD is continuously concerned with providing reliability, security and resilience in the face of various hazards.

Following the 1989 earthquake that damaged the water system, EBMUD initiated a major seismic upgrade program to its system after studying and evaluating the vulnerability and reliability of its critical facilities. The first step in the upgrade was a seismic evaluation which indicated that in a magnitude 7 earthquake, EBMUD could experience 4,000 to 6,000 main breaks in its over 4,200 miles of pipelines, plus damage to many of its storage, pumping, transmission lines and treatment facilities. As a result, EBMUD developed and implemented a retrofit program that invested more than US$350 million to strengthen its water and wastewater facilities for seismic safety. EBMUD continues to enhance seismic reliability with ongoing facility improvements.

In addition, EBMUD continues to enhance its emergency preparedness with its robust emergency plans to protect lives and ensure an orderly approach to disaster recovery. EBMUD prepares for emergencies by proactively monitoring and improving its facilities, conducting emergency training exercises, maintaining business continuity plans to recover critical functions quickly, and coordinating emergency preparedness efforts with other agencies. EBMUD has mutual aid response agreements with a water agency in southern California and a water agency in Nevada, both chosen to be outside the likely impact zone for most hazards that could strike EBMUD, but near enough to offer prompt aid. EBMUD has also worked with other water agencies to establish emergency intertie connections that could be utilized to transfer water supplies between EBMUD and the San Francisco Public Utilities Commission via the City of Hayward to the south, the Contra Costa Water District to the east, and the Dublin San Ramon Services District to the southeast.

In spite of EBMUD's efforts to strengthen its facilities and continually prepare for emergencies, EBMUD recognizes that a major seismic event will likely result in substantial water supply impacts to its customers. A 2015 study[i] of cross-sector interdependencies identified that an area of particular concern is other critical infrastructure sectors, i.e., those EBMUD relies upon to provide water service and those that rely upon water to perform their essential functions. In particular, that study determined that planning-level assumptions across critical infrastructure sectors were not consistent, and suggested that better information sharing across sectors might substantially improve overall societal resilience. In response to that finding, EBMUD undertook increased dialogue and outreach with the hospitals served by EBMUD. This paper describes the outreach process and key lessons learned, which might be helpful to other utilities seeking to reduce cross-sector impacts and increase societal resilience.

BACKGROUND

In EBMUD's service area, there are currently sixteen general acute care hospitals varying in size and characteristics (number of beds, building heights, age of building construction, etc.). These hospitals are located in different parts of the EBMUD water distribution system with different pressure zones and varying water pressure, storage and pumping supplies, and related infrastructure. Figure 1 presents the EBMUD water service area and the locations of the sixteen hospitals.

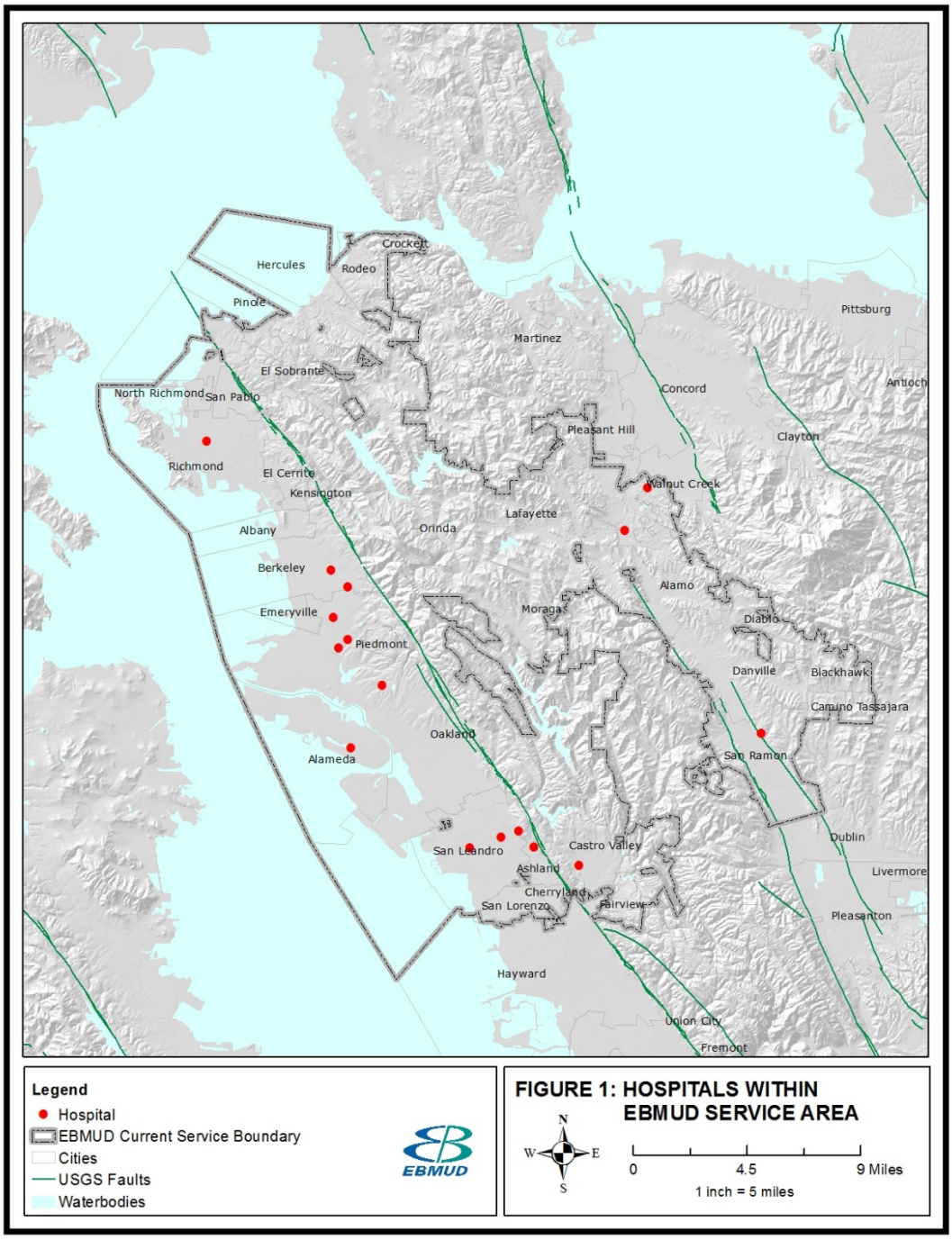
In 2001, a major new law known as SB 1953 was passed which called for hospitals in California to improve seismic performance. The law called for a suite of measures, including structural retrofits, non-structural retrofits, and provisions, to withstand up to three days' outage of lifeline services, including electrical power and potable water. The law set out various compliance dates for the measures. A complicating factor in compliance is that oftentimes a seismic structural upgrade to a hospital triggers a host of other regulations. For example, disabled access provisions may be required, which could make retrofits fairly complex or even lead to reconstruction in lieu of retrofit. Accordingly, the compliance dates for the law have been adjusted over the years.

To help hospitals chart a course toward compliance with SB 1953, EBMUD in 2002 embarked on a study to assess water service issues and evaluate water service reliability improvements to the hospitals in its service area. After two years of study and outreach efforts with the hospitals, EBMUD completed a final report[ii] that focused on each hospital's existing water service, water needs, and evaluation of potential alternatives, if any, to improve water service reliability. Some of the key findings and benefits of this initial outreach include:

- Hospitals' primary focus was on meeting regulatory requirements for seismic upgrades by 2013.
- All of the hospitals had some on-site emergency water supplies and the hospitals planned to augment these supplies to meet 2030 regulatory requirements (storage supply of 189 liters (50 gallons) per day per bed for 72 hours).
- Hospitals and EBMUD gained a better understanding of the hospitals' existing water service, water use, and emergency water needs and expectations.
- Hospitals were made aware of potential alternatives to improve water service reliability at their expense.
- The hospitals and EBMUD obtained up-to-date contact information.

The report was provided to the hospitals in 2004 and also recommended that EBMUD continue to maintain contact with all the hospitals to ensure contact lists and water supply information were updated. Accordingly, EBMUD has completed periodic updates by reaching out to the hospitals over the years. In 2015, EBMUD conducted a phone survey of the sixteen hospitals to obtain updated contact information and to assess the hospitals' emergency water preparedness. The survey highlighted a range of knowledge and level of emergency preparedness among the hospitals. The 2015 survey also revealed that there are frequently gaps between the water supplier's projections about possible water service interruptions and likely impacts, and the perceptions of its key customers as to their exposure to service interruptions. This gap was discussed in a 2015 paper[i] that examined cross-sector knowledge gaps.

As a follow up to the 2015 findings, EBMUD has conducted a concerted effort to reach out and meet with several hospitals that completed hospital retrofits or new construction. This paper will examine what EBMUD learned in regard to those hospitals' emergency preparedness improvements, particularly water supply improvements for emergency purposes.



HOSPITAL OUTREACH (2016 – 2017)

Description

In response to California's hospital seismic safety law, SB 1953[iii], mandating hospitals to meet updated seismic safety standards, six out of sixteen hospitals within the EBMUD service area recently underwent multi-million dollar seismic retrofits and improvements. To ensure ongoing communication with its most critical customers, EBMUD launched a hospital outreach program in 2016 targeting these six hospitals. The twofold purpose of this program is to survey and better understand the hospitals' current emergency water preparedness and to facilitate coordinated planning efforts to enhance water supply resilience.

The outreach largely consisted of meetings between EBMUD management and engineers and key hospital chief engineers, facility managers and/or emergency management staff. During these sessions, EBMUD shared the current state of its water system and emergency response, and interviewed hospitals about their emergency readiness and expectations. The hospitals provided updated information about their facilities and water service connections, which allowed EBMUD to identify strategies for hospitals to improve water supply reliability. Finally, EBMUD shared water distribution maps and fact sheets, distributed copies of industry guidance on emergency water needs for medical providers i.e., specifically, the Center for Disease Control's Emergency Water Supply Planning Guidelines for Hospital and Health Care Facilities[iv], and exchanged key contact information with the hospitals. In some instances, follow up meetings were conducted to initiate communications between hospital facility staff and EBMUD's first responders. Information collected during the outreach was used to update EBMUD's customer records, its emergency response system (known as Marconi), and its geographic information system (GIS).

Outreach Benefits

The outreach yielded a number of benefits for all parties as listed below:

- Hospitals gained a better understanding of EBMUD's water distribution system, including its strengths and vulnerabilities.
- Hospitals gained awareness of EBMUD's emergency preparedness initiatives as well as emergency response priorities and protocols.
- From tabletop discussions to field investigations with hospital staff, EBMUD confirmed water service connections and corrected discrepancies in its customer and mapping databases.
- EBMUD verified key hospital information such as the number of beds, acute care facilities, critical water service connections, and current and future improvement plans.
- EBMUD obtained updated information on new hospital facilities and emergency water supply.
- Hospitals were offered ideas to enhance their water supply reliability (at their expense).

The subsequent sections will focus on key outreach findings and opportunities for enhancing water supply resiliency from a water purveyor's perspective.

Hospital Emergency Preparedness

Most of the newly renovated hospitals have incorporated state-of-the-art building design, cutting-edge medical technology and equipment, innovative features and amenities, and some form of backup water and power supply. Having addressed critical infrastructure needs, the hospitals are no longer at a major risk of collapse during an emergency. However, it is unclear whether they can remain fully operational for the crucial 72 hours following a disaster without adequate emergency planning for basic resources such as water and fuel.

Generally, responses from the outreach indicate that hospitals are aware of potential water supply disruptions that can result from natural disasters or isolated incidents and have taken some steps to address water supply reliability. In this regard, survey responses indicate the following:

- Three of six hospitals have added some type of on-site potable water storage tank as part of their recent retrofits.
- Two hospitals have engaged a team of water consultants to conduct water use audits, evaluate emergency water preparedness, and identify opportunities to strengthen water dependent operations.
- All but one hospital have a sufficient drinking water supply in place to meet hydration needs for at least 24 hours.
- More than half of the hospitals cited internal emergency operation plans, water disruption plans, and/or code-dry policies that guide the management of water supply during an emergency.
- One hospital established a Memorandum of Understanding with a local water vendor to deliver water in the event of an emergency.

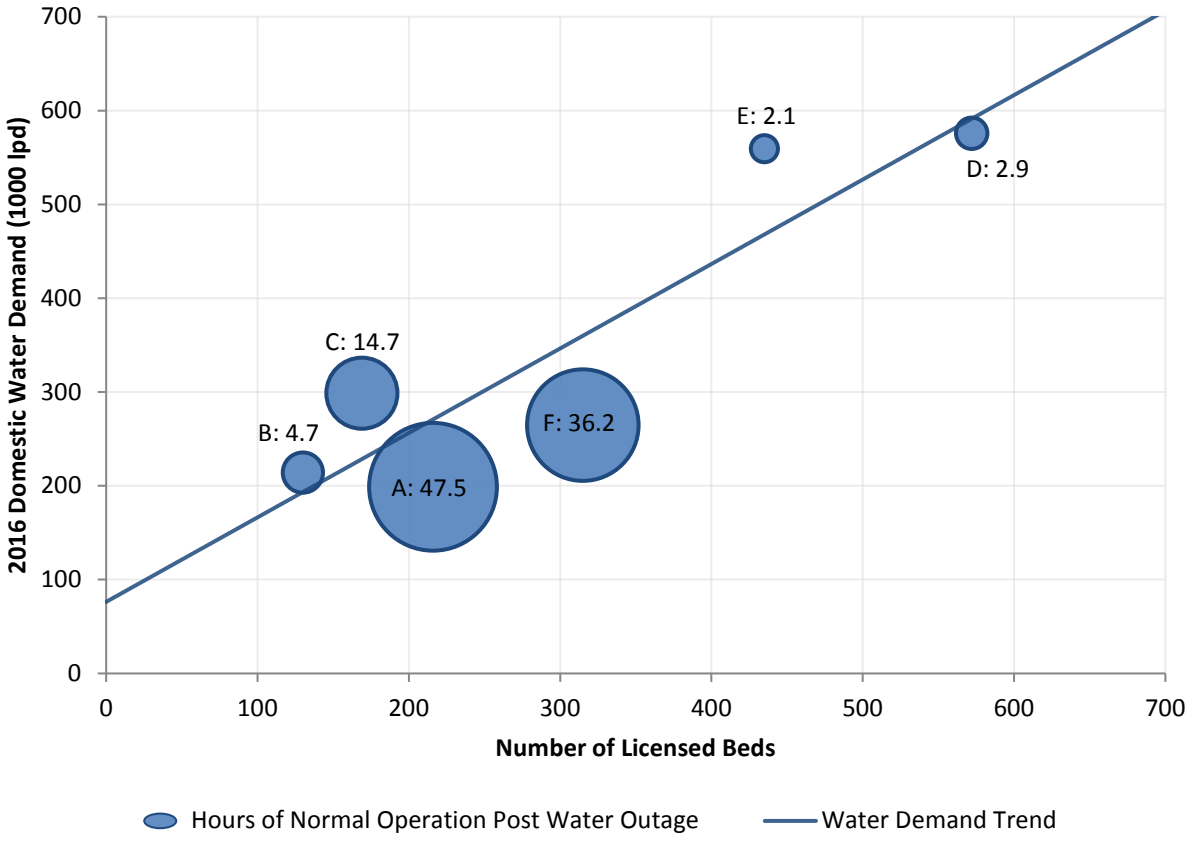
While most hospitals have made progress towards emergency water supply planning, few appeared to be adequately prepared to face the severity and length of possible water service impacts. The statistics indicate the following:

- All hospitals were surprised to learn that EBMUD may encounter 4,000 to 6,000 main breaks in a magnitude 7 earthquake and that the restoration period for full service recovery could range from a period of days to well over a year.
- Three of six hospitals were not aware of their baseline water usage.
- During recent retrofits, two hospitals removed existing plumbing interconnections, eliminating an important redundant water feed to the EBMUD distribution system.

Three of six hospitals have no current on-site potable water storage tanks. Despite the lack of on-site storage, some hospitals appeared to be optimistic about the quantity of water required to sustain operations, citing a belief that they can function for more than 48 to 96 hours following a water service failure. However, data on hospital baseline water use and available water supply shows that three out of the six hospitals can sustain fewer than five hours of normal demand during an outage. To examine this projection in greater detail, hospitals' average water demands are plotted against hospital size measured by the number of beds in Figure 2.

In 2016, average water demand at the six hospitals ranged from approximately 200,000 to 576,000 liters per day (lpd) (53,000 to 152,000 gallons per day (gpd)). As expected, the demand typically rose with increasing number of beds, and this trend can be modeled by linear regression as shown in Figure 2. Hospitals that fall above the regression line consumed more water per bed than the ones below the trend line. More importantly, Figure 2 displays the estimated hours a hospital can tolerate without water through the magnitude of the bubble plots. The estimates assume normal hospital operation and are based on the 2016 average daily water consumption and the total amount of emergency water supply available or planned at each hospital. Without any curtailment in water use, hospitals in this sample can sustain normal operations ranging from 2.1 to 47.5 hours. Specifically, hospitals without dedicated on-site potable water storage tanks (Hospitals D and E) can sustain no more than a couple hours of normal demand during an outage.

Figure 2: Water Demand and Hour of Normal Operation Post Water Service Disruption for Different Hospital Size

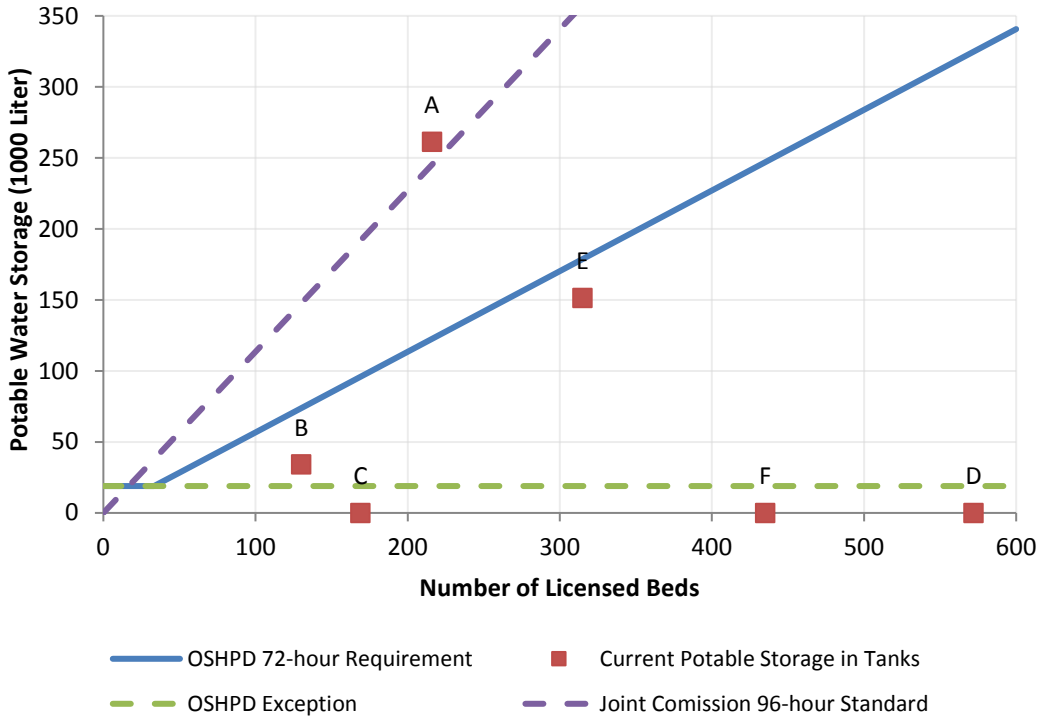


The California Office of Statewide Health Planning and Development (OSHPD) generally requires acute care hospital buildings to maintain sufficient on-site water supply to support 72 hours of continuous operation in the event of an emergency. Exceptions can be made with the installation of hook-ups that allow for the use of transportable sources and an approved Water Conservation/Water Rationing plan that provides onsite supply of potable and industrial water sufficient to support a minimum of 24 hours of operation. However, in no event shall the on-site water storage capacity be less than one tank with at least 18,927 liters (5,000 gallons) capacity. This requirement, which is implemented in the California Plumbing Code (CPC), affects new

acute care hospital buildings and will go into effect for all existing acute care hospital facilities in the state of California by the year 2030.[v] At the federal level, the Joint Commission calls for hospitals to have in place a plan to respond to a 96-hour loss of service for all utilities, including water. Through past experiences and disaster forecasts and projections, various governmental and non-profit groups such as Red Cross, Center for Disease Control (CDC) and FEMA advises all sectors, including medical, to be prepared for water outages of 3 to 14 days.[i]

Despite regulations and guidelines, only two out of the six hospitals indicated that they are in compliance with OSPHD's 2030 requirement. A third hospital plans to achieve compliance with the construction of an 88,389 liter (23,350 gallon) underground water storage tank in the next two years. Figure 3 illustrates the relationship between OSHPD's 72-hour storage requirement and hospital size measured by the number of licensed beds. The two parameters generally constitute a linear relationship because the regulation baseline calls for 189 liters (50 gallons) of potable water per licensed bed per day for 72 hours. Assuming OSHPD's 189 liters (50 gallons) per bed per day benchmark, the Joint Commission's 96-hour standard is also plotted for reference. The six data points on the chart represent the number of beds versus volume of potable water storage of individual hospitals. The area underneath the solid line denotes one of two conditions: 1) hospital does not have adequate potable water storage given its size; or 2) hospital may be able to achieve compliance through seeking OSHPD's approval of a Water Conservation/Water Rationing plan provided that a minimum storage tank of 18,927 liters (5,000 gallons) and an emergency hook-up connection are available.

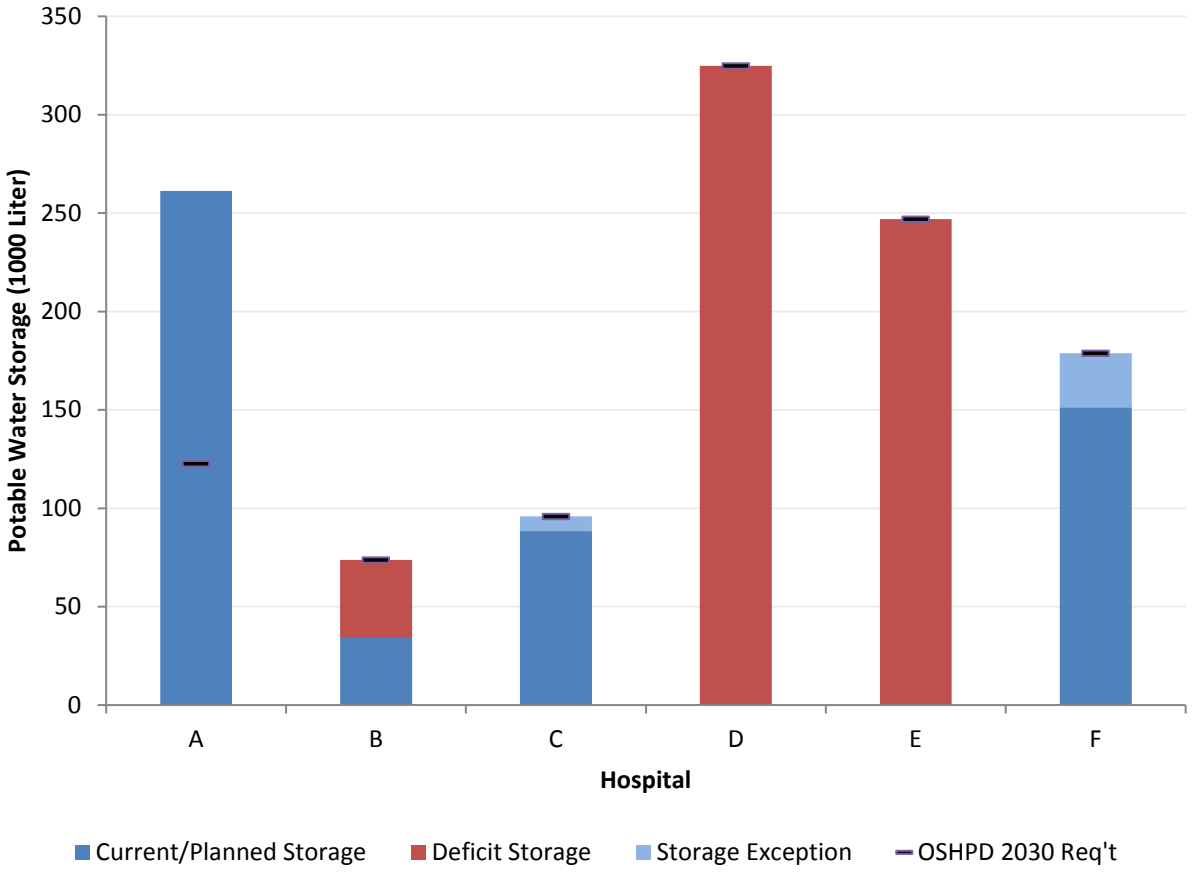
Figure 3: OSHPD 2030 Storage Requirement and Hospital Size



As Figure 3 suggests, Hospital A's emergency water supply is well over OSHPD's baseline requirement and has even exceeded the Joint Commission's 96-hour guideline. In contrast, Hospitals C, D and E have zero potable water storage at this point.

Figure 4 provides a separate view of the percentage of storage met for each of the six hospitals in the survey. For each hospital, the black marker indicates the baseline potable water volume required by OSPHD by the year 2030. The blue area denotes the portion of the requirement that is currently met or planned, the light blue area represents the portion of the requirement met through exceptions, and the red area shows the portion of the requirement that is not yet met.

Figure 4: 72-hour Potable Water Supply Compliance



The figure indicates that there are three hospitals that do not meet the 2030 OSHPD requirement. When questioned, these hospitals indicated that there are no immediate plans to increase on-site water supply or improve water supply reliability.

Table 1: Hospital Emergency Water Supply

ID	No. of Licensed Beds	Emergency Water Supply (liter)			Interconnected System
		Potable Water Tank	Non-potable Water Tank[b]	Bottled / Canned Water	
A	216	261,193	132,489		yes
B	130	34,069	7,949	MOU[c]	no
C	169	*88,389*[a]	94,635		no
D	572		37,854	30,904	no
E	435		37,854	11,924	yes
F	315	151,416	246,052	1,537	yes

a. Hospital C plans to construct an 88,389 liter (23,360 gallon) tank by 2019.
b. Non-potable tank includes hot water tanks, fire water storage tank, etc.
c. Hospital B has a Memorandum of Understanding (MOU) with a local vendor to deliver supplies of bottled water in the event of an emergency.

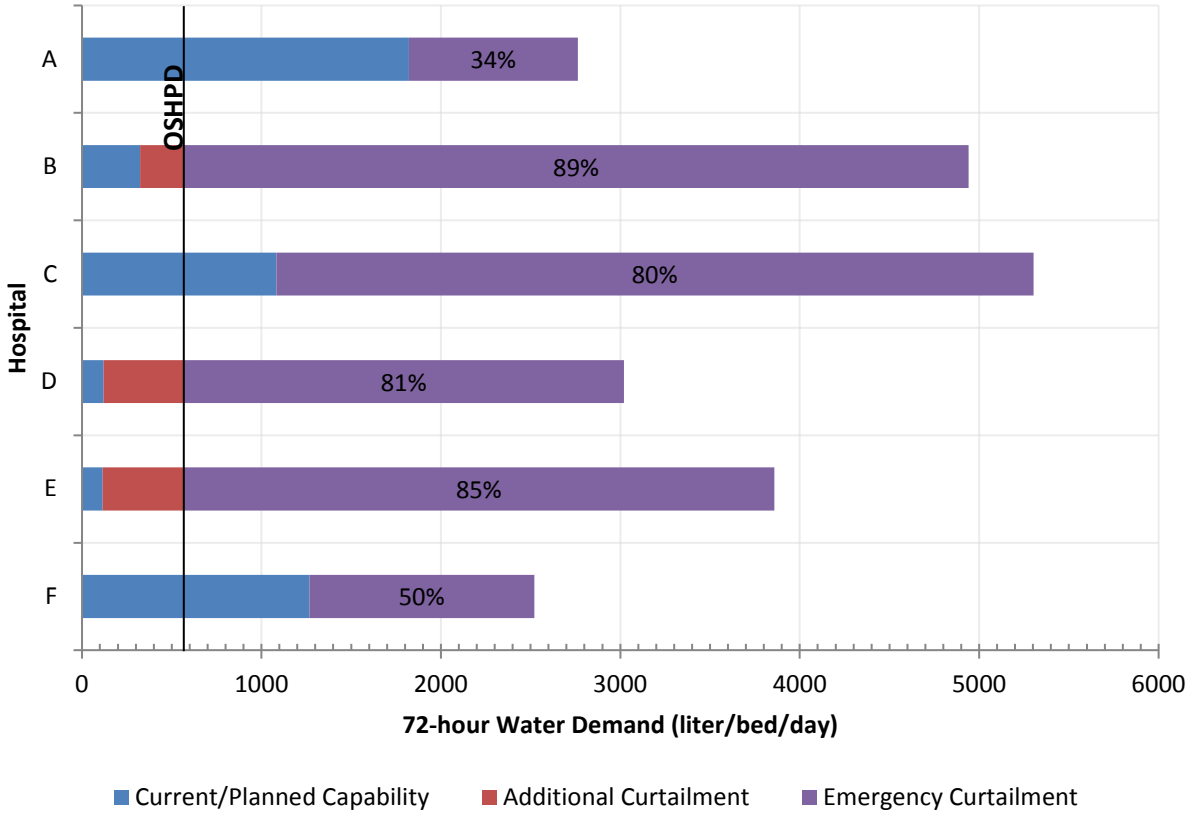
Table 1 summarizes the types of emergency water supply available at each hospital. In general, the hospitals' inventory of on-site water supply can be separated into three key categories: potable water tank, non-potable water tank, and bottled/canned water stockpile. Surprisingly, two of the largest hospitals in the sample did not integrate any on-site potable storage tanks in recent facility upgrades. At the same time, they also have the lowest non-potable water storage to licensed bed ratio. On the other hand, these two hospitals carry the largest inventory of bottled/canned water. One of the two hospitals cited that their inventory of bottled/canned water can provide up to 168 hours of drinking water supply. Yet, it is not apparent how the hospital will meet industrial (e.g. cooling towers, chillers, boilers), medical (e.g., dialysis, sterilization, magnetic resonance imaging units), and domestic (e.g. toilet flushing, hand washing, bathing, food services) water needs, which constitute the majority of the water usage in a hospital and are essential for a hospital to stay in operation. This finding is consistent with that of earlier research of different hospitals and suggests that this planning gap may be widespread.[vi]

Figure 5 shows the estimated amount of curtailment required to achieve OSHPD's guideline of 568 liters (150 gallons) per bed for 72 hours given the current average water consumption. It is assumed that hospitals can utilize their potable and non-potable supply sources to meet demands. On average, the hospitals need to curtail 70% of their water supply to either meet OSHPD's benchmark or their current supply reserves. In the case of Hospital A, only 34% curtailment would be needed due to the relatively higher amount of emergency water supply available. For Hospitals B, D, and E, additional curtailment beyond the OSHPD standard would likely be required if the hospitals intend to remain operational for 72 hours. Since Hospitals D and E have no on-site potable storage tanks in place, they will likely face severe challenges in addressing patient care beyond basic hydration needs. Based on Figure 5, it appears that most hospitals will need to make significant curtailments to function for the full 72 hours following an outage even with the required OSHPD water supply on site.

To help bridge the gap between emergency supply and demand, the American Water Works Association (AWWA) and CDC recommend that each hospital develop an Emergency Water

Supply Plan (EWSP) as part of its Emergency Operations Plan (EOP) to identify water use and water restriction protocols that will allow it to meet regulatory standards and codes.[iv]

Figure 5: Emergency Water Use Curtailment



Overall, there appears to be a wide variation in the knowledge and preparedness of emergency water supply planning across the six hospitals.

Water Reliability Alternatives

Beyond achieving the OSHPD 72-hour on-site storage requirement and developing EWSP, EBMUD has identified additional options that hospitals can pursue to enhance water supply reliability. Some of the improvement opportunities are detailed below.

- Interconnect/loop campus plumbing system with a second meter to improve water supply redundancy.
- Replace aging mains and mains with questionable seismic performance, such as asbestos cement.
- Install a stub out connection to allow water to be supplied via a hydrant or transportable source in an emergency.
- Establish contracts with water truck vendors to deliver water in the event of an emergency.

- Install an additional water service connection from an adjacent pressure zone for added redundancy.
- Apply for redundant water service from an adjacent water supplier as an alternative water source.

These options were presented to the six hospitals during multiple outreach sessions. Hospitals may wish to pursue them at their own expense.

EBMUD EMERGENCY PREPAREDNESS INITIATIVES

In addition to the Hospital Outreach Program, EBMUD has recently embarked on several other initiatives to improve water supply resiliency and emergency preparedness. The following section describes a few initiatives that are currently underway.

Critical Customer Identification and Communication

EBMUD is developing a Critical Customer Identification and Communication Pilot Project to establish a uniform process for managing critical customer information and communication for all stakeholders. The project outlines roles and responsibilities to enhance communication during interruptions in service or water quality impacts to critical customers. Additionally, it defines the process for identifying critical customers, obtaining and updating key customer information, notifying customers, and updating mapping database to include critical customer data. The project also involves the development of a tool to spatially allocate critical customer information onto online water distribution maps and GIS. This new feature will enable EBMUD first responders to readily identify and access critical customer information to ensure that priority is given to maintain and restore water to their services.

Pipeline Rebuild and Pipeline Replacement Program

The average age of pipelines in EBMUD's service area is 68 years (ranging up to 120 years) and some are beginning to fail. In response, EBMUD initiated the Pipeline Rebuild Program to ramp up the rate of pipeline replacement from 10 miles per year to 40 miles per year by 2030. To support this program, a new Pipeline Replacement Program (PRP) was implemented to prioritize pipeline replacements using a comprehensive risk analysis. The program evaluates pipeline risk based upon user defined likelihood and consequence of failure rankings for EBMUD's entire pipeline inventory. Risk scores are computed in ArcGIS using pipeline attributes and performance data such as pipeline age, leak history, ground slope, criticality of connected customers, whether a creek is being crossed, etc.

Using these parameters, the likelihood of failure (LOF) and consequence of failure (COF) of each pipeline are computed with a 1 through 5 ranking system, with 1 representing negligible LOF or no COF and 5 representing very likely LOF or very high COF. Under this system, pipelines with high LOF and COF scores are prioritized for replacement. As mentioned, criticality of specific customers is considered in EBMUD's Pipeline Risk Model as one of the several criteria used to calculate the COF scores for distribution pipelines. Critical customer designation is currently assigned to hospitals, health services, schools, airports, sanitary

collection and disposal facilities, electronic communication facilities, and electric, steam and natural gas facilities. Pipelines that serve water to these critical facilities are given a higher consequence of failure score. When replacing high risk mains, EBMUD also applies optimization techniques such as clustering the replacement of nearby pipelines to minimize overall cost, time, and resources. As a result of the PRP Risk Model and clustering, two major hospitals have benefitted by having multiple pipelines replaced near their campuses.

Pipeline Improvement Program

In addition to its PRP, EBMUD undertook a study to review aging, undersized mains serving critical customers and large fire services. This study was launched in 2013, after an old 4-inch diameter (100 mm) water main installed in the 1940s broke in a downtown area, causing a major disruption in water service to several high rise office buildings. This incident prompted a study that examined where such aging mains are concentrated, how many customers they serve, and which types of water customers they serve. This study determined that in some instances, these mains serve critical customers where an outage could result in significant impacts, and recommended how to sequence and prioritize their replacement.

The program resulted in a plan to replace 12 miles of aging 4-inch pipelines, including one mile of mains serving hospitals and health services. This program will initially focus on the replacement of approximately 6 miles (10 km) of mains that serve EBMUD's most critical facilities such as hospitals, health services facilities, laboratories, as well as office buildings and apartment buildings which have a fire service. In a second future phase, EBMUD plans to replace an additional 6 miles of mains that supply other facilities with fire services. A large majority of these mains (80%) provide service to critical facilities located in Oakland and Berkeley with a total of 197 fire services. Of these 197 services, which are connected to the mains that will be replaced in the first phase of this program, 71 (36%) serve wholesale and resale establishments, 66 (34%) serve multi-unit buildings, 31 (16%) serve schools or hospitals, and the remaining 29 (14%) serve other business types.

CONCLUSION

Cross-sector interdependencies will likely play a significant role in the aftermath of future major disasters. Left unaddressed, those interdependencies have the potential to increase overall societal impacts caused by damage to critical infrastructures.

A primary way of addressing interdependencies is to close knowledge gaps, so that experts within each distinct infrastructure sector understand what to expect from other sectors upon which they depend, and understand what is expected of them by other infrastructures. The hospital outreach described in this paper was done with that goal in mind. EBMUD gained an increased understanding of how critical care providers rely upon water supply, and those care providers gained important information on ways to improve resilience to water supply disruption.

In short, emergency preparedness is a joint effort and an effective emergency response will require ongoing support and commitment from both parties. The Hospital Outreach Program is a first step in paving the way for a variety of opportunities for both sectors to learn, grow, and

solve problems together. In the future, EBMUD will continue to reach out to critical customers, especially the remaining hospitals pursuing seismic retrofits, and the community to educate and raise awareness on emergency water planning, update critical customer information, and explore opportunities for coordinated planning and support. In addition, EBMUD will continue to look for opportunities to replace aging pipelines serving hospitals and health services facilities as part of its pipeline replacement and improvement programs.

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