Quick Response Research on the September 8, 2011, San Diego Blackout

Scott B. Miles, Hannah Gallagher, and Charles Huxford

Resilience Institute, Huxley College of the Environment, Western Washington University, scott.miles@wwu.edu

Introduction

This report focuses on research into the September 8, 2011, power outage that left areas of San Diego County, California, without electricity for up to 12 hours. While the blackout was roughly 1/10 the size of the 2003 Northeastern U.S. blackout, it was the largest in California history and one of the largest outages ever on the West Coast. The blackout affected parts of Arizona, California, and Mexico, but this work focuses only on San Diego. The power outage affected the entire service area of San Diego Gas & Electric (SDG&E). SDG&E provides electrical service to about 3.5 million people through 1.4 million electric meters—all of whom lost power. SDG&E was responsible for power restoration within their service area, which spans 4,100 square miles of Orange and San Diego Counties. This study looks specifically and power restoration in San Diego County.

The outage originated at about 3:30 p.m. in Arizona. News reports indicated the outage was likely related to a maintenance procedure performed by a worker for the Arizona power company APS. The full set of events leading to the outage, however, is unknown and under investigation at the time of this writing by the Federal Energy Regulatory Commission, the North American Electric Reliability Corporation, the Western Electricity Coordinating Council, and the California ISO.

The objective of this quick response research is to document and analyze the organizational and socio-economic impacts of the outage, as well as the infrastructure interdependence. The research employs a mixed-method approach to data collection and analysis. The remainder of this report is comprised of sections describing the data collection strategy, impact overview, lifeline interdependence impacts, socio-economic impacts, and conclusions.

Data Collection Strategy

For this exploratory field research, we used a mixed methods approach to develop our data collection strategy and gather data. Collected data includes interview transcripts, news and social media content, and information from government documents and databases. This exploratory data collection strategy is part of a more rigorous methodology for collecting data after infrastructure disruption events included in NSF Grant #0927356, “Repeat Disaster Impacts to Infrastructure Networks and Their Effects on Economic Agent Recovery.”

SDG&E Data Collection

Initially we planned to conduct interviews with SDG&E personnel to finalize our data collection strategy and provide the primary data set fort his study. However, after a short

phone interview and a few emails, SDG&E declined to be interviewed further or provide information of any kind, citing an ongoing federal, state, and private investigations of the company related to their role in and response to the outage. While we were not able to collect data directly from SDG&E representatives, we were able to collect SDG&E data through indirect sources. These include public statements available through media sources, regulatory data (SDG&E, 2012a), and data from SDG&E logged into the County of San Diego Office of Emergency Services's (OES) WebEOC system.

SDG&E used Twitter exclusively for social media-based public relations and, in part, as a means of communicating with public agencies. SDG&E used Twitter to provide advice on what to do during the power outage and also to announce when regions of their service area had been restored., We obtained a dataset of all the Twitter posts from SDG&E during the power outage, including the post text and timestamp. The dataset was created using the system of Butts et al. (2011). This server-based system is designed to obtain data from online communication sources, including Twitter. It automatically captures all public tweets that contain keywords used to infer the posting of disaster-related information.

SDG&E is required by the federal government to provide a variety of data and information on their Web site (SDG&E, 2012b),, including dynamic load profiles (SDG&E, 2012a), which were particularly useful for this study. Dynamic load profiles represent customer electricity consumption in units of kilowatt-hours sampled for each hour of each day. They are reported for several different types of customers.

OES logs and share information via WebEOC—an internet-based emergency information management system, therefore information provided by SDG&E to OES is available to the public. SDG&E data collected from OES quantitatively describe spatio-temporal restoration of the electric network.

Because of SDG&E's lack of participation in this study, we used news coverage of the outage to identify representatives from SDG&E customers to interview, specifically public agencies, hospitals, schools, and businesses. Additional representatives to contact were identified through snowball sampling. We conducted face-to-face or phone interviews with these study participants to gain insight on the outage impacts and response. Several participants from public agencies contacts provided documents to us directly or identified where to obtain documents (e.g., California Legislature, 2011; California State Assembly, 2011; City of San Diego, 2011; CPUC, 2011; CPUC, 2008; CPUC, 1998; LECG, 2011). All of the data collected as described above were synthesized to highlight the chain of events, the overall impacts, lifeline interdependency impacts, and socio-economic impacts.

Outage Overview

According to the California Public Utilities Commission, the power outage began at the 500kV North Gila substation in Arizona (CPUC, 2011). At 3:27:39pm on September 8, 2011 the substation went off line. Eleven seconds later all of the power was out in San Diego County. With the substation off line there was a loss of power on the Southwest Powerlink (SWPL) transmission line, which runs into San Diego County across the southeast border. Because of the loss in current on the SWPL there was increased current on the Path 44 transmission line that enters San Diego County from the northwest. With the SWPL offline,

Yuma, Arizona, Imperial Valley, California, Baja Norte, Mexico, and San Diego were wholly dependent on Path 44. This exceeded the safety setting of Path 44 and, in turn, shut down the San Onfre Nuclear Generation Station (SONGS) switchyard. This stopped the current into San Diego County from the northeast (Path 44) and the southeast (SWPL). Local generation in San Diego County could not meet demand and was disconnected to prevent damage as well. The series of events was unexpected because, pursuant to federal rules, electrical substations are designed with safeguards to prevent such cascading failures. Investigations of the outage are focusing on why safeguards and protocols did not work to prevent the cascade of events.

All of San Diego County is within SDG&E's service area and so restoration within the jurisdiction was conducted by SDG&E (SDG&E, 2011b). According to public information from SDG&E, as well as various public testimonies (e..g, California Legislature, 2011; California State Assembly, 2011; City of San Diego, 2011), the first instance of restoration occurred around 8 p.m. on September 8. According to the same sources, all but a few isolated customers were restored in about 12 hours—no later than about 3:30 a.m. on September 9.

Figure 1 shows two different types of recovery curves—one based on the number of customers restored and one calculated from SDG&E dynamic load profiles. The fraction of total customers restored over time (black line) is derived from San Diego County WebEOC logs. In addition, the figure shows the dynamic load profile of the SDG&E service area by economic sector. The load profile data shown starts at Hour 20 (or 8 p.m. on September 8) and ends at Hour 48 (or 12 a.m. on September 9). The load profile data are normalized using the load profile data for the same two days of the week for the week before (September 1 and 2). Thus, a value of one indicates the load is back to the "normal" load compared to the week before—that is, the load has recovered. (The load from the prior week was compared to other past weeks and found to be representative.) Except the large commercial and industrial sector, each economic sector plotted in Figure 1 had a spike in load before stabilizing to approximately the same load for the same time the week prior. It is unclear why the load spike for agriculture occurred more quickly than for the other sectors.

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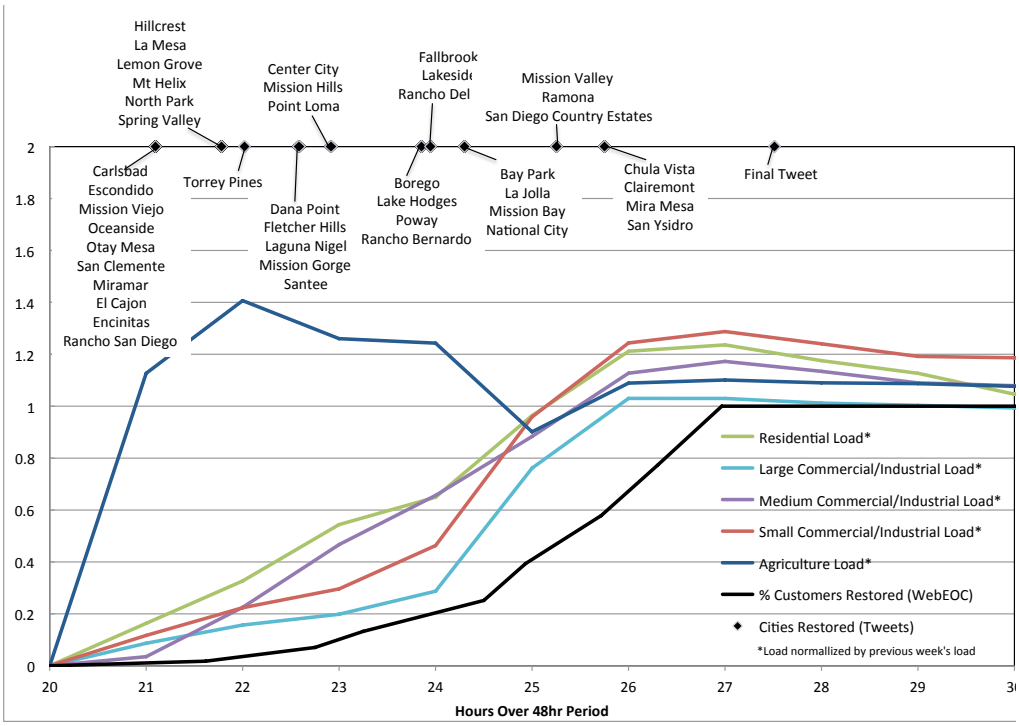

Figure 1. The fraction of total customers restored over time (black line) and the load profile of the SDG&E service area by economic sector. The load profile data starts at 8 p.m. on September 8, 2011 (Hour 20 on the *x* axis of the graph) and ends at 6 a.m. on September 9, 2011 (Hour 48). The load profile data for this period is normalized using the load profile data for the same two days of the week for the week before. A value of 1 indicates the load is back to the "normal" load represented by the prior week.

SDG&E posted messages on Twitter, providing updates on when municipalities were restored so we were able to assemble a quasi-spatial timeline. This is shown in Figure 1, We obtained detailed data of SDG&E's Twitter posts (2011) using the system developed by Butts et al. Based on this timeline, it is not clear that restoration occurred in the spatial pattern indicated by government agencies and SDG&E—initiating in the southwest, beginning with the North Gila substation and in the northwest with the SONGS substation and progressing inwards to the central part of the county. For example, Lemon Grove was restored well before Chula Vista and National City, even though these municipalities are close together in the southern-most part of the county. Fallbrook is close to the SONGS substation in the north, but was restored well after Torrey Pines, which is along the central part of the coast—much further away from SONGS or North Gila. The first two municipalities with restored power were Escondido and San Marcos according to updates from SDG&E logged into San Diego County's WebEOC. These municipalities are in the central part of the county.

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Lifeline Impacts

The San Diego power outage caused disruptions to interdependent lifeline infrastructure. These include communications, transportation, fuel, domestic water supply, and wastewater. The remainder of this section briefly describes in turn the impacts to respective lifelines caused by the power outage.

Communication Impacts

Communication networks, including emergency communications, telephone, cellular, Internet, and cable service were overwhelmed in the first 30-60 minutes following the blackout. Ninety percent of Time Warner Cable Company's customers lost service immediately. While some communication systems had backup power, there were several instances where either backup power did not work properly or was insufficient to handle the required load. For example, the city manager of El Cajon said the city experienced outages of their emergency communications system because of insufficient relay capacity.

SMS (texting) service on cellular networks worked fairly consistently, while voice and data services performed poorly during the 12-hour outage. Calls and texts from friends and co-workers about power service and restoration were frequently stated as the best source for information. Many people who had smartphones and could access their cellular data service used social media to disseminate and find information about the outage until their batteries ran down.

San Diego County Health and Human Services indicated that 911 call volume was three times higher than typical immediately after the outage,, exceeding surge capacity. According to it's former director, OES in collaboration with SDG&E issued about 500,000 reverse-911 calls to the public, particularly those with special medical needs. This was done using AlertSanDiego – a regional public notification system. The AlertSanDiego system was also used to notify residents and businesses in some areas of a boil-water advisory.

Transportation Impacts

The power outage had significant impacts on transportation. San Diego's light rail system experienced stoppage. San Diego International Airport remained open during the blackout. Backup power supplied about 25 percent of their operations, which were prioritized based on life safety and evacuation. No outbound flights were permitted and some inbound flights were delayed or diverted. The most critical impact was to traffic and freeway on-ramp signals, few of which had battery backup. Signals were either off or had reverted to flashing red. Traffic began to clear up approximately three hours after the initial outage. However, traffic signal operations were unreliable for about two weeks after the event. Traffic delays were exacerbated in downtown San Diego because rail-crossing arms were stuck in the down position.

Fuel Impacts

The outage severely impacted access to fuel service. The former director of OES observed that the most significant impact was on the ability of consumers, repair crews, and law enforcement to access gasoline. Without electricity, gas pumps were inoperable. For the most part, jurisdictions reported being able to operate their own fueling locations for first responder vehicles using manual pumps. Almost all of the gasoline stations in San Diego County were closed during the outage. Clearly there was an economic impact associated with gas station and convenience store closures, but no estimate has been done to our knowledge. Access to natural gas by consumers was also hampered as a result of the outage

for similar reasons. A local natural gas company said that they did not have backup generators.

Water and Wastewater Impacts

We interviewed the assistant director of PU to understand the impacts of the power outage on water and wastewater infrastructure. PU operates and maintains 82 pump stations as part of their wastewater system. Power was restored in approximately five hours and before SDG&E could deliver mobile generators. Of the 82 pump stations operated by PU, 54 have backup generators. One has duel natural gas powered pumps. Five have duel electrical feeds from separate SDG&E substations, which is in accordance with EPA standards for energy reliability.

The outage lead to failures at two pump stations at Los Penosquitos lagoon near Torrey Pines State Park (Pump Station 64) and South Bay (Pump Station 1), respectively. These pump stations are two of the five that have duel electrical feeds for electricity reliability. Closures and warnings were posted at beaches from the Scripps Pier in La Jolla north to Solana Beach about six hours after the spills started. All beaches and parks in San Diego were reopened by September 14. Approximately 2.6 million gallons of sewage were spilled into Los Penosquitos lagoon and is considered to be the biggest sewage spill in the county over the past decade. A local environmental group, San Diego Coastkeeper, reported fish kills as a result of the spill (San Diego Coastkeeper, 2011). San Diego Coastkeeper also reported elevated fecal coliform and reduced dissolved oxygen levels for at least a week after the outage. PU pumped 15 million gallons of contaminated water from the lagoon into San Diego Bay over two weeks as part of clean up efforts. Over 900,000 gallons of sewage were spilled from Pump Station 1 at South Bay into the Sweetwater River and, ultimately, the bay.

In areas without gravity-fed water networks, the loss of power impacted access to potable water in some cases. Seventeen of 166 small water systems in rural unincorporated San Diego County experienced low water pressure. It took almost two weeks to get these systems back up and running. Within the City of San Diego, 13 small areas experienced reduced water pressure. The City of San Diego Public Utilities (PU) has 17 generators to dispatch to their 49 pump stations in an emergency. In this case, the city dispatched generators to five of the boil-water advisory areas before SDG&E was able to restore power. A boil-water advisory was issued in areas with low pressure in case there was contamination from backflow. According to San Diego County Department of Environmental Health, this was done as a precaution; no instances of contamination were reported. Boil-water advisories were issued for these areas and lifted by September 11.

Socio-Economic Impacts

The September 8 power outage was short in duration. As a result, the direct economic loss was small. Even so, the event had several distinct impacts that can provide lessons to San Diego and other areas. The impacts to San Diego's economy, schools, health care system, and social services are described below.

Economic Impacts

The National University System Institute for Policy Research (NUSIPR) calculated the direct economic loss of the outage to be between $97 and $118 million. According to the president of NUSIPR, the calculation underestimates actual losses. Their estimate includes $12 to $18 million for food spoilage, $10 to $20 million for government overtime, and about $70 million for lost productivity (NUSIPR, 2011). These three estimates were based on estimates for the 2003 Northeast United States blackout, 2003 and 2007 San Diego wildfires, and 1996 San Diego brownouts, respectively. The original estimates were adjusted for various factors, such as population difference, to arrive at the estimates for this event. The NUSIPR estimate is not specific to the September 8 outage. As a result the estimate ignores several sources of direct and indirect losses associated with the outage, such as millions of dollars of losses suffered by medical care facilities (discussed below) and issues with child care for the day that schools were closed.

Of particular note were food-related businesses, including restaurants, bars, grocery stores, cold storage and food processing. Many such businesses chose to throw away, discount or give away perishables to avoid liability of serving spoiled food. Some bars and restaurants that had backup generators saw an increase in business. This garnered attention from the news media, citing the handful of "outage celebrations" at these establishments.

School Impacts

In response to the outage, San Diego County Office of Education (SDCOE) closed all schools in the 42 districts of San Diego County on September 9—the day after the outage. The SDCOE public information officer said that for the most part, schools in the area experienced little logistical trouble on the first day of the outage, with students able to get home because of the timing of the outage. Schools were closed in part for safety concerns related to traffic signal outages and the impact on bussing. SDCOE said that SDG&E's restoration approach was also a factor in this decision. SDG&E communicated to SDCOE that restoration of schools en masse would lead to a large spike in load that would make stabilizing the electrical network difficult and result in a prolonged outage. To avoid a small budget loss, some school districts petitioned the California Department of Education that the lost day not be considered in calculation of average daily attendance money because it was due to an emergency.

Health Care Impacts

There were no deaths or significant injuries reported as a result of the outage. There were several cases of various healthcare facilities transporting patients to other facilities for precautionary reasons or because of generator malfunctions, including one large nursing home. There were also instances where home-bound residents using electric medical devices were transported to nearby healthcare facilities. Because these devices typically have at least six hours of battery backup, these instances were infrequent.

Two hospitals experienced backup generator malfunctions: Sharp Memorial Hospital in Kearney Mesa and Scripps Mercy Hospital in Chula Vista. While Sharp Memorial was never entirely without power, Scripps Mercy was without power for 90 minutes until they brought in mobile emergency backup, according to the administrative director of disaster

preparedness for Scripps Health. The permanent backup generator failed to work because of a fuel pump problem. Scripps, like other health care facilities, is not permitted to test their generators for more than 96 hours per year because of California Air Resources Board regulations (ARB, 2012). The Scripps disaster preparedness director observed that, as a result of the regulations, the generator might not have been run long enough to catch the fuel pump problem during testing the week prior to the outage. Even so, the entire facility was eventually evacuated in coordination with San Diego County. Many of the medical equipment within Scripps Mercy have battery backup that lasted for all or most of the outage. Scripps Mercy had to cancel surgeries, exams, diagnostics, and close clinics serving more than 900,000 customers. Direct losses for Scripps Mercy were estimated to in the range of $5 million, including lost revenue and perishable medication that had to be discarded—the value of which is estimated to be in the millions of dollars.

Social Service Impacts

The CalFresh program issues nearly $30 million in food stamp benefits to about 200,000 low-income San Diego County residents each month. The San Diego County Department of Public Health manages the CalFresh program. Because the power outage occurred when recipients typically use a large portion of their benefits to purchase food, the county offered to reimburse recipients for up to one month's benefits to replace discarded food. For a large family, the value of the reimbursement could be in the thousands of dollars. Recipients could apply for the benefit replacement at one of 10 county family resource centers, using forms available in English and Spanish, but were required to apply within 10 days of the outage. It is unclear how many recipients knew that they could receive replacement benefits, but it is clear that only a portion of those eligible. In general, San Diego's food stamp participation rate for eligible residents has been among the lowest of urban centers in the county due to lack of awareness of eligibility rules.

Conclusion

San Diego had extensive disaster experience even before the September 8, 2011 power outage. Within five years, the county experienced two extreme wildfires. The San Diego area has participated in multiple statewide Great California Shakeout drills—an exercise that, until recently, was unique to California. Even so, the outage exposed significant obstacles for San Diego to successfully recovery from future disasters, considering the relatively limited impact of the power outage.

The power outage points to several areas where increased public awareness is needed. Residents should be reminded what 911 calls are appropriate during disasters and that sheltering in place facilitates emergency response during outages and earthquakes. The county could better raise awareness of the eligibility and process for replacing CalFresh food stamp benefits after disasters. This will require ethnically specific approaches, such as increasing the number of languages available for CalFresh applications and educational materials.

Looking at the public information provided by SDG&E, it is not clear if they approached the restoration in the way they claimed. Customers in their service areas—whether governments, businesses, or households—would undoubtedly benefit from having better

pre- and post-event knowledge of (if not involvement in shaping) SDG&E's restoration process, including prioritization criteria and restoration sequence.

The limited impacts of the power outage emphasized significant effects that could be overlooked in larger disasters. Environmental impacts, such as sewage spills, are one example. While certainly an issue in all extended power outages, food spoilage was of note in this case because of fewer impacts than would be the expected in a larger-scale natural disaster. The loss to small businesses, however, is not discountable and should be considered in business continuity planning for food-related businesses.

Backup power is central to the lessons learned from the power outage. Local businesses, governments, and critical facilities have been and should be compelled to reconsider their stances on planning for and investing in power continuity. Some businesses, particularly food services, may now perceive the benefits of backup generators to outweigh the costs. Public pressure may be applied to governments for increased energy assurance. For example, the City of San Diego, at the time of this writing, is planning on spending $11 million on permanent backup generators to prevent future disaster-related sewage spills (Lee, 2012). State and local governments might consider implementing or improving policies to promote electrical continuity for households and businesses during disasters. This could range from providing technical resources for calculating cost-benefit and determining necessary generator sizes to subsidizing or incentivizing the purchase of backup generators. There is also opportunity for improving plans and agreements to deliver mobile generators during disasters.

In general, federal or state regulations could be improved, put in place, or enforced to ensure power restoration considers community-based goals such as health care, environmental quality, small businesses performance, and rural communities. The former director of OES suggested that San Diego County require large-scale disaster exercises that focus on infrastructure interdependence so these goals can be evaluated. The Environmental Protection Agency should revise energy reliability standards to require backup power in areas where large-scale outages are likely to result from natural hazards. Similarly, the State of California should review current air quality regulations related to backup generator to ensure adequate testing is permitted. Lastly, the state should continue to consider the issue of whether power companies are required to consult certain critical organizations or agencies, such as SDCOE and PU, in planning for and responding to power outages.

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