Critical Infrastructure Protection in the National Capital Region

Risk-Based Foundations for Resilience and Sustainability

Final Report, Volume 20:
Hurricane Isabel: Critical Infrastructure Interdependency Assessment

September 2005

University Consortium for Infrastructure Protection

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Submitted in fulfillment of:
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NCR-CIPP

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– Notice –

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National Capital Region

Hurricane Isabel

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I. Executive Summary

Hurricane Isabel has been described as a 100-year storm - the type that hits only once every few generations. This unusual level of severity provides a unique test bed for evaluating large-scale emergency response and impacts to critical infrastructures under real conditions. This report examines the impact of Hurricane Isabel on the National Capital Region (NCR). In particular, the study addresses the resilience of key citizen services, such as electric power, telecommunications, transportation, and water. In uncovering and evaluating the interdependencies between critical infrastructures, this research effort focused on how specific utilities and organizations prepared for the hurricane; how they reacted to the hurricane; how they recovered from it; and, through analysis of these actions, what lessons have emerged. The study revealed the NCR's level of preparedness and ability to restore and recover critical infrastructure functions. The data collected demonstrates the remarkable performance of each in restoring service; and, also offers a snapshot of the National Capital Region in a specific situation, highlighting critical interdependencies and demonstrating areas for further development.

Data collected throughout the course of the study leads to several strategic conclusions. Each of the recommendations below reinforces the prevalent view that the NCR represents an important geographic region that is the locus of much of the federal government. Hurricane Isabel revealed highly interdependent infrastructure services as well as issues in public trust and confidence overlapping jurisdictions in law enforcement, fire and rescue, and other vital human services.

We draw three overarching conclusions:

First, the NCR should consider consolidation of emergency management into a framework of linked Emergency Operations Centers. The importance of coordinating the region's emergency management - and the potential damage that flows from retaining a fragmented approach - dominated our interviews and field observations.

Second, there needs to be interoperable communications and information exchange system that includes the private sector. The NCR's first responders and infrastructure providers performed extraordinarily well under the most difficult circumstances. First responders collaborated well across jurisdictional boundaries. Infrastructure providers successfully restored the most critical infrastructure functions in less than seven days -- as compared to 14 days after Hurricane Floyd in 1999. While certain pockets experienced delayed restoration, the NCR is more prepared and resilient than in previous years.

Third, Hurricane Isabel and the subsequent damage clearly identified that infrastructures are highly interdependent - water treatment facilities reliance on electricity for operation or hospitals reliance on water for patient care are examples. This finding supports the need for infrastructure owner-operators to be more aware of the interdependencies and to have contingency plans in place as a means to mitigate system degradation in times of service disruption or outage.

Summary of Findings

Research activities and interviews focused on the following areas outlined below. They have been arranged according to temporal importance to the event: pre-planning, initial response, preliminary recovery, interdependencies, and recommendations for remediation.

- *Preparation and Planning Prior to Event*
  - Municipalities were not as well-prepared because they did not include privately owned utilities in pre-disaster planning, and vice versa.
  - Most critical infrastructures did not prepare sufficient levels of redundancy. For example, even those entities with back-up power generation only expected to use it for a matter of hours, not days.
  - Alternative forms of public communication were not established (i.e. using radio instead of television, print media instead of the Internet).

- *Initial Response, Impact Assessment, and Communications/Coordination Actions*
  - Coordinating responses among infrastructures and organizations was often difficult. Although Hurricane Isabel caused simultaneous damage to multiple infrastructures (i.e., a tree downing power lines, telephone lines, and blocking a road all at once), there was no central mechanism or framework to coordinate appropriate response and recovery activities.
  - Coordination between state and local government and the privately owned utilities was also strained. Some Emergency Operation Centers (EOCs) had no utility representation, and had difficulty interfacing with utilities at the peak of the hurricane. Those EOCs that did have utility representation discovered that the representatives were not authorized decision-makers. This slowed critical responses to affected areas.
  - From the consumer perspective, the most common complaint was inadequacy of communications from privately owned utilities. The utilities had difficulties disseminating information, and alternative methods were not always used effectively. Frequently, the information provided was inaccurate.

- *Preliminary Recovery Assessment and Noted Lessons Learned (to date)*
  - Need for government and private sector organizations to develop an encompassing recovery plan, a need to test that recovery plan, and a need for a mechanism to develop and implement it.
  - GIS maps played an important role in identifying those areas more affected than others. Sharing of GIS data among infrastructures to the EOCs would have assisted in the response and recovery process.
  - Alternative forms of communication are necessary - when the television and Internet are not working, something else must be used to fill the gaps. It is also necessary to take into account regional information needs when crafting messages.

Summary of Findings (continued)

- *Infrastructure Interdependencies and Identified Consequences*
  - Short-term and longer-term impacts from failures in interdependent infrastructures were noted.
  - Loss of electric power affected almost every critical sector: water treatment plants were inoperable, traffic lights were down, and cellular towers experienced intermittent service disruption. These were the immediate, direct consequences of power loss.
  - The longer a service was out, the further the disruptions cascaded. For example, hospitals had to consider moving patients due to the inability to clean dirtied bed linens. Linens could not be cleaned because the laundry facilities had no water. Water systems became contaminated and a lack of power caused an overall shortage of water.

- *Recommended Remediation Actions Resulting from Event*
  - The most prevalent suggestion going forward from Isabel, voiced by representatives of almost every infrastructure, is centralization of emergency coordination on the local and state level. The communications, command and control, and resource management challenges that each sector faced during the hurricane could have been addressed if representatives from each sector had been working together. The EOC concept touches this, but should be developed further to include industry as well as government.

II. Project Definition and Methodology

Project Definition

George Mason University (GMU) was tasked to conduct an assessment of selected critical infrastructure service delivery interruptions and interdependencies resulting from Hurricane Isabel in the National Capital Region. This work is a component of the work being done in support of the Urban Area Security Initiative in the National Capital Region and serves as precursor to the larger scope of research proposed under this initiative. Hurricane Isabel's aftermath provides a unique opportunity to study the interdependencies between key impacted infrastructures. This endeavor focuses on a review of the energy, water, transportation, and telecommunications infrastructures in the National Capital Region to assess their independent and interdependent qualities. A necessary additional element of this analysis is a review of regulatory processes for these infrastructures. In line with the overall objectives of the larger NCR Project, the goal of this analysis is to lessen the impact of future disasters within the National Capital Region.

Methodology

George Mason University engaged expert academics from within the University, as well as partner institutions from across the National Capital Region, to conduct this interdependency assessment. Specific activities included an extensive literature review and a series of meetings and/or individual interviews with representatives from industry and government to explore the impact of Hurricane Isabel. The research team developed a survey instrument comprised of a set of questions to elicit input from interviewees about vulnerabilities and related interdependencies (Appendix A). Questions were crafted to address specific issues and identify interdependencies. In addition, a general set of questions was utilized in order to establish a baseline across sectors.

Through the series of meetings/interviews the team solicited input from high- level operators within each identified organization and the regulatory community regarding their experience with Hurricane Isabel. Following these meetings and preliminary analysis, GMU held a plenary session to collectively focus the industry and government representatives on critical interdependencies.

Energy

Representatives from four companies serving the National Capital Region (NCR) were contacted and interviewed. They included representatives from: Dominion Virginia Power, Potomac Electric Power Company (PEPCO), Washington Gas Company, and Chevron Services Corporation.

Water and Waste Water

Representatives from four agencies in the Water Sector serving the National Capital Region were contacted and interviewed. They included representatives from: Fairfax County Water Authority (FCWA), Washington Suburban Sanitary Commission (WSSC), the Washington Aqueduct, and the Interstate Commission on the Potomac River Basin (ICPRB, or Potomac River Commission).

Transportation

Representatives from six agencies serving the National Capital Region were contacted and interviewed. These included representatives from: the Virginia Department of Transportation (VDOT), Maryland State Highway Administration (MDSHA), Washington Metropolitan Area Transportation Authority (WMATA), Fairfax County Department of Transportation (FCDOT), Arlington County Department of Public Works (DPW), Dulles International Airport (IAD), and Reagan National Airport (DCA).

Telecommunications

Representatives from three companies serving the National Capital Region were contacted and interviewed. These included representatives from: Verizon, Motorola, and MCI/WorldCom.

Regulatory/Legislative

Nearly thirty area leaders, legislators, policymakers, and regulators serving the National Capital Region were contacted and interviewed. This includes representatives from: the Virginia State Corporation Commission, Virginia State Senate, Fairfax County CAO, Arlington County Manager's Office, Montgomery County CAO, Maryland Department of Homeland Security, Maryland Emergency Management Agency, Virginia Department of Transportation, and the Greater DC Council of Governments.

III. Preparation, Planning, and Response

The following section provides background information on each infrastructure reviewed in this analysis including energy, water, transportation, and telecommunications. In addition, preparation and planning activities conducted within each industry sector prior to Hurricane Isabel are examined.

Energy

The National Capital Region consists of three primary electrical service providers: Dominion Virginia Electric Power (Dominion) serving Virginia, Potomac Electric Power Company (PEPCO) serving the District of Columbia, and Baltimore Gas and Electric (BG&E) serving Maryland. These service providers have well-established emergency response organizations and procedures. Advanced warning of Hurricane Isabel made significant preparatory activities possible.

BG&E secured more than 3,000 utility personnel in advance of Hurricane Isabel's arrival. The utility urged customers to report power outages promptly through BG&E's automated phone system, which is designed to help identify the scope and location of outages on the system. As part of the 3,000 personnel dedicated to power restoration, BG&E mobilized 400 of its own crews, and secured 400 additional crews from utilities and contractors from at least nine other states. BG&E purchased nearly half-a-million pounds of dry ice to distribute and planned to make it available in areas most severely impacted by the hurricane. BG&E also established system restoration priorities in the following hierarchy: public safety, including downed and sparking wires; critical facilities, including hospitals, 911 call centers, and water treatment plants; large outages affecting the largest amount of customers; and customers that have been without power for the longest amount of time.

Prior to Isabel's arrival in the region, PEPCO put its Emergency Response Plan into action to engage the entire company. The utility lined up crews from distant utilities; procured over 300,000 pounds of dry ice and arranged distribution centers; and ordered replacement poles, transformers, other electric supplies and equipment to expedite the restoration process. Hundreds of support personnel were reassigned to help with customer calls, patrol for damage, check downed wires, lead outside crews and fulfill other tasks.

In addition, PEPCO issued media releases and conducted press conferences, urging customers to have flashlights, fresh water, first-aid kits and other supplies on hand. They also warned customers about the dangers of downed power lines and how to report them. All of these tips were repeated on PEPCO's web site under a dedicated storm section. The utility also initiated telephone calls to the 900 customers registered as being on life support to recommend they make alternate arrangements in the event of lost power.

Dominion also began preparing for Isabel prior to its arrival in Virginia. A workforce of 7,000 was initially mobilized to deal with anticipated outages. Repair crews were placed at staging areas in central, eastern and Northern Virginia so they could respond quickly to storm damage. The company also secured the supplies needed for massive service restoration, including poles, cross arms, transformers and wire.

On the communications front, Dominion issued several news releases to advise customers of expected lengthy outages and aired radio ads urging customers to prepare. The company utilized their web site as a crisis communications tool, providing links to emergency information, hurricane preparedness tips and real-time postings of company news releases. Dominion contacted 10,000 customers with special medical needs and in anticipation of outages, recommended they make alternative arrangements.

In addition, Dominion set up extensive contacts with all levels of government. In advance of the storm, they briefed officials on their preparations and provided company contacts for all officials. Regional storm centers set up by the company interfaced with all local Emergency Operations Centers through special telephone lines that expedited the exchange of critical storm-related information.

Water and Waste Water

Many water utilities serve the National Capital Region. Fairfax County Water Authority (FCWA) is Virginia's largest water utility and serves 20% of the state's population. More than 1.2 million people in Northern Virginia depend on FCWA, which operates four water treatment plants, for drinking water. During Hurricane Isabel, FCWA experienced communications challenges due to an increased amount of on-line email communication, causing personnel to be redirected to operate and respond to online communication. Additionally, it took six hours to realize that the County spokesperson and FCWA spokesperson were not coordinating to remedy the situation.

The Washington Suburban Sanitary Commission (WSSC) is the water and wastewater utility for Prince George's and Montgomery Counties, Maryland, and serves over 1.6 million residents. WSSC also operates and maintains four reservoirs, two water filtration plants, six wastewater treatment plants, the Blue Plains Water Pollution Control Plant, and more than 10,000 miles of water and sewer mains. During Isabel, the WSSC had about 12 to 24 hours of supply in reserve at the start of the storm. WSSC does not have sufficient emergency power backup to continue full service water supply during a prolonged loss of power, but this was not a factor. There was a short shutdown (a few hours) of the Potomac Plant due to pulses in the electric system, but there were no impacts on WSSC customers. Instead, local power outages affected home owners and businesses that rely on groundwater pumped from wells on the property.

The Blue Plains Wastewater Treatment Plant, which treats some of the wastewater from the WSSC system, received surges of inflow because of the rain. This was within normal ranges, and is due to infiltration and inflow of surface and ground water into the sanitary sewers. There was some flooding at the Blue Plains Wastewater Treatment Plant, due to the tidal surge caused by Isabel, but the impacts were minor. The WSSC Broad Creek wastewater pumping station overflowed as a result of storm-related power outages. When power was restored days after the storm hit, the electrical surge was thought to have contributed to breaking a sewer main connecting the Broad Creek and Swan Creek wastewater pumping stations to WSSC's Piscataway wastewater treatment plant. Both pumping stations had to be temporarily shut down to repair the broken pipe, but repairs were made within 24 hours. An estimated 11 million gallons of diluted wastewater overflowed into Broad Creek and Swan Creek, tributaries of the Potomac River.

WSSC's Western Branch wastewater treatment plant lost dual power feeds. Power was restored on Saturday morning, by which time an estimated 30 million gallons of diluted wastewater overflowed into the Western Branch of the Patuxent River. Luckily, these facilities are located in areas with little or no public access.

The Division of the U.S. Army Corps of Engineers (The Washington Aqueduct) supplies water to the District of Columbia, Arlington, Falls Church and parts of Fairfax, including federal offices and Reagan National Airport (RNA). The Aqueduct produces an average of 180 million gallons of water per day at two treatment plants located in the District of Columbia. The Washington Aqueduct maintains "several hours" of supply at all times. Essential federal offices and National Airport can be supplied longer in an emergency. A significant portion of both the WSSC and Washington Aqueduct systems are gravity flow and thus are not as dependent on electricity for pumping. As with the WSSC, the Washington Aqueduct does not have sufficient emergency power backup to continue full service water supply during a prolonged loss of power, but this was not a problem during Isabel.

Finally, the Interstate Commission on the Potomac River Basin (ICPRB), formed by a multi-state compact between Pennsylvania, West Virginia, Virginia, Maryland, and DC that facilitates decision making with regard to the Potomac River, did not play a large role during Hurricane Isabel. However, they participated in the "Regional Incident Communication and Coordination System" (RICCS). As defined in the Regional Emergency Coordination Plan (RECP), RICCS provides a system for Council of Governments members, the State of Maryland, the Commonwealth of Virginia, the federal government, public agencies, the private sector and volunteer organizations, and schools

and universities to collaborate in planning, communication, information sharing, and coordination activities before, during, and after a regional incident or regional emergency. It is a virtual system with multiple capabilities designed to facilitate regional communication. Participating organizations will use multiple means of communication, including conference calling, secure websites, and wireless communication systems.

In general, internal communications were degraded as either communication lines or SCADA (supervisory control and data acquisition) system components went down. As a result, operators/managers were working without full knowledge of the status of the system, while workers suffered because cell phone circuits were extremely busy, and/or telephone lines were down.

Transportation

The experiences of transportation agencies within the NCR were different for each jurisdiction and the issues varied across the region. A plan was developed by the Virginia Department of Transportation (VDOT) Northern Virginia Office to prepare for the anticipated consequences of Hurricane Isabel. A principal goal of the plan was to keep roads open and operating safely and to maintain and restore (as necessary) signal operations in a timely manner. Many preparatory actions were taken as part of this plan in addition to standard emergency procedures and included among other things: securing additional contractor resources to focus on handling downed trees, supply of road repair materials and assisting with traffic operations and signal systems; establishing contact with the local counties, police, and utility companies to initiate coordination of emergency response and services during the event; holding meetings and conference calls between members of the Maintenance and Operations Core Group to discuss preparations and relay key information; and working in partnership with external organizations (such as the counties and Dominion Power) to address issues.

Further, VDOT and the Arlington County Department of Public Works recognized the importance of equipment planning and maintenance of electrical power. Thus, steps were taken to ensure that there were backup power supplies in conjunction with the traffic signal control systems. VDOT operates more than 1000 signals in Northern Virginia and 660 did lose power at some point. Arlington County operates about 250 signals and about 50 lost power. Backup systems used by VDOT and Arlington County included battery applications or uninterruptible power supply (UPS) systems, both of which are also used in other parts of the U.S. and abroad. VDOT took steps to establish a remote backup system as a precautionary measure to assist the operations staff at the VDOT Smart Traffic Center (STC) in Arlington.

Washington Metropolitan Area Transportation Authority (WMATA) established a plan to address the anticipated impacts of Hurricane Isabel in concert with the Regional Incident Communications and Coordination System (RICCS). Included among the WMATA planning activities were monitoring the speed at which the hurricane was moving to anticipate its arrival; determining which critical services to continue operating during the hurricane and deciding when to terminate other services; and, coordinating termination of services with chief administrative officers and managers of suburban bus and commuter rail operators.

The Fairfax County Department of Transportation and the Arlington County Department of Public Works officials coordinated efforts with other emergency preparedness agencies in the region by participating in periodically scheduled teleconferences. All regional agencies have an emergency operations plan in place for snowstorms and agencies used this plan to develop an emergency plan for the hurricane. During the hurricane, county agencies internally monitored the consistency of the plans with the pro-

jected course of the storm and reported outages. Periodic updates from other local agencies kept the agencies' plans in sync with transportation operations throughout the region. In addition to the snowstorm-related operational plan, Arlington County also commissioned an emergency plan for Hurricane Isabel. Further, the County's Public Information Officer (PIO) provided updates to the media and the public on their emergency preparedness and citizen advisory notices every two hours.

About ten of the most critical intersections in Fairfax County have backup power. However, for preventing storm related damage to the infrastructure, the County disconnected the backup power during the storm and reconnected it soon after the storm. In addition to providing backup power at the most critical intersection, the County acquired 15 additional portable generators to be installed at various important intersections.

During Hurricane Isabel, Fairfax County planned to operate the Fairfax Connector bus service, a small operation that only services Metro rail stations on snow routes. The plan's exceptions were for routes that had potential for flooding, which were scheduled to be suspended at some point during the storm. The County coordinated their efforts within the area through their own emergency operation and those of other local agencies. Due to lack of good communication, some confusion about the operating schedule followed Metro's decision to shut down service but it was resolved quickly.

Dulles International and Reagan National airports, in conjunction with the Washington Metropolitan Airport Authority (MWAA), developed plans in preparation of Hurricane Isabel. The implementation of the plans was the responsibility of the directors of airport operations. Elements in these plans included: monitoring wind ratings and weather reports; securing materials and equipment on construction sites and equipment on ramps; determining the point at which no additional flights would be allowed; and, coordinating use of plumbers in flood prone areas. In addition, both directors coordinated critical activities with the MWAA police and fire and rescue services and the airlines. The director at Reagan National Airport also worked in close contact with WMATA and the United States Park Police, who have jurisdiction over the George Washington Memorial Parkway.

In preparation for Isabel, the Maryland State Highway Administration (MDSHA) initiated a number of internal activities including: coordinating activities for the potential evacuation of Maryland's Eastern Shore; and stockpiling materials such as sand, gasoline, traffic cones, food and supplies for operations staff that would be pressed into service for extended periods of time. MDSHA also took part in numerous teleconferences with agencies in the NCR that were conducted via the RICCS. Many of the actions that were taken by MDSHA prior to the arrival of Isabel were the result of a variety of ongoing training activities including mock incidents, tabletop exercises and classroom training. Specific operational procedures during Isabel were built off of other events that were managed by MDSHA and their partner agencies.

The focal point of MDSHA statewide operations during emergencies such as Isabel is the Coordinated Highways Action Response Team (CHART) Statewide Operations Center (SOC). CHART is a joint effort of the Maryland Department of Transportation and the Maryland State Police (MSP) to improve operations of Maryland's highways. The SOC is operated 24 hours-a-day, seven days a week and coordinates operations with satellite Traffic Operations Centers in Maryland. The CHART program is comprised of a number of sub-systems, including traffic monitoring, traveler information, incident management, and traffic management. Two additional emergency operation centers (EOCs) are also housed in the SOC. Field devices such as the Roadway Weather Information System are controlled from within the SOC and used during emergencies. Activation of the SOC during Isabel was based on a pre-determined threshold for wind-speed. The SOC also has a generator system for use during power outages and it was utilized for only a few hours during the hurricane.

Telecommunications

Regional telecommunications organizations are typically well-prepared for natural disasters. The telecommunications companies in the National Capital Region took specific action to prepare for and respond to Hurricane Isabel.

Sprint and other providers were concerned about their mobile phone towers, which are vulnerable to high winds. In the event that its physical infrastructure was destroyed and service disrupted, Sprint was prepared to use Cellsites on Wheels (COWs). These mobile facilities rely on wireless technology and can be utilized to restore communications. Sprint also had backup generators and additional fuel on hand in anticipation of power outages, and ensured that PCS cell site batteries were fully charged and emergency supplies were available for wireline and wireless sites. In addition, Sprint communicated with customers prior to the storm, advising only to make emergency calls, particularly if they were in areas where the power typically goes out, and asked them to report outages only once using a special number designated by the company. They also communicated with local emergency management organizations to offer their help.

Verizon makes preparations on a regular basis for natural disasters. Prior to Isabel, the company made sure that generators had fuel, batteries were charged, portable generators were on hand, and fuel companies were contacted to ensure that fuel was available should they run out. They also took measures to protect their physical infrastructure by placing sandbags, plywood and drop cloths at structures located in low-lying areas. Like Sprint and Nextel, the company had a fleet of COWs prepared for potential service disruption.

Verizon has an internal command and control infrastructure plan in which it places Network Operating Centers (NOCs) and certain personnel on alert. The NOCs monitor the network to detect any problems. During Isabel, there was concern about physical diversity because three of the four backup facilities and the corporate center for Verizon are located on the east coast.

Verizon counseled its customers on emergency precautions, such as charging wireless phone batteries, and hitting the send key after dialing 911. They also informed their customers that laptop computers would continue to function without power on Digital Subscriber Lines and dial-up lines. Verizon also had thousands of wireless phones and batteries on hand for emergency personnel.

AT&T planned to utilize its Network Disaster Recovery team, a component of their $300 million Network Disaster Recovery Program, during Isabel. The Team is prepared to respond to problems within two hours and has access to a fleet of 150 tractor-trailer trucks and support vehicles equipped with tools and machinery to restore services as necessary. These vehicles are positioned all over the United States and can be transported to any other location in the nation within a 24 hour period. If any of the fiber-optic cable was destroyed, there were plans to reroute traffic around the failed cables. Also, the integrated Global Enterprise Management System (iGEMS) was put in place to detect any problems relating to data storage and transfer.

AT&T also had backup generators and plenty of fuel on hand in anticipation of power outages. AT&T's Internet Data Centers and voice and packet data switching centers have two levels of emergency back-up power to support different length outages: for lengthy outages, diesel generators are utilized to support network equipment, cooling and lights. Several days of diesel fuel are always on hand and provisions to get more if needed in place. AT&T communicated with and advised customers prior to the storm about communications back-up plans.

Some of MCI/WorldCom's fiber optic cable was exposed and slashed in previous storms so the company was concerned about this happening again with Hurricane Isabel. WorldCom has two 54 foot mobile trailers, which can provide local and long-distance phone and Internet services.

Nextel maintains that their facilities are built to withstand the forces of inclement weather, but like Sprint and Verizon, they rely on COWs and Satellite Cellsites on Wheels (SatCOWS) that can respond at a national level along with an Emergency Response Team (ERT) that can communicate with appropriate agencies in less than 45 minutes. Nextel also provided communications capabilities to emergency responders, government officials, utilities, and other infrastructure organizations.

IV. Infrastructure Interdependencies and Their Identified Consequences

From the citizens' perspective, it may be obvious that if the power goes out, their lights, televisions, and computers that depend on power supply would also go out. This type of cause and effect relation is expected, and is not an unusual occurrence. What was unusual or unique to the experiences associated with Isabel were the less obvious interdependencies - for example, the fact that drinking water supply would be interrupted when a certain area was affected by a power outage. Hurricane Isabel highlighted some of the critical interdependencies among infrastructures. The following section describes some of the instances observed during Isabel, and analyzes in detail the interdependencies of telecommunications. Finally, some recommendations for planning and response in the NCR are presented, addressing the questions of public-private coordination and responsibility.

Energy

Power Transmission Dependence on Tree Maintenance

Significant impacts can occur when landowners (private and public) adjacent to electric transmission and distribution facilities do not adequately maintain trees on their properties. Leading to Isabel, several years of drought were followed by a very wet year, which diminished the capacity of many trees to withstand high winds. Apparently, many public and private land owners did not take appropriate proactive steps to control potential impact from tree damage.

Energy Operating Facilities Dependence on Cooling Water

All of the energy infrastructure organization's operating centers (both conventional and emergency operating facilities) are filled with computer-based control and communications equipment. This equipment requires cooling, either through air-based HVAC systems or through chilled water circulation systems. The loss of water pressure and/or water supply for significant periods (many hours) in both the NCR and Richmond during Hurricane Isabel put these operating facilities at risk. Loss of cooling can quickly result in shutdown and/or equipment damage.

Natural Gas Distribution Dependence on Cooling Water

Water pressure is also critical for natural gas compressor stations and other facilities supplying gas to electric power generating plants. If cooling water pressure and/or supply is lost at the compressor stations, the fuel supply for power production will be lost as the gas pressure is lost and the gas in the pipeline is used up.

Electric Utilities Dependence on Contracted Services and Facilities for Communications and Control

The majority of communications and control system circuits are carried on the electric utilities' own facilities. However, a certain amount of communications, control, and electronic sensor circuits are carried by other communications companies under contract. In many cases, these contracted circuits have a lower level of reliability under normal operations; and, many of these were significantly impacted by Hurricane Isabel. These constituted services resulted in a higher proportion of the utility communications and control system components that failed.

Telecommunications and Electricity Dependence on Joint-Use Distribution Poles

Within all areas of the NCR, joint use poles are common. These are poles that carry both electric distribution wires and communication wires and cables. Most are owned and maintained by the electric utilities but many are owned and maintained by the communications companies. When any of these poles are downed, and the attached wires/cables become a hazard, the restoration must be coordinated, with the lead taken by the owning entity. It is critical for these groups to coordinate their tree clearing activities as restoration efforts can become complicated.

Repair Crews Dependence on Commercial Wireless Systems

During Hurricane Isabel, commercial, wireless phone services were utilized by the large number of regional infrastructure repair crews, repair crews brought in from around the U.S. and Canada, and the public- and private-contracted tree removal services. However, because of the almost complete electric distribution system damage, many of the commercial relay towers and other facilities did not function and there were a number of communications "holes" where commercial service was not available.

Water and Waste Water

Water Dependence on Energy

Electric power is the principal infrastructure input interdependency for water utilities. Power outages might shut down pumping stations, thus preventing water from getting to customers who are not part of an altitude-driven system. This occurred with FCWA during Isabel as a loss of power kept approximately one-third of their customers without water for about eight hours. Although customers were advised to boil water to ensure safety, this was impossible for many customers who lacked gas or electricity to operate stoves.

Health Services Dependence on Water

Hospitals need water for many things: drinking, bathing, cooking, etc. They also rely heavily on laundry facilities to provide clean linens. These facilities require water, and are unable to function without it. During Isabel, disposable linen in the hospitals was depleted within 6-12 hours. Hospitals had to consider redirecting new patients to other facilities and/or transferring current patients.

Water Dependence on Transport

Transportation was not particularly problematic for the Water Sector during Hurricane Isabel likely because the roads were relatively clear and passable, and the number of vehicles on the surface roads was significantly reduced. Water personnel were able to reach their destinations via their regular routes as necessary.

Transportation

Traffic Control Dependence on Electricity

For the Maryland State Highway Administration, (MDSHA), the biggest challenge during Isabel was the loss of power. None of the field devices, including traffic signals, deployed statewide were equipped with back-up power systems, requiring police to direct traffic at critical intersections. When areas experience power outages, field devices are rendered inoperable, which caused significant problems with regard to the CCTV system in the NCR. Power to some devices controlled by MDSHA in the NCR was out for up to four days. At one point during Isabel, up to 60% of the field devices statewide were inoperable due to power outages.

Public Transit Dependence on Water

The Washington Metropolitan Area Transit Authority's standpipe and fire hydrant facilities depend on the Fairfax County water system. When the county lost water supply, WMATA had to terminate hot work activities including welding and grinding.

Airport Dependence on Drainage Systems

Flooding was reported, among other locations, at

Reagan National Airport (DCA). The heavy rainfall and the proximity of DCA to the Potomac River overwhelmed the drainage systems, and the impacts of the flooding ranged from inaccessibility of employee parking lots to a temporary loss of runway lighting.

Public Transport Dependence on Communications

The Transportation Sector's dependence on telecommunications was highlighted by Isabel. All transportation operators and personnel rely on varying levels of communication, including wire and wireless telecommunication technologies. Additionally, external communication is critical between operations staff, technicians, police, fire, and rescue authorities. In some instances transportation agencies require telecommunication services from local providers and dedicated services to control traffic signal systems. While no major telecommunication problems were reported by transportation agencies during Hurricane Isabel, the interdependency was recognized as a potential challenge in planning efforts prior to the Hurricane. This interdependency is expected to become much stronger in the future with the development and deployment of Intelligent Transportation Systems for traffic management, advisory and information functions, traffic control, etc.

Surface Transportation Dependence on Power Line Restoration

VDOT depends on Dominion to switch off and clear downed live power lines before it can clear trees from major arteries.

Telecommunications

Distinct Complexity of Telecommunications Interdependencies

The number of local jurisdictions within the region, along with various federal, state, and local emergency response networks, and the number of telecommunications providers, with their mix of both terrestrial wireline and wireless networks, combine to create unique regional complexity in the National Capital Region. Specifically, because of this region's convergence of national Internet, data, and publicly switched facilities, the loss of communications capabilities does not just have a regional effect, but a national effect as well. As seen in the 2001 Baltimore tunnel fire, the impact on the national communications infrastructure of a fire to a small section of a critical part of the communications network can have major impact not just on the regional telecommunications infrastructure but nationally as well.

Telecommunications Dependence on Energy

The primary and by far most critical interdependency within the entire telecommunications infrastructure is the requirement for non-interruptible electrical power for the public voice/data network (wireline & wireless). This issue has been previously addressed in the context of natural and man-made disasters; however, during Hurricane Isabel the outcomes of electric power loss became more visible due to duration of the outage in part of the DC metropolitan area and the cascading effects associated with this outage. In other hurricane-affected areas, such as Central Virginia and the Hampton Roads areas, which had longer periods of power loss these effects were even more severe. As identified in previous surveys, virtually all public telecommunication carriers have systems in place to supply either short term battery and/or onsite generator power backup. However, these systems were designed for short term outages ranging from a few hours to a couple of days. Even with these safeguards in place the telecommunications systems will experience failure when the secondary power runs out.

The continued outage of commercial power is of

great concern as both the core switching nodes in the public networks require electrical power, as does the wireless providers switching locations. Back-up measures currently in place provided only short- term relief. For example, most of the Verizon system was operational after the initial impact of the storm in the more severely affected areas of Central Virginia and Hampton Roads since central office locations that lost commercial power were switched to generator power or battery back-up. However, these additional facilities went off line during the next several days as fuel and battery power was exhausted.

This loss of the public telecommunications network in this region was compounded by the growing dependence, both with emergency responders and in the general public, on mobile communications devices; i.e. cell phones, mobile radios, etc. While originally thought to be a solution to the loss of traditional wireline communications capabilities it became apparent during this incident that their reliability can be severely compromised by "holes" in the wireless networks [one or more towers non-operational due to loss of commercial or back-up power.] A more general issue, which was compounded by the length of power outages in the Isabel event, was that the handheld mobile receivers themselves operate on batteries which, for the most part, are either 12V DC vehicle chargers or "desk chargers" that require commercial power. During this event it was noted that the inability to recharge batteries in these devices was an issue that previously may have been overlooked.

Telecommunications Dependence on Transportation

A critical interdependence and significant point of concern that was observed during Hurricane Isabel was the need to have clear access (i.e. passable roads) to reach telecommunications facilities. In particular, it was noted that in several instances that telecommunication service technicians were unable to access facilities to make needed repairs due to downed trees and/or power lines. Inability to access these sites compounded service restoration efforts.

Another important interdependency involving transportation is the need to ensure that roads, bridges, and tunnels are accessible to allow for the delivery of fuel to continue the operation of back-up generation at major switching locations. The particular issue of how to coordinate, inspect, and escort re-supply tankers into disaster areas is critical and needs to be addressed. This interdependency was identified previously when examining issues resulting from September 11th. At that time interviews with providers indicated that they were unaware of any coordinated plan that had been developed with local jurisdictions to identify critical switching locations and insure access to those facilities.

Also, major parts of the networks of leading U.S. communications providers are located in this region and use the same right-of-way paths and have critical "choke points" at certain locations, e.g. bridges, tunnels, rail lines, and Metro lines. Damage, flooding, and the inability of technical personnel to access equipment located at several of these locations created some service restoration problems during Isabel.

Recommendations

Coordinating Emergency Response Levels

With the many political jurisdictions in the National Capital Region, the communication among and coordination of all the infrastructure- related agencies and private companies and their emergency operating centers is a significant challenge. Most of these jurisdictions and organizations have specific and differing criteria for initiating emergency operations or increasing levels of security. Timely response by public agencies and private firms to infrastructure problems in emergency situations requires clear communication channels, coordinated planning, clear terms and language, and clear lines of authority and responsibility.

Clarifying EOCs' Authority

EOC operations during and after Hurricane Isabel brought to light some problems regarding authority, responsibility, and capability of infrastructure-related personnel in the EOCs. The clear role, responsibility, and authority of persons representing the many public and private organizations involved in the successful operation EOC needs to be thoroughly documented in policies and procedures, well known by the EOC team members, and regularly demonstrated in periodic training exercises. Making correct decisions in EOCs during emergencies depends on having the correct and up-to-date information available. A considerable number of discussions regarding critical infrastructure design information being available in EOCs have taken place among government and industry personnel before, during, and since Hurricane Isabel. A practical way of making privately held infrastructure design information available at the EOCs, while maintaining the proprietary and security aspects of the detailed data, needs to be found.

Harmonizing Electricity and Communications Service Restoration Priorities

Energy infrastructure organizations have well established restoration priorities based on operational needs; the specifics of these are not always well known. Different governmental jurisdictions and private customers may have very different service restoration needs and priorities. There does not seem to be a coordinated regional plan for identification of critical telecommunications facilities for the purposes of accelerated power restoration. A better plan is also needed to prioritize the clearing of local roads to ensure access by service personnel. Since there is a great deal of coordination needed among public and private organizations (because it takes crews from both public agencies and private organizations to clear downed trees and wires), closer coordination and communications regarding service restoration priorities and details is needed.

Improving On-Site Emergency Power Generation Capabilities

Hurricane Isabel demonstrated that coordinated emergency planning is essential for multi-day outages for the proper operation and availability of on-site emergency generating units. This is needed for both government and privately owned facilities. This short and longer term planning includes the availability and distribution of fuel for these generating units. Pre-event planning and arrangements, in-place contracts, and integration of the fuel distribution procedures into public agency emergency plans are required in order to transport bulk diesel fuel (and possibly propane) in a safe and timely manner around the NCR during emergencies. This was a critical problem in the World Trade Center area in New York on September, 11, 2001 where a number of operating generators shut down because of lack of diesel fuel; this increased the impact of the event and time and complexity of the recovery.

Addressing Responsibilities

The above examples also highlight a question that has arisen since Isabel on the scope of responsibility of infrastructure organizations regarding the provision of redundancies. Dominion is accountable only for direct power outage and restoration, but at what point does the focus shift from their efforts to those customers? Is it reasonable to expect that power to a hospital should be restored immediately, or is it reasonable to expect that a hospital will have back-up power generation? Should the electric power generating cooperatives that depend on Dominion for power transmission contribute to restoration efforts?

VI. Conclusion

One year after Hurricane Isabel struck the National Capital Region, we have again witnessed the destructive power of Hurricanes and are reminded of the need to focus on addressing our interdependent the power of natural disasters as we have observed the destruction brought on by our interdependent infrastructures.

Hurricane Isabel was overall a positive, but costly, learning experience for those involved in critical service provision in the National Capital Region. While the storm severely impacted certain areas in the National Capital Region, the handling of the event demonstrated significant regional capabilities, many developed since September 11th. At the same time, Hurricane Isabel identified significant areas that require further improvement. Interdependencies between vital sectors were key to these shortfalls, highlighting the need for greater coordination and collaboration among sector organizations. It is now necessary to focus on the lessons learned and ensure that appropriate changes are made prior to the next event, irrespective of its potential cause, whether weather-related event or man-made. This will require bringing together all key regional stakeholders and an unprecedented level of cooperation to develop and implement a regional preparedness strategy as rapidly as possible.

VII. Appendices

Appendix A Survey Instrument

Appendix B Tables

Appendix C Project Research Participants

Appendix A Sample Survey Instrument

General Research Questions

Documentation of Hurricane Isabel Impacts

A. What was the pattern of direct, hurricane-induced damage?
B. Did you experience any interdependencies? If so, did the interdependencies result in cascading failures? Document examples.
C. Were any of these interdependencies a point of failure during hurricane Isabel?
D. How did failures in other infrastructures/systems impact the organization's facilities?
E. How did failures in the organization's system impact other infrastructure facilities?
F. What were the service consequences? To the organization's facilities? To customers?
G. Based on the changes in emergency management procedures with the establishment of the Department of Homeland Security and upgraded state level emergency management offices, please answer the following questions:
    a. What has been the impact on your system operations of these new (Federal) and upgraded (state) organizations?
    b. What new roles and responsibilities did you have to comply with as a result of the establishment of the Department of Homeland Security? How do you coordinate with various headquarter activities during a disaster?
    c. Is there a marked change in operations at the regional level? Can you determine a marked change in operations within your organization? In general, what are the operational changes?
H. To what extent does your organization work with first responders (fire, police, EMTs)? Were there any concerns that were expressed on their part about their ability to respond to emergencies as a result of communications problems with your organization?
    a. Collect available public and industry reports, documents, and testimonies.

Response Actions by Infrastructure Organizations

A. When did emergency preparations start and what was the trigger mechanism? (e.g., NOAA or NWS warning?)
B. What pre-impact mitigation measures were taken to reduce expected damage?
C. What pre-impact measures were taken to facilitate service restoration?
D. Was the Regional Information and Coordination and Communication System (RICCS) implemented? Did it adequately support the needs of the public and private entities in the region?
E. Were any other voice or data communications systems utilized to support operations during the course of hurricane Isabel? Did they support communications with other agencies that own and operate critical infrastructure?
F. Were there any voice or data communications systems that failed during Hurricane Isabel? If so, what impacts did it have on your operations?
G. Were "special" customers or service users notified of potential interruption? If so, How? What is the notification criteria or "trigger"?
H. How do you prioritize how you respond to outages? Geographically? Customer-based? Needs-based versus respond as reports of outages come in?
I. How were customers (all classes) kept informed about service interruptions?
J. How were/are service restoration priorities set?

K. How were service restoration resources organized?
L. How were service restoration activities coordinated among other infrastructure organizations?
M. How were service restoration activities coordinated among government agencies and your organization: federal, state, county, city?
N. Did service restoration priorities change as a result of information received at Emergency Operations Centers? (e.g., DC's EOC)
O. How did service restoration operations change when extent of damage was realized (e.g., Friday A.M.)
P. How were customer information activities changed when it was realized that some long-term outages would be experienced?
Q. What were the impediments (e.g., physical, financial, regulatory, legal) to mitigation of potential risks, to continuity of operations, and to restoring services?
R. In general, how effective was your emergency management plan during and after Hurricane Isabel? Specifically, what worked and what didn't?
S. What are the present estimates for the direct and indirect costs of the impacts of Hurricane Isabel?

How Can Reliability, Resilience, and Security be Improved?

A. How can initial failure mechanisms be reduced?
B. How can propagation of failures be reduced?
C. How can interdependencies be strengthened?
D. What interdependencies can be reduced?
E. What interaction is needed with upstream suppliers, other infrastructure organizations, and downstream customers to reduce impact on and to facilities from natural disasters such as this?
F. Are there organizational policies within your organization or among federal, state, and regional levels that need to be reexamined to reduce the impact of or recovery from natural disasters?
G. Are there government policies that need to be reexamined to reduce impact of such natural disasters?
H. Are new policies/laws called for in the National Capital Region to address disasters such as Isabel?
I. How have the response plans/actions to this natural disaster benefited from previous security-related activities in response to 9/11?
J. How have the impacts of this natural disaster shown weaknesses in your or other infrastructure organization's security plans for response to terrorists actions?

Information Sharing Process in Emergency Scenarios

A. What process do you use to communicate priorities for service restoration/shut down with other providers and the government when your organization could not meet service delivery requirements?
B. What incentives do you have to share information?
C. What disincentives do you have to share information?

Energy

A. What role (if any) do you think recent electric utility restructuring had on the response to Isabel?
B. How much does your company invest in natural disaster preparedness/response? Are there plans to change this as a result of Hurricane Isabel and if so are there areas that need further investment and what are they?
C. Do you have an individual or group in your organization that is responsible for disaster preparedness/response for natural (and man-made) disasters?
D. To what extent was it necessary, or did you, work with other energy providers and/or other service providers in any manner during or after the storm?
E. What kind of data is needed to improve hurricane preparedness/ emergency response?

Water

A. How much does your company/agency invest in natural disaster preparedness/response annually?
B. Do you have an individual or group in your organization that is solely responsible for disaster preparedness/response for natural disasters? How large is this group? What level of authority do they have (is it headed by the CEO or an entry-level employee)? How much time is dedicated to this activity (e.g. person-years of effort per year)?
C. To what extent was it necessary, or did you, work with other water providers and/or other service providers in any manner during or after the storm? What were the other water and service providers with whom you worked? What was the nature of the interaction (when, what and who)?
D. What kind of data is needed to improve hurricane preparedness/ emergency response?
E. What parts of your disaster preparedness/response program worked most effectively during Isabel?
F. What are the top three internal changes you would like to make to your disaster preparedness / response program given your experience with Isabel? (These are changes you would make to the organization, management, equipment etc. within your company/agency.)
G. What are the top three changes you would like to make in your relationships with other companies/ agencies/ groups/ providers given your experience with Isabel?
H. What are the top three lessons with regard to disaster preparedness/response that you learned from Isabel?

Telecommunications

A. Do you have any estimate of how many if any of your customers lost service during the Hurricane? How was local service versus long-distance phone service affected? Was Internet service in the area impacted?

B. Was there any observable congestion on the network as a result of the storm and did this impact service in any way? Was it ever necessary to restrict incoming calls to the region and if so, to what locations? Was it necessary to reroute traffic?

C. How did you respond to service outages?

D. What precautions did you take to secure your physical infrastructure - i.e., switching centers, Internet Data centers, mobile phone towers and fiber optic cable, against flooding, rain and high winds (Including design and specifications, operations, maintenance)? Was any of the physical infrastructure affected by the storm and if so, what would you do differently in the future to better secure the facilities and equipment?

E. Did your organization to rely on emergency back-up power systems? Was it necessary to bring in portable generators and/or fuel from outside the region prior to, during, or after Hurricane Isabel?

F. To what extent did you need to rely on corporate emergency operating centers? Is the geographic diversity of these centers a concern particularly for natural disasters that large portions of your service area?

G. How much does your company invest in natural disaster preparedness/response annually? Any plans to change this as a result of the storm and if so are there areas that need further investment and what are they?

H. Do you have an individual or group in your organization that is solely responsible for disaster preparedness/response for natural disasters?

I. To what extent was it necessary, or did you, work with other telecommunications providers and/or service providers in any manner during or after the storm?

J. What kind of data is needed to improve hurricane preparedness/ emergency response?

Transportation

A. Explain the planning that went into ensuring the inclusion of necessary resources outside the domain of critical infrastructure so that operations were not disrupted. As an example, were law enforcement agencies engaged to support traffic control for extended periods of time when power outages became inevitable?
B. Were strategies defined based on predicted level of pending threats? As an example, based on weather forecasts for flooding were specific preparations made to respond to respond to the specific threat?
C. If Emergency Services Function (ESF #1) was implemented, how was the determination made as to who was the lead agency given that the emergency was truly regional in nature?
D. How much does your company invest in natural disaster preparedness/response annually? Are there any plans to change this as a result of Hurricane Isabel and if so are there areas that need further investment and what are they?
E. Do you have an individual or group in your organization that is solely responsible for disaster preparedness/response for natural disasters?
F. To what extent was it necessary, or did you, work with other transportation organizations and/or other service providers in any manner during or after the storm?
G. Were there any accidents as a result of the storm (during, but also after many of the traffic signals went out)?
H. Was the public advised before, during or after the storm? If so, how? Television, variable message signs, Internet, radio…etc? What advisories were given?
I. How was signal priority for emergency vehicles dealt with when many of the signals were out?
J. How were Intelligent Transportation Systems (ITS) - use of advanced technologies for managing and controlling traffic, improving safety, etc. affected during the storm? Were there any ITS's that needed to be deployed during the storm?
K. What kind of data is needed to improve hurricane preparedness/ emergency response?

Regulators

A. Were policies/laws implicated by Hurricane Isabel in a manner that caused impediments to remediation? If so, which policies/laws?
B. Would you recommend changing any policies/laws in the wake of Isabel? If so, which ones? Why?
C. What role (if any) do you think recent electric utility restructuring had on the response to Isabel?
D. Are new policies/laws called for in the National Capital Region to address disasters such as Isabel? What new policies/laws, if any, would you recommend?
E. To what extent was it necessary, or did you, work with other regulators in any manner during or after the storm?
F. What kind of data is needed to improve hurricane preparedness/ emergency response?

Appendix B Tables

Table 1: Hurricane Isabel-Related Infrastructure Interdependencies: Energy

Energy	
Failures Experienced	• Complete loss of utility distribution system in area for multi-day period. • Flooding of the Potomac River at Reagan National Airport.
Interdependencies Noted	• Required customers to operate emergency backup generators. Impacted air pollution levels and caused health risk from CO poisoning. • Liquid petroleum facilities gasoline - regional distribution facilities and retail outlets lost power and could not provide fuel for commercial, industrial, and residential customers. • Cell phone towers went out when battery back-up systems were exhausted. Cell phone service area holes appeared interrupting/degrading service. • Cell-phone-based systems are used to coordinate many of the repair/recovery crews operating in the field. When service "holes" appeared, coordination was impacted: electric repair crews and tree trimming crews did not arrive at same site at same time. • Computer and communications equipment failures at most businesses. Conventional telephone service continued to operate (has an independent power supply). But any system that is powered by electric utility-based service went down after local battery back-up was exhausted. • Some Emergency Operating Centers do not have on-site emergency generators installed.
Actions Recommended	• Need for more thorough permitting and inspection of residential back-up generation facilities. • Provide pumping power from more reliable transmission and transmission /distribution systems. Last resort is on-site generators. • Critically reexamine use of cell-phone based communications systems for coordinating repair/recovery crews. • Need for reexamination of all cell-phone facilities that are used by critical infrastructure emergency personnel. Need to evaluate on-site energy capability for multi-day outages. • Reevaluate potential use for emergency service and then require retrofit for operation for multi-day period. • Correct EOC building specifications to include mandatory on-site energy supply for multi-day period. • Provide high reliability/ independent power from more reliable transmission and transmission/distribution systems for critical traffic locations. Begin to examine alternatives -- solar-powered lights; micro-generators, etc. • Runway lighting system design specification needs to consider submergence of system. Runways only few feet above river. • Provide pumping power from more reliable transmission and transmission /distribution systems. Last resort could be on-site generators.

Table 2: Hurricane Isabel-Related Infrastructure Interdependencies: Water

Water	
Failures Experienced	• Sewer over flows due to high water or high runoff. • Wastewater treatment plants overflowed due to high rainfall. • Failure of power to water treatment facilities (even those with underground lines). FCWA was out of electricity for 12 hours. One-third of people out of water for approximately eight hours.
Interdependencies Noted	• Water sector dependent on power for water treatment facilities. • The gas company cools various parts of its system with water from FCWA. Due to loss of coolant, the gas company might have been forced to shut down part of its systems. • Hospitals need water for many things: drinking, bathing, cooking. The loss of water caused hospitals to get close to the point where new patients would have had to be redirected to other facilities. • Internal communications were degraded. Either communication lines or SCADA (supervisory control and data acquisition) system components were down. The result was operators and managers were working without full knowledge of the status of the system. • Communication between workers was degraded because cell phone circuits were busy, and/or telephone lines were down. • External communications. One-third of communications with customers/ outsiders were by email. Personnel had to be redirected to respond to this new mode of communication. It took six hours to realize that the County spokesperson and FCWA spokesperson were not coordinating their messages.
Actions Recommended	• Improve crisis communication between energy company operations and water utility operations. • Improve public education: public understands water being turned off due to a main break, but does not understand boil-water warnings following treatment plant failures. • Build in redundancies (generators) for potential power outages. • Address customer service issues so accurate information is disseminated. • Evaluate contingency plans for vital services such as hospitals.

Table 3: Hurricane Isabel-Related Infrastructure Interdependencies: Transportation

Transportation	
Failures Experienced	• Failure of power to highway traffic signals. • Failure of drainage systems to handle overflow along streets, parking lots, and runways / / taxiways. • Failure of telecommunication system to transmit information among operators, fire and rescue, and police authorities. • Trees and lines down in roads prevented safe passage. • VDOT Fairfax headquarters lost power during storm - made it difficult to track crews /progress.
Interdependencies Noted	• Transportation sector dependent on power company to clear downed lines from major arteries. • Flooding at Reagan National Airport caused lights to go out on runways. • Traffic signals are dependent on electrical power. • Transportation sector depends on telecommunication systems to respond to emergencies involving fire and rescue services and other first responders and other agencies responsible for clearing incidents; VDOT officials relied on cellular technology for communication during the storm.
Actions Recommended	• Ensure that all transportation agencies in the region are aware of the Regional Incident Communication and Coordination System (RICCS) adopted by the D. C. Council of Governments and that the RICCS is employed by all agencies. • Have regular preparatory meetings between key transportation agencies, emergency response providers, and electrical power and telecommunication companies. • Test disaster mitigation plans regularly and establish a training and exercise program. • Establish backup and redundant strategies for traffic signals, lighting, traffic management centers, and other systems reliant on electric power for critical functions; generators, batteries, and uninterrupted power supplies should be considered, where applicable. Coordinate GIS maps with EOCs and energy company. Update frequently during emergencies. • Address customer service issues so accurate information is disseminated to commuters and other transportation users. • Consider further evaluation cost/benefit analysis for alternative or redundant power supplies (such as burial of lines) to critical operations. • Liaison more directly with energy sector (relied on faxes and phone calls during storm). • Set up a central database/list of road closings so all maintenance areas can coordinate efforts accordingly.

Table 4: Hurricane Isabel-Related Infrastructure Interdependencies: Telecommunications

Telecommunications	
Failures Experienced	• Phone lines down. • Cable outage. • Internet outage.
Interdependencies Noted	• Customers without electricity could not access Internet for emergency information. • Cellular systems experienced intermittent electrical service disruption. • Telecommunications sector dependent on power company to clear downed lines before telecom lines could be cleared. • Customers with downed phone lines relying heavily on wireless services. • Service restoration vehicles responding to down lines and poles often travel over rights-of-way "soft ground" containing buried telecommunications lines, and subsequently caused fiber line breaks.
Actions Recommended	• Address customer service issues so accurate information is disseminated. • Evaluate alternative forms of communication during emergency (for example, newspaper, which came every day, or public radio access systems). • Explore emergency back-up for switching stations. • Evaluate tree removal/trimming; incorporate findings from North American Electric Reliability Council's Vegetation Management recommendations resulting from the Northeast Blackout. • Centralize coordination with companies before, during, and after event. • Consider relaxation/flexibility of regulation on who can perform tree/debris removal. • Coordinate with energy sector on responsibilities during emergency (tree clearing, etc.). • Consider/evaluate methods for vehicles to transverse "soft ground" without imposing damage, i.e. ramps, steel plates to distribute weight.

Table 5: Government and Regulator Perceptions Across Sectors

Energy	
Failures Experienced	• Lines down. • Failure of power to water treatment facilities (even those w/underground lines). • Failure to coordinate with other power companies, government. • Failure to communicate accurate information to government. • Failure to communicate accurate information to public. • Emergency Assistance and priority requests revealed that dependent organizations and community entities lack their own mitigation plans beyond simply calling the power company. • Lack of coordination between localities, municipalities and companies to determine when an EOC is necessary. Some operate prior to the event (if anticipated- such as energy), while others operate for only a limited time, and others are operational long after the event. As each varies, it makes coordination and communication between these EOC's difficult.
Interdependencies Noted	• Electric cooperatives dependent on monopolies for transmission. • Water sector dependent on power for water treatment facilities. • Hospitals depend on water to clean linens, but water was unavailable because power was out. • Transportation sector dependent on company in energy sector to clear downed lines from major arteries. • Flooding at DCA caused lights to go out on runways. • Traffic lights were out. • Telecommunications sector dependent on company in energy sector to clear downed lines before telecom lines could be cleared. • EOCs dependent on power for communication/coordination of efforts. • Mutual assistance groups share equipment from different sectors, which becomes a factor in utility repair, and in particular, in the alignment of repair priorities. • Government failure to maintain healthy trees. In clearing trees, the coordination falls between cities, counties and various municipalities, but power lines are the sole responsibility of the power companies.
Actions Recommended	• Evaluate idea of placing an energy company representative at all EOCs. Should be someone who can make critical decisions when necessary. All critical sectors to have liaison at EOC for decision-making. This may be possible at a localized event, but a large event requires greater coordination, so decision making capabilities at an individual EOC must be coordinated. There are further complications when the situation is a multi-jurisdictional event. • Embed a representative with technical expertise available at central EOC to interpret / explain power company decisions. • Establish a centralized mechanism to prioritize / coordinate triage efforts and communicate those priorities to interested parties. Currently, each jurisdiction has differing priorities, which are locality specific, and at times, event specific. • Have regular preparatory meetings between emergency responders and related stakeholders to establish professional relationships - e.g., know exactly who to call in emergency, quickly de-conflict competing demands across the NCR, work with stretched resources in collaborative manner, etc.. Since Sept. 11, drills have generally focused on terrorist related scenarios, and the focus on weather related drills and events has decreased. • Test disaster mitigation plans regularly for evaluation - establish a training and exercise program. • Those reliant on electric power for critical functions (hospitals, EOCs, etc.) build in redundancies (generators). • Coordinate GIS maps with EOCs and energy companies and update frequently during the emergency. This is an on-going project, but the larger goal should be to have greater information sharing in this area to allow each locality or sector to share this information and create maps to overlay into the system. • Address customer service issues so accurate information is disseminated. • Pursue authoritative delivery process such as public radio access systems.

Government and Regulator Perceptions Across Sectors (continued)	
Telecommunications	
Failures Experienced	• Phone lines down. • Cable outage. • Compatibility of emergency services systems.
Interdependencies Noted	• Customers without electricity could not access Internet for emergency information. • Cellular systems experienced intermittent electrical service disruption. • Telecommunications sector dependent on power company to clear downed lines before telecom lines could be cleared. • Customers with downed phone lines relying heavily on cellular. • Service restoration vehicles responding to downed lines and poles often travel over rights-of-way "soft ground" containing buried telecommunications lines, and subsequently caused fiber line breaks.
Actions Recommended	• Consider further evaluation cost/benefit analysis for alternative or redundant power supplies (such as burial of lines) to critical operations. • Evaluate NCR power plants for degradation. • Address customer service concerns including anticipated duration of service outage and availability of emergency support services so accurate information is disseminated. • Evaluate alternative forms of communication during emergency (for example, newspaper, which came every day, or public radio access systems). • Ensure emergency back-up for switching stations. • Evaluate tree removal/trimming situation. • Centralize coordination with companies before, during, and after event. Companies may not have most efficient plans given the needs across the NCR. • Consider relaxation/flexibility of regulation on vegetation management to achieve most prudent balance across the NCR. • Coordinate with energy companies about responsibilities during emergency (tree clearing, etc.). • Consider/evaluate methods for vehicles to transverse "soft ground" without imposing damage, i.e. ramps, steel plates to distribute weight.
Transportation	
Failures Experienced	• Trees and lines down in roads prevented safe passage. • VDOT Fairfax HQ lost power during storm - made it difficult to track crews/progress.
Interdependencies Noted	• Transportation sector dependent on power company to clear downed lines from major arteries. • VDOT workers relied on cellular technology for communication during storm.
Actions Recommended	• Liaise more directly with energy company (relied on faxes and phone calls during storm). • Set up a central database/list of road closings so all maintenance areas can coordinate efforts accordingly. • Build in redundancies - i.e. generator for HQ operations. • Conduct emergency operation drills so people and process are known when emergency occurs. • Build (physical building) EOCs that are more conducive to group activities. • Coordinate plans and processes that have more reliability in communications and updating authoritative time dependent information.

Most recommendations focused on centralization of coordination between entities. Primary suggestions included:

- Have an energy company representative at all EOCs. Should be someone who can make critical decisions when necessary. All critical sectors to have liaison at EOC for decision-making. The National Communications Center, housed in the National Communications System, provides an excellent model on how infrastructure sectors leverage EOC skill sets at multiple levels (local, regional, national and across appropriate infrastructure stakeholders).
- Have a centralized mechanism to prioritize/coordinate triage efforts and communicate those priorities to interested parties.
- Coordinate GIS maps with EOCs and energy company. Update frequently during the emergency.
- Have regular preparatory meetings between emergency actors to establish personal relationships - know who to call in emergency.

Second in importance was consumer communication. Primarily, the issue during Hurricane Isabel was availability and accuracy of information. Suggestions for improvement include:

- Have additional customer services available after peak times are over.
- Change automated voice message to reflect events.
- Evaluate alternative forms of communication during emergency (e.g., , newspaper, which came every day). Partnerships between infrastructure stakeholder, NCR officials, and the broadcast and media sectors can be leveraged to achieve these messaging objectives.

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