



E-PRO[®]
ELECTRIC INFRASTRUCTURE PROTECTION

E-PRO[®]
HANDBOOK II

VOLUME 2 \ WATER

Electric Infrastructure Protection (EPRO®) **Handbook II**

Volume 2 - Water

Water Sector Resilience for Black Sky Events



**The ELECTRIC
INFRASTRUCTURE
PROTECTION (EPRO®)
HANDBOOK® SERIES**

A peer-reviewed, research-based resource, examining opportunities for expanding the resilience of lifeline utilities and their government and NGO sector partners to address severe, Black Sky hazards.



EPRO[®] Handbook II

Volume 2

Water Sector Resilience
for Black Sky Events

EPRO Handbook

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EPRO Handbook II is dedicated to the memory of

Dr. Jack Templeton

His remarkable sense of personal responsibility
to promote the welfare of Americans and people
everywhere was a model for all of us.

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Executive Summary

Note: This Executive Summary, which appears in Volume I of the EPRO II Handbook, is also included here, in its entirety, for the convenience of the reader.



INTRODUCTION

Deepening interdependencies between the electric power grid and other critical infrastructure sectors pose immense challenges and opportunities for strengthening national resilience. “Black Sky” power outages lasting a month or more, covering multiple regions of the United States, would inflict cascading failures across the electricity-dependent sectors essential for preserving the economy, public health and safety and national security, and for sustaining the lives of the population in affected regions. The EPRO Handbook project is structured to help private and public partners protect against such cascading failures and limit their societal impact.¹

This two-volume work, EPRO Handbook II, provides options to strengthen the resilience of two especially vital infrastructure components against Black

1 The EPRO Handbook project is part of a broader, integrated set of resilience initiatives supported by the Electric Infrastructure Security (EIS) Council. For an overview of EIS Council's programs, please visit www.EISCouncil.org

Sky power outages: the water sector, with its uniquely essential services, and the natural gas infrastructure on which power generation increasingly depends. EPRO II provides a detailed range of preparedness options that infrastructure owners and operators can consider and adapt to help meet their own system-specific needs.

The Handbook also offers a methodology for developing Black Sky playbooks to help these sectors guide emergency operational planning and resilience initiatives. This approach is designed to be useful for water, wastewater and natural gas system owners and operators, and those partner sectors with whom they share interdependencies, or upon whose services they will rely in extreme outages. This playbook methodology, rooted in classic Systems Engineering methodology, may also represent an important framework for progress in other infrastructure sectors that would be severely disrupted by Black Sky power outages.

The United States and partner nations remain at risk of blackouts far more severe than those which occurred in Superstorm Sandy (2012), Hurricane Katrina (2005), or any previous event.

The electric power industry is making great strides in strengthening its protections against the natural and manmade hazards that could cause severe outages. The industry is also rapidly improving its ability to restore power when blackouts occur. Yet, much greater progress will be necessary to build preparedness for Black Sky outages – that is, outages covering multiple U.S. states or regions that last a month or longer.

While the power industry is making great strides in strengthening protection against more conventional hazards, the United States and its allies remain at risk from particularly severe, multi-region Black Sky outages.

The first volume of the EPRO Handbook Series, EPRO I, provided options to help the electric subsector protect against two especially significant Black Sky hazards, which are now the focus of growing resilience initiatives by industry and its public sector partners. The first hazard is that of severe solar storms. These storms create geomagnetic disturbances (GMD) that can damage unprotected high voltage transformers and other high voltage grid components over multistate regions. The second threat is that posed by an Electromagnetic

Pulse (EMP) strike, with associated electromagnetic effects that will damage or destroy a portion of unprotected grid equipment, and over exceptionally wide areas, making discovery and replacement particularly challenging.

While utilities in a growing number of U.S. regions are hardening their systems against these threats, many more years of risk-based, strategically-targeted investments in protection will be required before the grid as a whole is even minimally resilient. Ensuring that utilities can recover their costs for such prudent investments will be critical for sustaining progress against electromagnetic threats.

Sustained investment will also be required against catastrophic storms, combined cyber and kinetic attacks on key grid components, and other threats to the electric subsector. Yet, while such protection efforts must continue, it will never be possible to fully prevent large scale outages due to Black Sky hazards. Most notably: no remotely affordable investments in grid resilience can ever prevent Black Sky outages from occurring if (or rather, when) cataclysmic earthquakes strike in the Cascadia seismic zone, the Hayward fault, New Madrid seismic zone, and other regions in the United States and in many partner countries.

Thus, Black Sky power grid protection efforts have two priorities. The first is to find cost-effective ways to accelerate targeted electric subsector resilience investments and preparedness planning against the full range of Black Sky hazards. The second is to strengthen collaboration with the subsector's partners to make the policies and regulatory changes needed to facilitate protection and power restoration operations, and ensure that electric utilities have the external support functions they will require severely disrupted environments. Handbook I recommended an array of options to scale up such capabilities from the electric subsector's partners for Black Sky events, many of which are now going forward.² The Handbook also emphasized the development of capabilities

2 For example, in discussions facilitated by EPRO Steering Committees, an array of Non-Governmental Organizations (NGOs) are exploring how to strengthen their support for utility power restoration operations, including both traditional functions (such as support for debris removal and road clearance) and novel missions, (such as targeted support for the families of utility crews on extended deployments). Similarly State Public Utility Commissions have now initiated an EPRO Regulatory Sector Steering Committee process, with ten states participating in the inaugural meeting, cohosted in June, 2016 by the Governor of Pennsylvania, the Pennsylvania PUC and EIS Council. <http://www.eiscouncil.com/EPro/Esc>

and plans for “whole community” preparedness against Black Sky outages, including contributions from individuals and families, the private sector, and Non-Governmental Organizations (NGOs).³

The first volume of the Handbook also identified an urgent need for follow-up analysis to strengthen cross-sector resilience. While EPRO I focused on building the grid’s resilience and restoration capabilities against Black Sky hazards, wide area, long duration power outages would also disrupt other infrastructure sectors that depend on the flow of electricity.

These disruptions could cause catastrophic problems to public health and safety. Two of these problems represent particularly critical challenges. If water and wastewater systems failed in communities across multiple states or U.S. regions, the societal consequences and risk to the lives and safety of affected populations would be difficult to overestimate. Black Sky events could also disrupt the flow of natural gas on which electricity generation depends in a growing number of U.S. regions, and thereby magnify the difficulty of restoring power just when lives depend most on bringing the grid back into service.

EPRO II offers proposals to address two primary challenges associated with long duration outages caused by Black Sky hazards: Sustaining water and wastewater service to communities, and ensuring continuity of fuel delivery to electric power plants.

This publication, EPRO Handbook II, offers proposals to address both of these challenges. Section I of this executive summary briefly summarizes the findings and recommendations of EPRO II for strengthening the resilience of the water sector, which includes both water and wastewater systems, against Black Sky outages. Section II examines opportunities to strengthen the resilience of fuel supplies for power generation in Black Sky events, especially natural gas. Section III identifies future priorities for analysis, including those that reflect the ongoing evolution of cyber threats and other Black Sky hazards.

3 FEMA, Whole Community. <https://www.fema.gov/whole-community>



I | WATER SECTOR RESILIENCE

A key finding of the EPRO I Handbook was that the ability of the water and wastewater systems to sustain emergency operations in a Black Sky event will offer a particularly valuable means to avert catastrophic threats to societal continuity and human life. Water pumps, lifts, water and wastewater treatment systems and other critical system components depend on electricity to function. If those components fail in a power outage across multiple cities and states in a wide area, long duration blackout, it will not be possible to provide emergency drinking water to millions of affected U.S. citizens. Failure of wastewater systems across multi-state regions would also result in contamination of available surface water, and likely become a primary factor in spreading disease. EPRO I emphasized that, “Nothing could pose such an immediate threat to public health and safety, or be more likely to prompt a massive, unplanned migration from a major urban area, than the loss of municipal water service for drinking and fighting fires.”⁴

4 Electric Infrastructure Security (EIS) Council, EPRO Handbook I, p. 83.

This follow-on publication, Handbook II, finds that the water sector is significantly strengthening its ability to sustain operations during typical, short duration power outages. A growing number of utilities are installing their own emergency power generators, or arranging with partners (including the U.S Army Corps of Engineers) to install generators when an emergency strikes. Many utilities are also expanding their capacity to store generator fuel onsite, and are improving their ability to provide mutual assistance when severe events occur.⁵ This progress needs to be sustained and provides a valuable foundation on which to build preparedness for longer-duration events.

Yet, such bottom-up progress alone will never be adequate for resilience against Black Sky outages. In addition, this Handbook recommends that the sector and its partners will need to build resilience from the top down, and develop a water sector playbook to guide resilience investments and emergency plans scaled up for Black Sky events. Individual water and wastewater systems can then use that sector playbook as a framework for developing their own system-specific plans and capabilities.

Water sector leaders will be able to develop and execute some resilience initiatives internally, often in collaboration with regulators and other resilience stakeholders. However, to sustain even reduced operations in an outage lasting a month or more, many systems will also depend on government and private sector partners to provide them with replacement backup power generators, resupply fuel for those generators, deliver essential treatment chemicals and provide other essential services. These “external partners” will also need to account for -- and prioritize -- water sector support missions in their own Black Sky playbooks.

Building on progress being made in resilience to more conventional disasters, sector resilience for Black Sky hazards will require the kind of “top down” progress and planning that can be hosted by development of a Water Sector playbook for these hazards.

5 The Water and Wastewater Agency Response Network (WARN) network offers especially significant mechanism for utilities to provide for mutual assistance, and help each other respond to and recover from emergencies. See American Water Works Association, Water/Wastewater Agency Response Networks. <http://www.awwa.org/resources-tools/water-knowledge/emergency-preparedness/water-wastewater-agency-response-network.aspx>

“The Summary of Findings and Recommendations” in Volume II of this two-volume Handbook provides a comprehensive review of recommendations to strengthen water sector resilience. Key initiatives and their sequence for developing Black Sky playbooks:

- **Step One: Define top level goals.**

The first step will be for the water sector and its external partners (including regulators and emergency managers) to determine the basic, overarching goals that the sector should seek to achieve in Black Sky events, focused on ensuring societal continuity and recovery. The options examined by this volume are aimed at minimizing the potentially catastrophic threats to public health and safety that disrupted water service will otherwise entail, and limiting the impact on sustaining lives, and on the U.S. economy and national security.

- **Step Two: Establish minimalist, sustainable service levels.**

Based on the top level goals for the water sector, water and wastewater systems will need to define an actionable range of sustainable, “bare minimum” service levels for meeting customer needs in wide area blackouts lasting a month or more, where normal levels of service will become increasingly difficult (if not impossible) to sustain due to limited fuel and treatment chemical resupply and other logistical problems. Coordination and consensus with regulators, emergency managers and other external sector partners will be essential in establishing these minimalist service levels.

- **Step Three: Develop internal requirements – specify infrastructure investments and other requirements to maintain minimalist service, and develop the emergency operations plans needed to achieve those service levels.**

Water and wastewater utilities will need to make carefully prioritized investments in emergency power generators, onsite fuel storage tanks and other infrastructure necessary to implement the service level they select from the range summarized in the water sector Black Sky playbook.

The water sector and its external partners will also need emergency operations plans to sustain these service levels. A growing number of water and wastewater systems have emergency plans that are well suited for outages lasting a few days, and can rely on established planning

guidelines to prepare for such events.⁶ For preparedness against Black Sky hazards, utilities will not only need to ramp up those plans, but also consider stringent new measures to reduce water service in terms of areas served, water quality, and other service parameters.

- **Step Four: Develop external requirements – define support requirements or policy changes the water sector will need to implement and complement its own Black Sky resilience measures and sustain reduced levels of service.**

Many of the water sector's Black Sky resilience investments and operational planning will require additional funding that must be approved by utility boards of directors or government officials. Other investments, including those in water and wastewater treatment and in power generators and fuel storage, may require regulatory policy development and associated pre- or post-outage waivers of Clean Air Act standards and other regulatory policy changes. Developing new approaches to account for tradeoffs between Black Sky resilience and regulatory objectives will be essential for progress.

External partners will also need to improve their ability to meet essential water sector requirements for critical services and support. As noted above, private contractors and government agencies will need to be able to supply replacement generators, fuel and treatment chemicals despite the severe disruption of transportation and communications systems that Black Sky hazards will create. And, at a minimum, water sector utilities will need to be included in planning for a Black Sky outage-compatible emergency communication system, to ensure at least minimal communication can occur between utilities and partner sectors.

Volume II provides detailed options for how the water sector and their partners can develop these playbook components. However, one size will not fit all. Each water and wastewater utility system faces its own particular Black Sky resilience challenges, and will need to adapt these options to fit their system-specific circumstances and priorities.

6 See, for example, the preparedness recommendations in American Water Works Association (AWWA), "Electric Power Reliability for Public Water Supply and Wastewater Utilities," Resolution as adopted and revised by the AWWA Board of Directors, January 19, 2014. <http://www.awwa.org/about-us/policy-statements/policy-statement/articleid/198/electric-power-reliability-for-public-water-supply-and-wastewater-utilities.aspx>



II | RESILIENT FUEL RESOURCES FOR POWER GENERATION IN BLACK SKY EVENTS: THE KEY ROLE OF NATURAL GAS

Gas is rapidly replacing coal as the primary fuel for power generation in many regions of the United States. At the same time, key components of gas pipeline systems, including the compressors and industrial control systems that keep gas flowing to power generators and other users, are increasingly reliant on electric power. These growing interdependencies create risks of cascading, mutually-reinforcing failures across both the Electricity and Oil and Natural Gas (ONG) energy subsectors, and magnify the potential risks of catastrophic power outages to public safety, the economy, and national security.

The natural gas industry is well positioned to collaborate with the electric subsector to meet these resilience challenges. The natural gas industry has

achieved a strong record of safety and reliability against traditional hazards.⁷ Drawing on lessons from Superstorm Sandy, natural gas companies are investing to improve their ability to sustain service in future events, and also strengthen the gas systems' resilience against cyberattacks and other emerging threats.⁸ These investments provide a solid basis for additional progress in building cross-sector resilience. So, too, do the growing collaborative efforts between the ONG and electric subsector coordinating councils.

However, Black Sky events will pose extraordinarily severe challenges to cross-sector resilience, and will require an array of new, Black Sky-focused initiatives by the two subsectors and their external partners (including regulators and state government officials).

1. Sustaining the Flow of Natural Gas for Power Generation

As the electric industry increases the protection of key power generators against EMP effects and other Black Sky hazards, it will also be necessary to ensure that both surviving and repaired generation plants will have the fuel they need to restore the flow of electricity across the affected region.

For some types of fuel, generators will have assured access to adequate supplies. Nuclear reactors, for example, typically load sufficient fuel in their

With natural gas rapidly replacing more fuel-secure generation in many regions of the nation, ensuring the resilience of gas collecting, storage and distribution systems is an important priority to address long duration outages.

7 U.S. Government Accountability Office, GAO-13-168, Better Data and Guidance Needed to Improve Pipeline Operator Incident Response, January, 2013. <http://www.gao.gov/assets/660/651408.pdf>; VanNess Feldman LLP, Natural Gas Pipeline Safety and Reliability: An Assessment of Progress, American Gas Foundation, 2015. <http://www.napsr.org/SiteAssets/mediainfo/Pipeline%20Safety-AGF%20Report%202015.pdf>

8 Revkin, Andrew, "How natural gas kept some spots bright and warm as Sandy blasted New York City," *The New York Times*, November 5, 2012. http://dotearth.blogs.nytimes.com/2012/11/05/how-natural-gas-kept-some-spots-bright-and-warm-as-sandy-blasted-new-york/?_r=0; and Learning from Superstorm Sandy: PSE&G Improves Infrastructure, Communications and Logistics, PSEG, October 28, 2014. <https://www.pseg.com/info/media/newsreleases/2014/2014-10-28.jsp#.V2rPtPkrKUK>; American Gas Association, "2016 Playbook," <http://playbook.aga.org/#p=1>

core to sustain operations for 18 to 24 months. Hydroelectric power plants typically have assured access to their gravity-fed generation facilities. Coal-fired generators also have such assured access to fuel; sufficient coal is usually stored onsite to enable these generators to produce electricity for many weeks before resupply becomes necessary. This onsite storage and built-in resourcing gives hydroelectric, nuclear and coal-fired generators significant resilience against disruptions in their fuel supplies.

However, hydroelectric power is available only in limited locations, nuclear generation is trending downward in the United States, and generation companies across the nation are rapidly retiring coal-fueled plants and increasing their reliance on generators that run on natural gas. The Department of Energy notes that natural gas is not typically stored onsite and must generally be delivered as it is consumed.⁹

The direct destructive effects of Black Sky hazards on gas gathering infrastructure, interstate transportation pipelines and distribution systems could disrupt the flow of natural gas to power generators. The gas industry is already making significant investments to protect its systems against many natural and manmade hazards.¹⁰ Ramping up that progress, and providing for cost recovery in investments in protection and system redundancy will be essential for Black Sky resilience.

Black Sky hazards can also jeopardize gas deliveries in an indirect fashion, by disrupting the flow of electric power on which many gas system components depend. Such power losses will create the risk of spiraling, cross-sector effects: as gas systems lose the electricity they need to function, the flow of gas to power generators will also be disrupted, leading to still further cuts in power availability for gas systems and other critical customers.

9 U.S. Department of Energy (DOE), "Natural Gas Infrastructure Implications of Increased Demand from the Electric Power Sector," February 2015, p. v. http://energy.gov/sites/prod/files/2015/02/f19/DOE%20Report%20Natural%20Gas%20Infrastructure%20V_02-02.pdf. As will be discussed in volume I, storage of natural gas in salt caverns or other facilities colocated with power generators may offer viable storage options in some regions – but only if those storage facilities have the power they need to operate.

10 American Gas Association, Natural Gas Utilities Value Effective Security Partnership with TSA, April 19, 2016. <https://www.aga.org/news/news-releases/natural-gas-utilities-value-effective-security-partnership-tsa>

2. Resilience Options

The “Volume Summary” (in Section One of Volume I) provides a comprehensive overview of recommendations for fuel supply resilience for Black Sky power generation. These recommendations also specify which of their action items will need to be advanced 1) internally, within either the electric or natural gas subsectors; 2) collaboratively, through coordinated or joint initiatives by both industries; and 3) externally, through improved support missions or policy changes by regulators, government leaders, private contractors, and other resilience partners for the gas and electric systems.

Key opportunities for progress

- **Increased Use of Dual-Fuel Generators.**

Dual-fuel power generators offer an especially effective means to hedge against disruptions in natural gas supplies. These generators can run on either natural gas, their primary fuel, or -- if gas supplies are interrupted -- use clean diesel/#2 fuel oil or other secondary sources of fuel to sustain operations until the flow of gas is restored. However, dual-fuel generators are declining in numbers in many U.S. regions where they were once common. Changes in environmental regulations and new incentives and cost recovery mechanisms will be vital to reverse this trend.

- **Mitigate the Resilience Challenges Posed by Gas Pipeline Compressors.**

Gas transmission systems need compression pumps to sustain the flow of gas to power plants and other customers. Historically, these compressors were fueled with gas taken from the pipelines themselves. However, in many regions of the United States, these compressors are being replaced by variable speed electric-powered units to reduce onsite methane emissions and increase compressor efficiency. Black sky outages could interrupt the flow of electricity to these units, and (in a classic case of spiraling effects) magnify those outages by disrupting gas deliveries to power generators essential for power restoration.¹¹

11 Even if compressor stations rely exclusively on gas-powered compressors, these stations typically require; electricity for other functions, including control, gas cooling, and telecommunications systems. Most compressor stations have backup power generators to keep these systems

Reassessing the regulations that are driving the transition to electric compressors, and incentivizing the use of dual-fuel compressors that can revert to gas-fueled operations if a blackout strikes, offer important starting points to address these resilience challenges.

- **Coordinated Investments in Infrastructure.**

Significant opportunities are emerging for gas and electric utilities to coordinate such investments to account for their interdependencies and reduce the risks of cross-sector failure. Colocation of new gas storage and power generation facilities offers a prime example. If power generators can be sited adjacent to storage facilities, a ready supply of backup fuel will be available until pipeline flows are restored. Coordinated decisions on pipeline construction, generator siting and other infrastructure investments can offer significant resilience benefits as well.

- **Prioritized Restoration of Power to Electricity-Dependent Gas System Components.**

In a number of blackouts examined in this Handbook, power distribution companies were not always aware of the electricity-dependent gas transmission system components in their footprints, and were unable to prioritize the delivery of power to them so that gas flows to generators could be sustained or restored. Collaboration between the gas and electric subsectors to provide for prioritized restoration of critical gas system assets can help reduce the duration of Black Sky outages.

- **Prioritize and Plan for the Delivery of Gas to Power Generators in Black Sky Events.**

Many electric utilities rely on lower cost “interruptible” (versus “firm”) gas delivery contracts that leave them susceptible to curtailed service in emergencies. Moreover, under the laws and regulations of a large number states, gas companies are required to treat power generators as a much lower priority for sustained service than homes and other customers, further increasing the likelihood that generators will suffer

functioning if outside electric service is interrupted. However, if compressor stations rely on electric powered compressors versus gas alternatives, their generator and fuel resupply requirements will be significantly greater.

gas curtailments in Black Sky events. Measures to enable generation companies to recover the costs of shifting to firm contracts can help address these challenges. State authorities should also reassess curtailment laws and regulations to strike an appropriate balance between gas delivery priorities when catastrophic blackouts occur.

3. Black Start Operations as a Special Fuel Resilience Priority

In the power outages caused by Sandy, Katrina and other previous events, electric utilities have restored power from the “outside-in.” Under this typical approach to restoration, utilities bring in power from beyond the blackout region, and use that power to re-start the generators that had gone off-line.

Black Sky events are likely to require restoration from assets within the outage region through black start operations: that is, re-energize the grid by using specially designated generation resources within a blacked-out area, rather than by importing power from outside that zone.¹²

Ensuring that at least a designated portion of black start resources have adequate onsite fuel for weeks of operation will be essential to power restoration from extreme, Black Sky hazards.

Black start operations depend on two basic types of generators: black start units and cranking path generators. Black start units are power generators (often either hydro or diesel-fueled) that can start without support from an outside electric supply.¹³ Once started, these units then provide power to start larger generators along a specially designated cranking path to gradually re-

12 “Blackstart resources are generating units that have the ability to be started without support from the rest of the bulk power system, or are designed to remain energized without connection to the remainder of the bulk power system, and can be used to re-start other generating units as part of the process of re-energizing the system.” North American Electric Reliability Corporation (NERC) and Federal Energy Regulatory Commission (FERC), “FERC-NERC Regional Entity Joint Review of Restoration and Recovery Plans,” January 2016, p. 1. <https://www.ferc.gov/legal/staff-reports/2016/01-29-16-FERC-NERC-Report.pdf>

13 PJM, “Black Start Service,” <http://www.pjm.com/~media/committees-groups/subcommittees/rscs/20130815/20130815-item-02-1b-m-12v28-srstf-black-start-changes.ashx>

energize the grid.¹⁴ Black start units, cranking path generators, the associated transmission system and the other electric system components essential for black start operations are collectively termed “black start resources.”

Coal-fired generators have served as crucial black start resources in many regions of the United States, especially in areas where hydroelectric plants are of limited availability. Major coal units typically have sufficient fuel stored onsite to operate for many weeks before they need to be resupplied. As these coal units are shut down and replaced by gas-fired generators that require a steady flow of fuel, new challenges will continue to emerge for maintaining the current resilience of black start systems -- especially given the growing interdependencies between gas and electric systems.

Many of the action items highlighted in the preceding section can be specifically targeted to strengthen black start resilience. Two other initiatives will also be vital.

First, a designated, geographically-distributed portion of cranking path generators and the other grid components essential for black start power restoration will need to be hardened against the direct, destructive effects of electromagnetic pulses and other Black Sky hazards. Second, through closely coordinated planning with the electric subsector, the ONG subsector will need to launch equivalent hardening initiatives for those gas system components on which gas-fueled black start cranking path generators depend. All such investments will need to be supported through appropriate cost recovery mechanisms.

Black Sky hazard hardening of a designated portion of black start and cranking path generators, and of the gas delivery systems that supply them, will be essential to ensure resilience in long duration outages.

Broader efforts will also be necessary to ensure that black start systems will function as needed in Black Sky events. The Black Sky/Black Start Protection Initiative (BSPI) examines the special challenges that EMP attacks and other

14 NERC defines the cranking path as “a portion of the electric system that can be isolated and then energized to deliver electric power from a generation source to enable the startup of one or more other generating units. NERC, Glossary of Terms, p. 33. http://www.nerc.com/files/glossary_of_terms.pdf

Black Sky hazards will pose to black start resources, operational plans, and coordination mechanisms. This initiative is also developing options for the electric subsector to help strengthen the resilience of black start systems in the face of increasingly severe threats.¹⁵

15 EIS Council, Black Sky / Black Start Protection Initiative, <http://www.eiscouncil.com/Protection/ItemDetails/60>



III | ADDITIONAL PRIORITIES FOR PROGRESS

While EPRO II focuses on interdependencies between the electric grid, natural gas systems and the water sector, preparedness against Black Sky hazards will also require broader initiatives to strengthen cross-sector resilience. The analysis that follows provides a framework for assessing these requirements, and highlights four especially urgent areas for progress (all of which are the focus of ongoing analytic and partner support projects by EIS Council):

- Plans and capabilities for the prioritized distribution of emergency generators, emergency fuel, and associated technical support in long duration, wide area power outages, when demand for these assets will vastly outstrip currently available supplies. Coordinated planning for the prioritized distribution of treatment chemicals and other “consumables” vital for water treatment systems and other critical infrastructure components, in the highly disrupted environments that would otherwise disrupt the availability of such products.

- Long duration outage-compatible, widely distributed emergency communications systems to support restoration of critical services and other Black Sky response operations.
- Opportunities to build on the National Response Framework and National Disaster Recovery Framework to coordinate and facilitate response/recovery operations in Black Sky events.¹⁶

1. A Typology of Black Sky Effects on Critical Infrastructure: An Agenda for Action

Measures to strengthen infrastructure resilience against Black Sky hazards will need to account for three different categories of disruption. They include:

- **Direct, sector-specific effects.**

An EMP attack, earthquake or other Black Sky event will damage or destroy some of the infrastructure within most, if not all of the 16 infrastructure sectors identified as critical by Presidential Policy Directive (PPD) 21, Critical Infrastructure Security and Resilience (February, 2013).¹⁷

As in the case of the electric, natural gas and water infrastructure, strategically targeted investments to protect carefully selected, key system nodes for the 16 critical sectors against direct damage from Black Sky hazards will be necessary to sustain essential functions and support broader restoration of service. Cost recovery mechanisms to support those investments will be vital to facilitate such progress.

Sector-specific Black Sky playbooks, initially for those critical infrastructures essential for power restoration or immediately saving and sustaining lives, will also be necessary to help set core sector goals.

16 U.S Department of Homeland Security (DHS), National Response Framework, May 2013, FEMA, http://www.fema.gov/media-library-data/20130726-1914-25045-1246/final_national_response_framework_20130501.pdf; U.S Department of Homeland Security (DHS), National Disaster Recovery Framework, FEMA, September 2011. http://www.fema.gov/media-library-data/20130726-1820-25045-5325/508_ndrf.pdf

17 Presidential Policy Directive (PPD) 21, Critical Infrastructure Security and Resilience, February, 2013. <https://www.whitehouse.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil>

These goals will establish minimalist levels of service and functionality to sustain, and scale up existing emergency operations plans and capabilities to account for the catastrophic effects of Black Sky hazards. Over time, similar playbooks will be required by all 16 critical infrastructure sectors. The analysis in EPRO II of playbook requirements and methodologies for the water sector can serve as a model for other critical infrastructure sectors to modify and adapt to reflect their own structural features and resilience requirements.

- **Indirect, collateral impacts.**

The gas-electric interdependencies examined in EPRO Handbook II are part of a much broader category of risk in Black Sky events. If a catastrophic cyberattack or other Black Sky hazard disrupts one infrastructure sector -- for example, the electric subsector -- natural gas systems will suffer collateral effects from the loss of electric service, even if their own systems were not directly attacked. In turn, because the electric grid depends on the flow of natural gas to sustain and restore electric service, the collateral effects on gas systems will severely disrupt power restoration operations (leading to still further cross-sector disruptions).



Power restoration also depends on infrastructure beyond the natural gas subsector. In particular, the availability of communications systems to help utilities coordinate and conduct restoration operations will be absolutely vital during Black Sky events. Yet, as occurred in Superstorm Sandy, the loss of electric service on which cell towers and other communications nodes depend, can cripple communications systems. Assessing and mitigating the indirect, collateral effects that Black Sky events will create, ultimately to include all 16 infrastructure sectors, will be essential for progress.

DHS and its government and private sector partners have taken important steps to facilitate such progress. The Critical Infrastructure Cross Sector Council is structured to help identify and support collaboration between infrastructure sectors.¹⁸ Sector Coordinating Councils, including the Electric Subsector Coordinating Committee (ESCC), are increasingly reaching out to other sectors to advance cross-sector resilience initiatives. The National Infrastructure Advisory Council (NIAC) has proposed to establish a Strategic Infrastructure Executive Council (SIEC) to “identify national priorities and develop joint or coordinated action plans for cross-sector resilience.”¹⁹

The EPRO Executive Steering Committee and Sector Steering Committee process supports such cross-sector coordination, with a special focus on extreme, Black Sky hazards, facilitating coordinated planning among a growing number of critical sectors and the public and private sector partners necessary to build resilience against these uniquely severe scenarios.²⁰

All such initiatives should be ramped up and be aligned for unity of effort to strengthen Black Sky preparedness.

- **Multi-sector, cascading failures.**

As in Katrina, Sandy and other catastrophes, Black Sky hazards will simultaneously disrupt many -- if not all -- infrastructure sectors. The risk of a combined cyber-kinetic attack on multiple sectors illustrates this risk. In the 2015 cyberattack on the Ukraine power grid, the perpetrators struck both power distribution systems and the phone system; the latter attack prevented customers from reporting outages and disrupted the ability of grid operators to focus on restoration operations accordingly.²¹

18 Critical Infrastructure Cross Sector Council Charter, Approved: November 12, 2015. <https://www.dhs.gov/sites/default/files/publications/cipac-cross-sector-council-charter-2015-508.pdf>.

19 Wallace, Michael and Kepler, David. Executive Collaboration for the Nation's Strategic Critical Infrastructure: Final Report and Recommendations, National Infrastructure Advisory Council, March 20, 2015, p. 7, <https://www.dhs.gov/sites/default/files/publications/niac-executive-collaboration-final-report-508.pdf>

20 EIS Council. <http://www.eiscouncil.com/EPro/Esc>

21 ICS-CERT, Cyber-Attack against Ukrainian Critical Infrastructure, February 25, 2016. <https://ics-cert.us-cert.gov/alerts/IR-ALERT-H-16-056-01>

To achieve similar synergistic effects, adversaries may launch simultaneous attacks on the electric, communications, and other sectors. Such multi-sector attacks (and the cascading failures they would produce) would compound problems for infrastructure restoration.²² Cascading failures would also present immense restoration and recovery challenges in catastrophic earthquakes, EMP attacks, and other natural or manmade Black Sky hazards.

Cross-sector exercises will be particularly critical to plan and train for the unique, well-coordinated multi-sector planning needed for Black Sky hazards.

Exercises offer a key means to reveal unanticipated risks of cross-sector failure and develop mitigation strategies to address them. In November 2015, GridEx III examined the cascading failures that would be created by an attack on the power grid, and the ways in which resulting disruptions in the communications and financial sector would disrupt power restoration operations.²³ The summer 2016 Hamilton Exercise has further assessed the impact of power outages on the financial sector. The DHS Cyber Storm V exercise, conducted in March 2016, also examined cross-sector restoration challenges for the health, retail, and communications sectors.²⁴ Exercises specifically focused on Black Sky events will also be vital to help government and private sector partners identify risks of cascading, multi-sector disruptions of infrastructure, and build plans and capabilities for resilience against them. A series of EIS Council Black Sky exercises is now underway to help meet these requirements. In a June, 2016 exercise in

22 For additional analysis of the risks of cross-sector cyberattacks and mechanisms to coordinate responses to them, see Homeland Security Advisory Council (HSAC), Final Report of the Cybersecurity Subcommittee: Part I: Incident Response. June 2016. https://www.dhs.gov/sites/default/files/publications/HSAC_Cybersecurity_IR_FINAL_Report.pdf

23 North American Electric Reliability Corporation (NERC). GRID Security Exercise: GridEx III Report, March 2016. <http://www.nerc.com/pa/CI/CIPOutreach/GridEX/NERC%20GridEx%20III%20Report.pdf>

24 U.S. Department of Homeland Security, Cyber Storm: Securing Cyber Space. <https://www.dhs.gov/cyber-storm>. See also U.S. DHS, Informing Cyber Storm V: Lessons Learned from Cyber Storm IV, June 2015. <https://www.dhs.gov/sites/default/files/publications/Lessons%20Learned%20from%20Cyber%20Storm%20IV.pdf>

Pennsylvania, Governor Tom Wolf noted that the state's Black Sky exercise (which included participation from multiple infrastructure sectors and all levels of government) was essential to help participants “minimize the impact of such an event and recover as quickly as possible.”²⁵ In the coming years, EIS Council anticipates working with partner organizations on an expanded set of multi-sector, Black Sky exercises, designed for broad, international participation. These **Emergency All-sector Response Transnational Hazard Exercises (EARTH EX™)**, now in planning, are being developed to help build planning and training to address the unique requirements, associated with Black Sky hazards, for exceptionally well-coordinated cross sector planning.



Equivalent exercises should go forward in additional states and regions.

2. **Emergency Power: Addressing a Critical Gap in Black Sky Preparedness**

In Black Sky events, an enormous mismatch will emerge between demands for emergency power generators and the ability of public agencies and private contractors to supply them. Volume II of this Handbook finds that to meet potential generator requirements of the water sector alone, generator providers in many regions of the United States would find their inventories inadequate for long duration, wide area outages.

Moreover, water and wastewater utilities will be in a de facto competition for emergency generators against oil refineries and chemical plants, hospitals, nursing homes, and many other critical facilities. This competition will grow especially intense as generators begin to break down from extended use and need to be replaced. The net result: far fewer emergency generators will be

25 Pennsylvania Public Utility Commission, PUC, Governor and EIS Council Host 'Black Sky' Exercise to Prepare for Large-Scale Outage Event, June 3, 2016. http://www.puc.state.pa.us/about_puc/press_releases.aspx?ShowPR=3700

available in a Black Sky event than the water sector -- and the Nation as a whole -- will require.

A similar shortfall will exist in supplying the fuel for these generators. In a power outage lasting a month or more, affecting multiple states or regions of the United States, without advance planning, private fuel contractors would generally not be prepared to operate in the highly disrupted environments associated with these scenarios. And, without thorough preplanning, any attempt to sustain private fuel contractor deliveries would be overwhelmed by the simultaneous requirements for resupply that many thousands of critical infrastructure system owners and operators will create. The difficulties of meeting these requirements will be magnified by the disruptive effects of Black Sky events on communications, family support for key personnel, gas stations along key evacuation routes and major transportation corridors, food and water supplies, fuel supply chains and transportation systems.

A series of 2016 exercises based on catastrophic earthquake scenarios, including Clear Path IV and Cascadia Rising, have helped highlight the severity of these challenges for emergency power and the broader resilience of U.S. energy systems.²⁶ The after-action reports from these exercises should provide rich opportunities to clarify shortfalls in generator and fuel stockpiles and delivery capabilities, and provide a basis for consensus-building on options to fill these gaps.

Planning initiatives are also underway to meet these resilience challenges. Especially important, the Federal Emergency Management Agency (FEMA) is partnering with the Department of Energy (DOE) to develop a new Power Outage Incident Annex to the Response and Recovery Federal Interagency Operations Plans (FIOPs), which will address the response and recovery to a mass or long-term power outage regardless of the cause. FEMA is expected to release this annex in late 2016. In the coming years, FEMA will expand this national planning effort to include joint federal-state plans conducted at FEMA

26 Testimony of Patricia A. Hoffman, Assistant Secretary for Office of Electricity Delivery and Energy Reliability, DOE, Before the Committee on Transportation and Infrastructure: Subcommittee on Economic Development, Public Buildings, and Emergency Management, April 14, 2016. <http://transportation.house.gov/uploadedfiles/2016-04-14-hoffman.pdf>; Cascadia Rising 2016 Exercise, June 7-10, 2016. <https://assets.documentcloud.org/documents/2724308/Cascadia-Rising-2016-Exercise-Plan-REVISED-DRAFT.pdf>

Regions to increase fidelity into plans and expand agency partnerships with local and regional power providers and other key energy resilience stakeholders.²⁷

FEMA, the U.S. Army Corps of Engineers (USACE), and other Federal agencies are also making significant progress in strengthening U.S. emergency generator inventories and fuel delivery capabilities.

However, Black Sky events will entail such demanding requirements that consideration should be given to creating a new entity to provide for cross-sector, nationwide coordination of emergency power assets and delivery operations. Consideration should be given to the creation of a National Emergency Power Council (NEPC) or equivalent organization to help meet these requirements.²⁸

Similarly, availability of critical consumables required by water and wastewater utilities, electric utilities, ONG companies and other critical facilities will only be available in such highly disrupted environments if thorough public-private sector coordination and preplanning is in place.

3. Survivable Communications for Black Sky Restoration and Response Operations

Many critical infrastructure system owners and operators maintain robust backup communications systems to use if hurricanes or other hazards disrupt their primary means of communication. Such backup systems are absolutely essential to guide the repair and replacement of infrastructure when primary communications links go down, and to help maintain situational awareness and provide for coordination with public and private sector partners as restoration operations go forward.

Backup communications capabilities will be especially important, but also at great risk, in Black Sky events. The direct effects of EMP attacks, earthquakes, or other Black Sky hazards could cause highly disruptive damage on communications system components. These hazards could also degrade

27 U.S. Department of Homeland Security (DHS), Written testimony of FEMA Administrator Craig Fugate for a House Committee on Transportation and Infrastructure, Subcommittee on Economic Development, Public Buildings and Emergency Management, "Blackout! Are we Prepared to Manage the Aftermath of a Cyber-Attack or Other Failure of the Electrical Grid?" April 14, 2016. <https://www.dhs.gov/news/2016/04/14/written-testimony-fema-administrator-house-transportation-and-infrastructure>

28 EIS Council. <http://www.eiscouncil.com/Protection/ItemDetails/64>

communications systems indirectly, by interrupting the flow of electric power on which communications infrastructure depends. Most important: unless backup communications systems are protected against Black Sky hazards, they will go down along with primary systems and jeopardize restoration operations.

The National Security Telecommunications Advisory Council (NSTAC) report by the Communications Resiliency Task Force (2011) recommends a range of options to strengthen the resilience of communications systems against emerging threats.²⁹ The NSTAC Information Technology and

Communications (ITC) Mobilization Report (2014) provides additional resilience options.³⁰ Implementation of these recommendations will make significant contributions to preparedness for Black Sky events, especially against increasingly severe cyber threats to the communication sector.

However, the unique requirements associated with extreme, long duration Black Sky outages suggest the need for development of a “back pocket,” Black-Sky-robust communication system. In such scenarios, at least minimally adequate voice and data communication will be required for a remarkably wide set of critical stakeholders, including the critical lifeline utility sectors, emergency fuel and consumables supply chain companies and distributors, emergency responders, critical facility operators and many others. And, as a critical requirement, such a system, and all of its assets, must be operable without external power for at least the baseline 30 days planned for in Black Sky scenarios.

Widely distributed emergency communication, capable of operation without external power for at least 30 days, will be essential to restoration and recovery from severe, Black Sky hazards. The ECOM system architecture study represents one approach to implement such requirements.

29 National Security Telecommunications Advisory Committee (NSTAC), Report to the President on Communications Resiliency, April 19, 2011, p. 29. <https://www.dhs.gov/sites/default/files/publications/NSTAC-Report-to-the-President-on-Communications-Resiliency-2011-04-19.pdf>

30 National Security Telecommunications Advisory Committee (NSTAC), Report to the President on Information and Communications Technology Mobilization, 2014. [https://www.dhs.gov/sites/default/files/publications/ICTM%20Final%20Draft%20Report%2011-2014%20\(2\).pdf](https://www.dhs.gov/sites/default/files/publications/ICTM%20Final%20Draft%20Report%2011-2014%20(2).pdf)

The ECOM Emergency Communication System Architecture Project provides one approach to build such a Black Sky-specific, “back pocket” system, with options for a national communication system designed for use in such extended, multi-region power outages. While focused primarily on the voice and data needs of lifeline utilities and their government and NGO partners, the ECOM architecture is also structured to support very wide distribution among the many stakeholders among whom communication will be essential to save and sustain lives in Black Sky outages. Designed to provide users with the multi-level services they will need, ECOM is also designed to support eventual incorporation into an overall National Recovery Coordination Support System, that will include situational awareness and assisted decision-making tools for response agencies, utilities, key service providers and other stakeholders.³¹

4. Coordination of Black Sky Response and Recovery

A critical finding of EPRO Handbook I was that the existing framework for disaster response and recovery in the United States, including the National Response Framework and the National Recovery Framework, provide a strong foundation on which to build preparedness for preserving public health and safety in Black Sky events.³²

The Handbook also noted that FEMA and its interagency partners were making considerable progress in integrating private sector partners into decision-making to help guide and prioritize support for infrastructure restoration operations. Most notable, the establishment of an Energy Task Force during the response to Sandy (and giving the electric industry a “seat at the table” at FEMA’s National Response Coordination Center) constituted a major step forward in strengthening

EPRO Handbook III will explore options to build on existing national recovery planning, with suggestions for a Black Sky-focused National Recovery Coordination Support Framework that could support the unique needs for thorough, advance multi-sector coordination that will be essential in such scenarios.

31 EIS Council. <http://www.eiscouncil.com/Protection/ItemDetails/62>

32 Electric Infrastructure Security (EIS) Council, EPRO Handbook I, p. 19.

government-industry collaboration, and provided valuable lessons learned for how restoration operations can be better coordinated in future disasters.³³

However, Black Sky events will entail vastly greater response and recovery coordination challenges. All 15 Emergency Support Functions (ESFs) will need to function in a coordinated, integrated fashion with the owners and operators of systems in all 16 critical infrastructure sectors.³⁴ Moreover, these coordinated operations will need to go forward in a severely disrupted and politically white-hot environment, where response and recovery support assets will inevitably fall far short of need. Given the extraordinary and unique challenges, thorough advance planning, resourcing and training of such a multi-sector coordination process, along with the many new tools and capabilities it will need (many, but not all of which have been highlighted above), will be essential to success.

EPRO Handbook III will assess these challenges and offer options for structuring a Black Sky-focused National Recovery Coordination Support Framework that could help to meet them. But the recommendations that follow in this volume provide a critical starting point to do so. Measures to increase the resilience of the water sector and the flow of fuel for power generation will make enormous contributions to Black Sky preparedness, and greatly facilitate response and recovery operations when – not if – Black Sky hazards strike.

33 FEMA, Hurricane Sandy, FEMA After-Action Report, July 1, 2013. https://www.fema.gov/media-library-data/20130726-1923-25045-7442/sandy_fema_aar.pdf

34 For a description of these emergency Support Functions, see FEMA, Energy Support Function Annexes: Introduction, January 2008. http://www.fema.gov/media-library-data/20130726-1825-25045-0604/emergency_support_function_annexes_introduction_2008_.pdf

2

WATER SECTOR

RESILIENCE

FOR BLACK SKY

EVENTS

1

SECTION ONE

INTRODUCTION AND SUMMARY



INTRODUCTION

During Superstorm Sandy, loss of electric power was the single greatest factor affecting water service operations, even for utilities that had emergency generators.¹ Catastrophic earthquakes, electromagnetic pulse (EMP) attacks, and other Black Sky hazards can create much more severe power outages than occurred in Sandy. To build water sector resilience against

Assistance from partner sectors will be an essential element of the planning called for in the water sector's Black Sky playbook.

1 American Water Works Association (AWWA), "Superstorm Sandy After-Action Report," Water/Waste Water Agency Response Network, p. 6, 2013. <http://www.awwa.org/Portals/0/files/resources/water%20knowledge/rc%20emergency%20prep/rc%20warn%20situation%20reports/SandyAAR2013.pdf>; Lau, Constance H. and Scott, Beverly, Strengthening Regional Resilience, National Infrastructure Advisory Council (NIAC), November 21, 2013, p. 107. <https://www.dhs.gov/sites/default/files/publications/niac-regional-resilience-final-report-11-21-13-508.pdf>

such outages, water and wastewater utilities will need to identify their core goals for maintaining service in Black Sky events, develop a playbook to achieve those goals, and invest in standby generators and other assets essential for sustained emergency operations.

Maintaining emergency service in Black Sky outages will also require support from partners of the water sector. Electric utilities can help avert water and wastewater service disruptions by prioritizing the restoration of power to key pumps and other water system components. However, until power is restored, other partners will be vital for sustaining emergency service.

Government agencies and private contractors responsible for providing standby generators and fuel to operate them will play vital support roles. Contractors who resupply water treatment chemicals will also be critical in long-duration outages, as will emergency managers, Non-Governmental Organizations (NGOs), and other partners who can provide emergency drinking water if service interruptions occur. However, in order to provide this support, the water sector's partners will themselves need to be resilient against Black Sky hazards, and prepared to handle the massive fuel resupply and other assistance operations that the water sector (and many other critical functions and facilities) will require.

Previous power outages have revealed major gaps in partner support plans and capabilities. As the blackout in Sandy entered its second week, a growing number of water and wastewater systems found themselves on the knife's edge of disaster as their fuel tanks ran low, their requests to be resupplied went unmet, and emergency generators broke down from extended use.²

During Superstorm Sandy, loss of electric power was the single greatest factor affecting water service operations, even for utilities that had emergency generators.

A Black Sky event would push these systems over the edge. In Sandy, electric utilities restored power to the vast majority of their customers in two weeks or less. Coordinated cyber and kinetic attacks on key infrastructure components, massive space weather events, and other Black Sky hazards could create outages lasting a month or more over

2 National Infrastructure Advisory Council (NIAC), *Strengthening Regional Resilience* (2013), p. 105.

wide areas of the United States. This volume focuses on strengthening resilience against such Black Sky outages -- that is, outages that cause 90 percent of customers in a multi-state region to lose power for at least 30 days.³



Power Restoration in New Jersey [Source: Liz Roll, FEMA 11/2/2012]

A | What's at Stake: Societal Urgency of Black Sky Resilience

Building the plans and capabilities necessary to sustain water and wastewater services for a month or more will present major challenges. Yet, the benefits of making progress towards this goal are compelling, and provide a key starting point for building consensus on resilience priorities for the water sector.

All the facilities vital to saving and sustaining lives in a Black Sky event depend on water and wastewater service to function. Many water utilities already have plans to ensure emergency service to hospitals and other disaster response facilities. Ramping up their plans to account for long duration outages, and including them in an evolving playbook for Black Sky operations, will protect countless lives when severe outages strike.

Water sector resilience will also be critical for averting unplanned, chaotic mass migration of U.S. citizens in Black Sky events. If extended power outages

3 Stockton, Paul, "E-PRO Handbook I," The Electric Infrastructure Security Council, March 1, 2015, p. 68.

shut down water service over many cities in multi-state regions, delivering bottled water or other emergency water supplies – especially in the disrupted environment that would result from such outages – would present insuperable logistical problems. Operations to restore power and re-establish the functioning of transportation and other sectors would also be greatly complicated by shutdowns in water service.



Settling Tank at Water Plant

The loss of wastewater service to homes and offices would quickly render them uninhabitable as well. Forestalling mass evacuations in Black Sky events, and enabling the largest possible number of citizens to shelter in place for as long as possible, should be prime goals for the water sector and should help drive the development of the sector's Black Sky playbook to prepare for such catastrophes.

Resilient water service can also provide a less-recognized but increasingly important benefit: that of contributing to U.S. national security. The 2012 Department of Defense (DOD) Mission Assurance Strategy highlights the growing risk that adversaries may seek to disrupt U.S. defense capabilities indirectly, by attacking the critical infrastructure systems on which military bases depend.

The Strategy focuses particular attention on the dependence of defense installations on the electric grid. However, water and wastewater services are

Enabling “sheltering in place” should be a primary goal of the water sector’s playbook. Failure of water and wastewater systems in long duration blackouts would result in catastrophic, chaotic mass migrations, with unacceptable societal consequences.

equally vital for ensuring that DOD can execute its priority missions. Military bases cannot function without water to help cool their computers and other electronic systems, provide for fire suppression, and meet other drinking and non-drinking water requirements. Absent wastewater service, major defense office buildings and other national security facilities would become unusable. Ensuring that the water sector can sustain such service, even if adversaries launch coordinated cyber/kinetic attacks or EMP strikes on the power grid, will directly strengthen DOD mission assurance.

Water sector resilience can also contribute to national security more broadly. In a severe crisis, adversaries may attack the grid to put the health and safety of the American people at risk, and raise doubts about the ability of the U.S. government to protect its citizens.

Ensuring that the water sector can still function in a Black Sky outage will help counter such threats. Investments in resilience may even help deter such attacks from occurring by raising adversary doubts about whether the expected benefits of attacking U.S. infrastructure are worth the potential costs that a U.S. response would inflict. The rationale for strengthening water sector resilience should account for these sector contributions to citizen survival and national security.

Drinking water and wastewater utilities are encouraged to conduct or update risk assessments as well as to prepare or revise Emergency Response Plans on a regular basis. EPA's Vulnerability Self-Assessment Tool (VSAT) provides water sector utility owners and operators with qualified and quantified risk assessment processes.⁴

However, at present, most water and wastewater systems and their partners would find it difficult to sustain operations in a blackout for more than a few

Sustained minimal water service to major cities is also essential to the functioning of military bases and defense facilities, and therefore basic national security.

Failure to assure water sector resilience could also cause adversaries to doubt the ability of the government to protect its citizens, resulting in greatly increased strategic threats.

4 EPA, Water Security and Resiliency Highlights, <http://1.usa.gov/1UvhWzL>

days, much less a month or more. Given the gap between current levels of preparedness, and what will be required to sustain emergency operations in Black Sky outages, it will be essential to develop practical, affordable ways to close that gap.



Settling Tanks in Sewage Treatment Plant

Even without emergency power generators, water utilities can often avoid service interruptions because they store sufficient treated water in elevated tanks to sustain operations in brief outages. Increasingly, however, water and wastewater systems are either installing emergency generators at critical pumps and other electric-dependent system components, or are pre-arranging for generators to be delivered and hooked up by contractors or the U.S. Army Corps of Engineers (USACE) if a blackout occurs.

This expansion of emergency power capabilities for short-duration blackouts provides a foundation on which to build preparedness for more severe outages -- including, ultimately, Black Sky events. The American Water Works Association's Emergency Preparedness Practices Standard provides a helpful foundation for building Black Sky preparedness. The standards define the minimum emergency preparedness requirements for water, wastewater or reuse facilities to respond to emergencies and restore normal operations, and to minimize the disruption of critical services and risks to public health.⁵

The water sector can gain significant advantages by leveraging ongoing efforts for preparedness against typical, relatively short duration outages, and

5 AWWA Management Standard, Emergency Preparedness Practices, November 1, 2011. <http://www.awwa.org/store/productdetail.aspx?productid=28052>

working from the “bottom up” towards Black Sky resilience. For water and wastewater systems that lack any backup generators or fuel storage tanks, adopting an initial goal of being able to operate for 48-72 hours offers a relatively affordable starting point. Moreover, since such short outages are also most common, even limited investments in emergency power can have significant benefits for utility customers.

Yet, building resilience from the bottom up alone will never be sufficient against Black Sky hazards. The water sector and its partners will also need to work from the top down: that is, develop the specialized plans and targeted capabilities that will be vital in Black Sky events and useful as well when lesser catastrophes strike.

The need for top-down planning reflects harsh lessons from past emergency preparedness efforts. Craig Fugate, Administrator of the Federal Emergency Management Agency (FEMA), notes that emergency managers often fail to plan for worst-case events. In particular, they fall into the “trap” of hoping that they can scale up their plans and capabilities for typical disasters to meet the requirements of catastrophic events.

Catastrophies often demand entirely different preparedness measures, however. Fugate emphasizes the necessity of “planning for the worst that can happen” to identify these requirements.⁶ By following that recommendation, and planning for Black Sky outages, the water sector and its partners can identify risks and mitigation options that preparations for lesser blackouts will never provide.

Diesel fuel resupply for emergency power generators at water and wastewater facilities offers a case in point. Major fuel contractors are typically committed

“Bottom up” investments that increase preparedness for short term power outages can provide a valuable starting point. However, “top down” preparations, designed to address the minimal needs of Black Sky outages, will be essential to achieving resilience for these severe scenarios.

6 Johnson, Nate. “FEMA administrator: Government agencies don’t often plan for worst-case scenarios”, WRAL.com, February 18, 2016. <http://www.wral.com/fema-administrator-government-agencies-don-t-often-plan-for-worst-case-scenarios/15386176/#WUAOs4DwmfuzUclz.99>

to serve a large number of customers with emergency generators, under the assumption that not all customers will need to be resupplied at the same time, and that the contractors themselves can be resupplied as needed by diesel fuel terminals and distribution systems.



Emergency Power Supply Generators Staged at the Incident Support Base for possible use during Spring Flooding in the Midwest, Twin Cities Army Ammunition Plant, Arden Hills, MN. [Source: FEMA 03/18/2011]

These assumptions and the resupply plans that rest on them are perfectly suited for brief, limited-area outages. However, those plans cannot be scaled up for Black Sky events and are certain to fall short of water sector needs. Without thorough, well-organized preplanning, fuel contractors, like virtually all private businesses in long duration outage regions, will be unable to support the water sector at even minimal levels. The cascading effects of such outages on other infrastructure sectors would be particularly devastating for fuel contractors. Without electricity, communications, and functioning gas stations along delivery routes, fuel resupply to water and wastewater systems would quickly come to a halt. Black Sky outages will require state, regional and national-level plans and capabilities for prioritized fuel delivery to the water sector, consistent with the foundational importance of that sector for citizen survival and national security.

Craig Fugate, Administrator of the Federal Emergency Management Agency (FEMA), notes that emergency managers often fail to plan for worst case events. In particular, they fall into the “trap” of hoping that they can scale up their plans and capabilities for typical disasters to meet the requirements of catastrophic events.

To make implementation of those plans possible, fuel contractors and their partners will also need to build their own resilience against Black Sky hazards.

The analysis that follows examines opportunities for the water sector and its partners to meet the especially severe challenges that Black Sky outages will create, while also leveraging the progress the sector is already making to prepare for shorter duration power interruptions.

Wide area, long duration blackouts will require state, regional and national-level plans and capabilities to prioritize and plan for the delivery of fuel to the water sector



I | STRUCTURING THE WAY AHEAD: DEVELOPING A BLACK SKY PLAYBOOK FOR THE WATER SECTOR AND ITS PARTNERS

Strengthening the resilience of the water and wastewater systems against Black Sky hazards will require a complex array of initiatives, many of them interrelated, by both the water sector and by partners outside the sector that support its emergency operations (including suppliers of generators, fuel and treatment chemicals).

Creating a Black Sky playbook will be essential to help organize and facilitate the implementation of these efforts. Other critical infrastructure sectors are already developing operationally oriented playbooks to address more conventional hazards. For example, the Electric Subsector Coordinating Council (ESCC) has created a version that provides a crisis management

framework to enable senior executives from industry and government to coordinate effectively on response and recovery matters.⁷ The chemical sector's playbook extends beyond such response protocols. That playbook encompasses pre-identification of critical facilities, assets, functions and interdependencies to reduce pre- and post-event risks.⁸

A playbook to strengthen water sector resilience against Black Sky hazards will need to go still further. Borrowing from systems engineering methodologies that are increasingly used to guide complex projects, such a playbook should:

- Specify and sequence the steps that will be required to strengthen resilience; and
- Facilitate implementation by determining which specific initiatives would most effectively be led by 1) by the water sector, often in collaboration with sector partners, and 2) by the sector's partners.

The water sector playbook will need to borrow from systems engineering methodology to build the complex, multi-layer and cross-sector planning essential for such extreme scenarios.

A | Key Steps

A series of initiatives will be required to develop a Black Sky playbook for the water sector and its external partners. Given the complexity of the planning required, systems engineering methodologies (provided as Appendix A) can provide a best-practice framework for this effort.

7 Caitlin Durkovich , DHS Assistant Secretary for Infrastructure Protection, written testimony for hearing House Committee on Transportation and Infrastructure, Subcommittee on Economic Development, Public Buildings and Emergency Management hearing, "Blackout! Are we Prepared to Manage the Aftermath of a Cyber-Attack or Other Failure of the Electrical Grid," April 14, 2016, <https://www.dhs.gov/news/2016/04/14/written-testimony-nppd-house-transportation-and-infrastructure-subcommittee-economic>

8 Chemical Sector Coordinating Council, Playbook for an Effective All-Hazards Chemical Sector Response, October 11, 2013, <http://www.ilta.org/WhatsNew/2013/ChemSectorPlaybookFirstEditionOctober2013.pdf>

The process starts with consensus building on the core objectives to achieve in Black Sky outages, followed by evolving, increasingly detailed plans necessary to accomplish those goals.

1. Step One: Define Top Level Goals

The first step will be for the water sector and its external partners (including emergency managers) to determine the basic, overarching goals that the sector should seek to achieve in Black Sky events, focused on ensuring societal continuity and recovery. The options examined by this volume are aimed at minimizing the potentially catastrophic threats to public health and safety that disrupted water service will otherwise entail, and limiting the impact on the U.S. economy and national security.

2. Step Two: Establish Minimalist, Sustainable Service Levels

Based on the top level goals for the water sector, water and wastewater systems will need to set sustainable, “bare minimum” goals for meeting customer needs in wide area blackouts lasting a month or more, where normal levels of service will become increasingly difficult (if not impossible) to sustain due to shortfalls in fuel resupply and other problems. Dialog and consensus building with emergency managers and other external sector partners will be essential in establishing these minimalist service levels.



Emergency Water Supply on Staten Island Post-Hurricane Sandy

External partners will also need playbooks to manage the impact of reduced levels of service on public health and safety. In particular, disaster response plans developed by emergency managers, Non-Governmental Organizations (NGOs), and the National Guard will need to account for those water system

customers who will no longer receive their typical levels of service. Utility plans to limit the geographic scope of water service, the quality of water provided, or other service reductions in Black Sky outages will create significant emergency water needs by those affected in the community. Emergency managers and other external partners will need to pre-plan to assist water customers most likely to be affected by these reductions in service.

3. Step Three: Develop Internal Requirements – Specify Infrastructure Investments and Other Requirements to Maintain Minimalist Service, and Develop the Emergency Operations Plans Needed to Achieve those Service Levels

Water and wastewater systems will need to make carefully prioritized investments in emergency power generators, onsite fuel storage tanks, and other infrastructure necessary to implement their Black Sky playbooks.

The water sector and its external partners will also need emergency operations plans to sustain these service levels. A growing number of water and wastewater systems have emergency plans that are well suited for outages lasting a few days, and can rely on established planning guidelines to prepare for such events.⁹ For preparedness against Black Sky hazards, utilities will not only need to ramp up those plans, but also consider stringent new measures to reduce water service in terms of areas served, water quality, and other service parameters.

4. Step Four: Develop External Requirements – Define support requirements, or policy changes, the water sector will need to complement its own Black Sky resilience measures, to achieve its Black Sky service levels

Many of the water sector's Black Sky resilience investments and operational planning will require funding approval by regulators or other government officials. Reassessments of the value of water service in catastrophic outages,

9 See, for example, the preparedness recommendations in American Water Works Association (AWWA), "Electric Power Reliability for Public Water Supply and Wastewater Utilities," Resolution as adopted and revised by the AWWA Board of Directors, January 19, 2014. <http://www.awwa.org/about-us/policy-statements/policy-statement/articleid/198/electric-power-reliability-for-public-water-supply-and-wastewater-utilities.aspx>

especially in terms of potential costs avoided (as well as national security benefits of emergency service) can help advance discussions of cost recovery.

Other investments, including those in power generators and fuel storage, may require waivers of Clean Air Act standards and other regulatory policy changes. Developing new approaches to account for tradeoffs between Black Sky resilience and regulatory objectives will be essential for progress.

External partners will also need to improve their ability to meet essential water sector requirements for critical services and support. Most important, despite the severe disruption in transportation and communications systems that Black Sky events will create, government agencies and private contractors will need the plans, capabilities, and coordination mechanisms necessary to sustain the following support functions:

- Providing generators to water and wastewater utilities, primarily replacements for generators that will burn out in long duration outages, or at facilities pre-prepared to accept them.¹⁰
- Delivering fuel to operate those generators.
- Resupplying chemicals necessary to sustain minimalist, Black Sky levels of water and wastewater service.
- Addressing additional categories of external support, including NGO and government agency planning for assistance to affected populations (and, potentially, the families of water sector employees) in Black Sky events.



10 Given the complexity of installing emergency generators in facilities that lack advance electrical preparation, emergency generator support available to water utilities in Black Sky hazards will be primarily limited to replacement of burned out generators, or providing generators to facilities already prepared to receive them.

B | Internal versus External Initiatives: Clarifying Lead Responsibilities

Both the water sector and its partners will have crucial roles to carry out the playbook development steps summarized above. In such complex and far-reaching initiatives, effective implementation and coordination of these efforts will be possible only if responsibilities to lead them are clearly identified.

This volume divides resilience initiatives into two separate yet mutually supportive categories. The first constitutes those initiatives that water and wastewater utilities can lead. Many of these “internal” water sector initiatives will also require engagement with regulators, state and local elected leaders, emergency management officials, hospitals and other critical customers, and other resilience stakeholders. Nevertheless, the specialized expertise and leadership responsibilities of water sector personnel will make them essential for recommending realistic but effective requirements that represent the core of a water sector Black Sky playbook, and assessing investment priorities to strengthen their systems’ resilience.

This volume divides resilience initiatives into two categories: Those that will need to be led by the water sector, and those that partner sectors can best lead.

The second category of initiatives constitutes those investments and planning requirements that will require leadership by “external” partners beyond the water sector, with strong input from water and wastewater system owners and operators. Government agencies, in partnership with private contractors, will need to build plans for emergency generator replacement, emergency fuel distribution and treatment chemical resupply in highly disrupted Black Sky environments. Regulatory bodies will also need to examine policy changes that will be essential to water sector Black Sky resilience. Appropriate power restoration priority preplanning from such agencies, as well as from the electricity subsector, will also be essential, as will support plans from mass care NGOs.

Such planning will play a pivotal role in enabling water and wastewater utilities to sustain emergency operations in Black Sky outages. The water sector will need to provide vital insight into their needs for such support, summarized

as evolving “external requirements” for such support in the water sector’s Black Sky playbook. Ultimately, however, external sector partners themselves will have to lead the development of plans and capabilities to meet the water and wastewater sector’s external support needs.



I-45 in Hurricane Rita Evacuation

II | SUMMARY OF FINDINGS AND RECOMMENDATIONS

A “one size fits all” approach to building water sector resilience would be guaranteed to fail. Each water and wastewater utility will have its own unique circumstances, customer needs, system architecture, degree of access to investment funding, and other key characteristics. Based on these system-unique factors, utility leaders will need to determine the level of service they can realistically seek to maintain in a Black Sky outage, and tailor emergency operations plans and investment strategies accordingly. Nevertheless, strengthening preparedness for Black Sky events entails a fundamental set of requirements for planning and emergency operations that are broadly shared across the water sector.

The summary material below reviews the water sector’s most important resilience requirements. More comprehensive lists of internal and external requirements, with detailed background material and context, are provided in the remainder of this volume.

A | Water Sector Requirement: Establish Top Level Goals for Black Sky Resilience

Finding: Unplanned mass evacuations caused by loss of water and wastewater service would be chaotic, unmanageable, and would result in catastrophic loss of life.

Hurricanes have highlighted the challenges of conducting mass evacuations. During Hurricane Rita (2005), for example, as many as 2.5 million residents of Houston and surrounding areas jammed evacuation routes, creating colossal 100-mile-long traffic jams that left many people stranded and prompted warnings from Houston’s mayor that “being on the highway is a deathtrap.”¹¹ Black Sky outages that jeopardize drinking water supplies (especially if impacted by the loss of wastewater service) could prompt vastly larger and more chaotic evacuations.

A key Black Sky resilience goal: Enable the largest number of families to shelter in place throughout the emergency, or for as long as possible.

Black Sky goal: Water and wastewater systems should focus on helping communities avoid the “tipping point,” and enable the largest possible number of customers to remain in their towns and cities for as long as possible. Forestalling mass flight in Black Sky outages must be an overriding priority for the water sector and its partners. The sector should seek to provide sufficient emergency service (along with partner efforts to provide bottled water and other supplemental supplies) to enable customers to remain for as long as possible in their homes, or, as needed, in nearby shelters.

11 Blumenthal, Ralph. “Miles of Traffic as Texans Heed Order to Leave”, New York Times, September 23, 2005, http://www.nytimes.com/2005/09/23/us/nationalspecial/miles-of-traffic-as-texans-heed-order-to-leave.html?_r=0

Finding: Water and wastewater service is essential for national security.

Sustaining at least minimal levels of service in Black Sky outages will be necessary to sustain the ability of defense installations to execute their critical missions. Water sector resilience can also contribute to U.S. security more broadly, by providing a hedge against adversary efforts to create blackouts that threaten the survival of American citizens and disrupt the national economy.

Black Sky goal: Water sector leaders should partner with Federal and state agencies to target resilience initiatives on security-related priorities. Many water utilities already have specialized emergency service plans to help sustain the operations of hospitals and other facilities critical for disaster response. Utilities should not only ramp those plans up to account for Black Sky outages, but also expand their lists of priority customers to include military bases and other security-related installations. DOD and other installation owners should also partner with the water sector and other resilience stakeholders to develop mechanisms to recover the costs for investments in such resilience.

Mass evacuations represent a primary risk of extreme hazards.

During Hurricane Rita, more than two million people jammed evacuation routes from Houston, creating colossal 100-mile-long traffic jams that left many people stranded. Houston's mayor warned, "Being on the highway is a deathtrap."

B | Water Sector and External Partner Requirements: Determine Minimalist, Sustainable Levels of Service to Provide During Black Sky Events, and Develop Emergency Plans to Maintain that Reduced Service

Based on the Top Level goals that the water sector adopts, individual water and wastewater systems can then set the levels of service they will seek to maintain and develop the emergency operations plans they require. They can also prioritize and target infrastructure investments necessary for those reduced levels of service, and clarify rock-bottom, “must meet” requirements for fuel resupply and other partner support missions.



Emergency Supplies Help to Alleviate The Impact of Sudden Outages

Beyond the water sector, external partners (including contractors and government agencies) will also require playbooks to execute these critical support functions, even in the face of massive, cross-sector demand for generators, fuel, and other requirements for sustaining operations in a long-duration outage.

Finding: In Black Sky outages, even the best-prepared water systems will find it increasingly difficult to serve all of their pressure zones with water that fully meets Federal and state drinking water quality standards.

As generators burn out and fuel and chemical resupply operations become more difficult to sustain, few if any water utilities will be able to provide the

levels of service that they are prepared to offer in short duration outages. Indeed, acquiring needed equipment and developing plans to systematically “ratchet down” those service levels will be critical for sustaining operations as fuel and other supplies run short.

Water sector requirement: Water and wastewater systems should identify their “bare minimum” levels of emergency service to sustain. Water service is not an all or nothing proposition. Utilities should develop playbook options to scale down their levels of service by 1) reducing the quality of water provided from drinking-level standards to water that must be boiled or otherwise treated by customers; 2) cutting back on the number of pressure zones that receive such service; 3) ensuring that at least minimal flows of water that cannot be made drinkable are available for fire suppression, sewerage, and other non-drinking water requirements.

Finding: Delivery of water that meets all drinking quality regulations will become especially difficult to sustain as outages continue.

Under the best of circumstances in Black Sky events, the rate with which emergency managers and contractors will be able to supply emergency fuel and treatment chemicals will be limited. Onsite supplies at water utilities will also be limited. Such events will make it essential for utilities to reduce the rate at which they draw down their onsite emergency fuel and supplies of treatment chemicals, and cut back on their resupply requirements as they sustain operations. Limits on the number of emergency generators that utilities will be able to keep in operation are also likely to reduce the ability of many systems to maintain sufficient minimum water pressure in their pipes (typically considered as 20 pounds per square inch) to prevent contaminants from seeping into water supplies.

Water sector playbook option: Pre-plan to scale back on the quality of water delivered, and assist customers to effectively follow pre-arranged emergency water treatment measures. Notifying customers that they must begin using prearranged, pre-communicated emergency home treatment measures for water is a well-understood and frequently utilized means to help meet drinking water needs when emergencies make it impossible for utilities to meet quality standards. Leveraging this approach on a wide scale could provide a crucial

means to help customers shelter in place during Black Sky outages (though it will also be necessary to ensure that emergency planning for the community has ensured wide distribution of equipment and chemicals required for basic, home water treatment methods).

External partner playbooks: Federal and state agencies and other key stakeholders in water quality should partner with utilities to develop emergency waivers of selected regulations, especially those related to chronic (versus acute) threats to public health and treatment requirements for water odor and other aesthetic characteristics.

Finding: Especially for water systems with pressure zones at widely differing elevations, sustaining even reduced quality of service (i.e., water that must be boiled) to all such zones will become problematic.

Sustaining service in high-elevation zones may require an inordinate amount of emergency power for pumps that serve those zones. Moreover, not all zones will be equally important for meeting minimalist Black Sky service goals. It would be highly beneficial if water systems could prioritize the delivery of water to zones that have especially high population density, or that have hospitals, mass care shelters, defense installations, or other critical facilities.



By Reducing Pressure, Water Systems May Preserve Water Availability and Reduce Chemical Consumption

Water sector playbook option: Develop plans and capabilities to identify specific zones for sustained Black Sky service. Utilities should explore whether and how they might be able to provide water on such a prioritized

basis, including an assessment of whether adequate control mechanisms and other systems exist to enable such operations. As these utilities modernize their infrastructure, they should also consider making targeted investments in capabilities that facilitate prioritized service in the future.

External partner playbooks: Based on utility plans for reduced service to selected pressure zones, emergency managers, the American Red Cross and other NGOs, the National Guard, and other and other partners essential for delivering emergency water supplies and for mass care/sheltering should develop targeted playbooks to assist those most at risk of losing water service.

Finding: Even if utilities are unable to provide water in any of their service zones that customers can make drinkable, sustaining the flow of water for non-drinking purposes will be extraordinarily important in Black Sky events.

The 2015-2016 water crisis in Flint, Michigan has highlighted the imperative to maintain adequate water quality.¹² In previous disruptions of water service including Toledo, Ohio (2014) and Charleston, West Virginia (2014), water quality was so compromised that customers could not make it drinkable through filtering, boiling or other means.¹³ Yet, water company officials and state and local leaders quickly reached consensus on the need to sustain the flow of water. In an emergency, such contaminated water is still vital for fire suppression, sewerage, and other non-drinking needs. Sustaining sufficient pressure within pipes can also help prevent them from breaking when pressure is lost, especially for older water distribution systems. Avoiding such breakage is critical; otherwise, repair and replacement of underground pipes will greatly lengthen system restoration times.

12 In 2016, the EPA determined that water in the Flint, MI system could be rendered safe for drinking by most consumers by using approved water filters. United States Environmental Protection Agency, Flint Drinking Water Response, <https://www.epa.gov/flint>.

13 WTOL Staff, "Do Not Drink, Do Not Boil' Water: Crisis Closes out Second Day with Little Information." Wtol.com, August 3, 2014. <http://www.wtol.com/story/26178506/do-not-drink-do-not-boil-water-advisory-issued-for-issued-for-lucas-county-surrounding-area>; Smith, Charlotte F. "Water warning now in 9 counties; emergency supplies on order", Charleston Gazette-Mail, January 9, 2014, <http://www.wvgazette.com/News/Kanawha/201401090067>

Water sector playbook option: Ensure that as a fallback plan, utilities are able to sustain water flows sufficient to meet non-drinking needs. Adopting this option will require far more substantial deliveries of bottled water or other sources of emergency drinking water supplies than if “boil water” quality can be maintained. Nevertheless, even if those deliveries cannot be adequately sustained, and communities need to be at least partially evacuated, the ability of customers to return when power is restored will be vastly accelerated if sufficient pressure is maintained in water systems to extinguish fires and minimize pipeline breakage.



Discolored Water in the Foreground is From Sewage Discharged into the Cuyahoga River by the City Pump Station [Source: National Archives and Records Administration (NARA). 02/14/1955]

External partner playbooks: If utilities are able to sustain water service suitable only for non-drinking requirements (which would still be enormously valuable), requirements for emergency managers and other external partners to ramp up the delivery of bottled water and other emergency water supplies will increase accordingly. These partners should pre-plan to sustain such operations in their Black Sky playbooks for as long as possible on a local, state and regional basis.

Finding: Despite implementing all of these playbook options, some residual risk of “complete failure” will remain.

Some utilities, especially those in arid regions that have no nearby sources of raw water (and which depend on long water transmission systems that may be disrupted by earthquakes or other Black Sky hazards), will face special difficulties in sustaining even minimal water service in long duration outages.

Water sector playbook option: To provide for worst-case preparedness, utilities develop plans to accelerate restoration of service when the power grid returns to operation. Utilities should develop complete failure scenarios in which their systems are depressurized and all service is halted. Based on those scenarios, they should identify the sequence of steps to follow for service restoration, identify support requirements from sector partners, prioritize the restoration of service, and meet other planning requirements to facilitate restart of water and wastewater service.

External partner playbooks: In alignment with such worst-case planning, emergency managers and NGOs responsible for Emergency Support Function #6, “Mass Care, Emergency Assistance, Temporary Housing, and Human Services Annex,”¹⁴ should develop contingency playbooks to provide for temporary relocation and mass care for towns and cities that are at greatest potential risk of total loss of water service in a Black Sky event. The overriding goal for Black Sky events should be to avoid chaotic, unplanned mass migrations. External partner playbooks should help hedge against such events through prudent, targeted pre-planning -- including the designation of regional “water-secure” locations for mass care facilities that can serve evacuees.



NGOs Play a Key Role After a Black Sky Event

14 Federal emergency Management Agency, Emergency Support Function #6, “Mass Care, Emergency Assistance, Temporary Housing, and Human Services Annex,” May, 2003, https://www.fema.gov/media-library-data/20130726-1913-25045-4194/final_esf_6_mass_care_20130501.pdf

C | Water Sector and External Partner Requirements: Prioritized, Targeted Improvements in Infrastructure, Resupply Systems, and Other Prerequisites for Black Sky Operations

Based on the goals and plans for reduced service that water and wastewater systems develop, the next step in building Black Sky resilience will be to make targeted, carefully prioritized investments in infrastructure necessary to implement those plans and sustain the reduced levels of service required for long duration outages. Key areas of investment include:

- Expanded installation of emergency power generators
- Increased onsite storage for generator fuel
- Additional onsite chemical storage; and
- Hardware changes required to support Black Sky service levels and operational plans

Even if utilities make such investments, however, very few are likely to be able to continue emergency operations in a Black Sky outage 30 days or more without replacement of burned-out generators and periodic (limited) delivery of fuel and essential chemicals. External partners for the water sector that are responsible for such resupply operations (including both contractors and government agencies) will need to develop new plans, capabilities, and coordination mechanisms to provide such assistance.

1. Emergency Power Generators

Finding: Some widely used means of strengthening system resilience will fail in Black Sky events.

As utilities assess the emergency power requirements that their playbooks will entail, it will be essential to reassess the viability of their current plans and capabilities to sustain service in Black Sky outages.

For example, a significant number of water and wastewater systems rely on redundant power feeds to provide resilience against blackouts- if one line

goes down, another line can still provide electricity. Multi-state or multi-region outages will render such redundancy strategies useless. Other water systems strengthen their resilience by maintaining connections with other systems that can supply water in an emergency. Again, while helpful in small-scale outages, such interconnections will offer little value in wide area blackouts.

Water sector requirement: Water and wastewater utilities should assume that they will need their own emergency power supplies to function during a Black Sky event, and that multiple feeds and water system interconnections will prove inadequate to help them sustain service. To prioritize investments in emergency power capabilities, utilities should examine which lifts, major pumps, and other system components are most critical for sustaining the bare-minimum service goals they have established (and, based on what is technically feasible for particular pressure zones, adjust their playbook's operational plans accordingly).

Finding: “Just in time” strategies for acquiring emergency power will need thorough revamping and reassessment.

Many water and wastewater systems do not have emergency power generators or fuel tanks in place to sustain emergency operations. Instead, they either have contracts with private companies to install that power infrastructure when a blackout occurs, or will rely on emergency management agencies or the U.S. Army Corps of Engineers (USACE) to do so. Such “just in time” strategies offer a highly cost-effective approach to preparedness against typical power outages. However, in Black Sky events, an enormous number of the more than 160,000 water and wastewater systems in the United States may require standby generators to sustain emergency operations. Water utilities will be competing for access to generators against hundreds (and more likely, many thousands) of other facilities requesting in extremis support, including nursing homes, health care institutions, and other priority needs. They will also be competing for the power connection cables and qualified personnel required to install those generators – assets that will also be in extremely short supply.

Water sector requirement: The water sector should build strategies to address the enormous mismatch that will emerge in Black Sky events between the number of water and wastewater systems requesting just-in time

installation of emergency generators, and available supplies and installation labor. Individual utilities should also reach out to their generator providers to assess the degree to which those providers are at risk of being overwhelmed by demand in Black Sky events.



Water and Wastewater Plants Require Emergency Power To Continue to Function After a Black Sky Event

Finding: Until better data exists on the water sector’s emergency power plans and capabilities, it will be impossible to develop strategies to mitigate shortages in generator supplies.

The starting point to address the wide disparity between potential water sector demands for emergency power generators and available supplies is to assess overall sector requirements. No comprehensive, nationwide assessment currently exists of the number of water and wastewater systems that have emergency generators and fuel storage systems installed on site, versus how many will hope to have them installed if a Black Sky event occurs (including those that do not yet have contracts in place or the power connections necessary to do so).

Water sector requirement: The water sector utilities, associations, and their public sector partners (including the EPA) should conduct surveys to determine how many U.S. water and wastewater systems in the United States 1) have onsite emergency power generators and fuel storage tanks; 2) have contracts in place for generators to be installed when an event occurs; and 3) have neither generators nor contracts for their installation.

Finding: More comprehensive data will also be required on the size of generators required relative to their supply.

Utilities vary enormously in the power output that emergency generators will need to provide for critical lifts, pumps, and other electricity-dependent infrastructure essential for playbook implementation. USACE and private contractors have relatively plentiful stocks of generators that provide power in the tens or low hundreds of kilowatts. However, at higher power levels that can be required by major water and wastewater systems, supplies are much more limited and may fall short in wide-area power outages.

Water sector requirement: Surveys of water sector emergency power plans and capabilities should, over time, gather data on the specific number and size of emergency power generators required for sustaining operations in blackouts (and bare-minimum service levels in Black Sky events).

Finding: As power outages extend beyond the first week of an event, an increasing number of generators will burn out and require replacement.

Water and wastewater utilities should not base their assessments of generator requirements solely on what they will need for emergency operations at the outset of an event. As became apparent in Superstorm Sandy, generator burnout will become a growing problem as they operate beyond a week, and – in a Black Sky event – will greatly contribute to the mismatch between multi-sector demands for generators and available supplies for water and wastewater utilities.

Water sector requirement: Utilities should develop dynamic (versus static) assessments of their generator requirements, and account for likely replacement requirements over time. Water systems that experienced generator failures during Sandy have increased their stockpiles of replacement generators since that event. Other utilities should consider adopting a similar approach.

Finding: Existing mechanisms to prioritize and coordinate delivery of replacement generators are limited.

As a Black Sky outage continues, and generators increasingly burn out in water utilities, wastewater systems, and in facilities and systems within other

key infrastructure sectors, the United States will need far more replacement generators than currently exist in either public or private sector inventories. Improved mechanisms will also be necessary to provide technical support for installation of these generators (or repair of in-place generators), and to prioritize and coordinate delivery of both generators and diesel fuel on a regional and nationwide basis.

External partner requirement: Consider the creation of a National Emergency Power Council (NEPC) or equivalent organization. While USACE, FEMA and other Federal agencies are making significant progress in strengthening U.S. emergency power capabilities, Black Sky events will entail such demanding requirements that consideration should be given to create a new entity to provide for cross-sector, nationwide coordination of emergency power assets and delivery operations. A NEPC initiative would support planning and operations to provide these capabilities by multiple agencies, in all levels of government.¹⁵

2. Onsite storage for generator fuel

Increasing the amount of fuel that water and wastewater systems store to sustain emergency generator operations can have significant benefits for Black Sky resilience. During Sandy, emergency managers and fuel resupply contractors failed to meet utility requests for fuel resupply, and shortfalls in fuel became a prime cause of disruptions in water sector service.

Fuel shortages will pose far greater challenges in Black Sky outages. As with the providers of emergency power generators, fuel suppliers will face overwhelming demands for resupply, and will need to be able to sustain resupply operations for much longer than in any previous event. Black Sky hazards will also disrupt the supply chains and transportation systems on which resupply of diesel fuel and other distillates depend.

Expanded onsite bulk fuel storage capacity will lengthen the time that water and wastewater systems can operate before they require resupply. In fact, targeted initiatives to increase onsite fuel storage, combined with reductions in fuel consumption made possible by cutbacks in water service levels, will

¹⁵ EIS Council. <http://www.eiscouncil.com/Protection/ItemDetails/64>

be essential to help downsize the challenges of cross-sector fuel resupply that private and public sector providers will face in Black Sky events. However, water and wastewater utilities will face a series of obstacles in expanding their storage capacities.



New York Army National Guard Pfc. Weslow Caple, a member of the New York National Guard's Company A, 1-69th Infantry from Staten Island, carries fuel from a refueling vehicle up 13 floors to a 1,000-gallon fuel tank that runs a Manhattan hospitals' emergency generator during Operation Sandy, Oct. 30, 2012. The mission was essential to keeping the hospital supplied with power.

Finding: Multiple spot generators and associated fuel storage facilities provide challenges for fuel storage expansion and resupply.

Many utilities provide for backup power by installing (or contracting to have installed) individual “spot” generators at each of the pumps and other system components that will require electricity in a blackout. This approach can help gradually build out the coverage of the system for emergency operations. However, with every spot generator requiring its own storage tank, significant problems can emerge for expanding fuel storage and limiting the number of points that will require fuel resupply when delivery vehicles will be overtaxed.

Water sector requirement: A number of water utilities are expanding centralized storage facilities to meet the fuel needs of large numbers of generators, and are purchasing or contracting for fuel delivery trucks. These options should be examined sector-wide. As will be discussed in the sections that follow, however, more far-reaching measures by the sector and its partners will also be necessary to deal with the challenges of fuel resupply in Black Sky events.

Finding: Air quality and other regulatory standards create challenges for expanded storage.

A variety of bulk storage options exist for diesel and other distillates, with above-ground fixed roof tanks offering a relatively inexpensive approach to expanded storage.¹⁶ However, for water and wastewater systems to gain permitting approval for expanded storage, they must typically deal with increasingly stringent Federal, state and local air quality standards that limit emissions from storage tanks. The cost and difficulty of going through the permitting process and meeting emissions standards provide an impediment to storage initiatives that would otherwise be helpful for Black Sky resilience.

External partner requirement: Improved air quality is an important goal. However, given the absolutely vital role that the water sector will play in saving lives during a Black Sky event, sector leaders should engage with regulators to explicitly examine the tradeoffs between improved sector resilience (through expanded storage and other infrastructure investments) and environmental regulations. At the Federal level, the EPA is both the Federal sector-specific agency responsible for the water sector and the Federal lead for environmental regulations. Bringing those two portions of the Agency together to conduct such a tradeoff analysis between sector resilience and emissions goals could provide a model for doing so at state and local levels as well.

Finding: Current fuel resupply capabilities and coordination mechanisms will fall drastically short of need in Black Sky events.

While fuel resupply problems put numerous water and wastewater utilities at risk of failure in Superstorm Sandy, Black Sky outages lasting 30- days or more will create far more severe shortfalls, both within the water sector and the many other critical infrastructure assets and facilities that will run short of fuel in such events. Private contractors and government agencies are poorly positioned to sustain deliveries of this scale, especially in the disrupted transportation and

16 See EPA, Emission Factor Documentation for AP-42 Section 7.1: Organic Liquid Storage Tanks Final Report, September 2006. www.epa.gov/ttn/chief/ap42/ch07/bgdocs/b07s01.pdf

communications environments that earthquakes and other Black Sky hazards would create.

External partner requirement: Include fuel resupply as an additional responsibility for the National Emergency Power Council (NEPC) or equivalent organization. Taking an integrated approach to emergency resupply operations, and including generators, installation support, maintenance and fuel delivery responsibilities within a single coordinating body, would facilitate unity of effort across these functional efforts and consistent prioritization between in serving the water sector and other sectors.¹⁷



Fuel shortages will pose significant challenges for the water sector.

3. Chemical storage

As water and wastewater systems develop and evolve their playbook for Black Sky outages, ensuring the availability of chemicals necessary for meeting minimalist service goals will pose a significant challenge. Many water utilities store sufficient stocks of chemicals onsite to sustain operations for a few days until they are resupplied. In outages lasting a month or more, such resupply operations will become increasingly difficult to maintain, especially as power outages cripple transportation systems and chemical supply chains. Increased onsite storage capacity for chemicals can help mitigate risks that such operations will be disrupted. Ultimately, however, the partners that provide for chemical resupply will need much more comprehensive resilience investment and

17 EIS Council. <http://www.eiscouncil.com/Protection/ItemDetails/64>

prioritized plans and capabilities to support the water sector's execution of its Black Sky playbooks.

Finding: Significant opportunities exist for water and wastewater utilities to downsize their chemical storage and resupply requirements for Black Sky operations.

Water systems maintain supplies of chemicals and other “consumable” supplies for water treatment that are primarily used to achieve goals for color, odor, taste, and other characteristics that are mostly aesthetic, rather than necessary for preventing serious illness. Achieving these aesthetic goals will become less urgent in Black Sky outages. Instead, sustaining adequate quantities of water that meet bare minimum health-related requirements -- or can be treated by customers to achieve that level of quality -- will be of paramount importance in such events.

Water sector requirement: As water utilities build playbooks to reduce the quality of water they deliver they should stringently prioritize the chemicals that they need to store. Water and wastewater systems should identify which chemicals such and other consumables are necessary to meet their minimalist service goals. In many systems, for example, calcium hypochlorite or sodium hypochlorite will be critical for achieving such scaled-back water quality goals. Initiatives to expand onsite storage facilities should focus exclusively on meeting these essential needs.

Finding: While improvements in onsite storage have significantly reduced requirements for resupply, few water and wastewater utilities will find it practical or affordable to store the consumables needed to sustain operations for a month or more without resupply.

Strengthening sector-wide resilience against Black Sky outages will require significant improvements in partner plans and capabilities to restock critical treatment supplies.

Water sector requirement: Water sector leaders should reach out to private and public sector partners responsible for chemical resupply to ensure that

their priorities can be met. Water and wastewater systems are best positioned to determine their “rock bottom” requirements that resupply contractors must be able to meet, even in severely disrupted environments. These systems should reach out to emergency managers and contractors to advise them of their minimal requirements, and encourage adequate resilience investment and planning. Outreach will also be required 1) to prioritize sustained chemical resupply operations in long duration outages that affect large numbers of utilities, and 2) to coordinate on developing broader, region-wide strategies to ensure that deliveries will be adequate.

Finding: Ensuring the supply of chemicals on a cross-sector, nationwide basis poses an unresolved challenge for Black Sky preparedness.

The water sector is not alone in facing problems of resupply for chemicals and other “consumables.” The Oil and Natural Gas (ONG) subsector also needs such resupply operations if they are to help sustain the production of fuel for power generation and meet other critical national needs in a Black Sky event. Other sectors will face such needs as well.

External partner requirement: Consider creating a National Emergency Utility Consumables Council (NEUCC) or equivalent organization. A National Emergency Utility Consumables Council would serve as a parallel initiative to NEPC. In Black Sky environments, water and wastewater utilities and other essential service providers can sustain critical, minimal service only if they can be assured of carefully defined, periodic delivery of essential consumables. NEUCC would host planning with relevant government agencies, utility sectors and chemical manufacturing and distribution companies to develop this capability nationwide.¹⁸

4. Other Hardware Changes to support Black Sky Operations

Implementing Black Sky operational changes, from geographic service reductions to water and wastewater treatment changes, will sometimes involve additional valving, facilities changes or other system modifications.

18 EIS Council. <http://www.eiscouncil.com/Protection/ItemDetails/65>



Valves at Water Plant

III | STRUCTURE OF THE VOLUME AND AREAS FOR FURTHER ANALYSIS

The next portion of this volume, Section II, examines the nature of Black Sky challenges for the water sector and the external partners that support its emergency operations. Section II analyzes lessons learned from past disasters, and surveys the significant progress that many water and wastewater utilities are making in their emergency power capabilities. Section II also assesses the severe financial constraints under which the sector operates, and examines the implications for developing practical, affordable strategies to build resilience against Black Sky outages. The section concludes by specifying the key features of Black Sky events that serve as a “design basis” for clarifying the resilience requirements that the water sector and its partners should address in tailored, utility-specific ways.

Section III offers recommendations on how water and wastewater systems can determine the overall goals they should seek to achieve in Black Sky events, including that of avoiding the tipping point into unplanned, mass migrations.

Section IV examines options for water and wastewater utilities to establish realistic, sustainable levels of service to sustain in Black Sky events, and to develop emergency plans and capabilities to sustain reduced service in outages lasting 30 days or more.

Section V examines opportunities for water and wastewater systems to make targeted, prioritized investments in infrastructure to strengthen their resilience against Black Sky events. That section also examines opportunities for external partners of the water sector to strengthen their ability to provide critical support functions to the sector, especially for resupply of generators, fuel and chemicals.

Issues for further analysis

Beyond the topics that provide the principal focus of this volume, three additional lines of analysis will be needed to support Black Sky resilience initiatives by the water sector and its external partners. These issues will be addressed in follow-on projects to be sponsored by the Electric Infrastructure Security (EIS) Council and collaborating public and private sector organizations.

- **Hardening of water/wastewater infrastructure against direct physical damage from Black Sky hazards**

This volume principally focuses on how the loss of electric power caused by Black Sky events can jeopardize water sector operations, and measures to mitigate those disruptive effects. Yet, earthquakes and other Black Sky hazards will not only disrupt the flow of electricity, but also inflict physical damage on water and wastewater system components. Cyberattacks or an EMP event could also disrupt the industrial control systems on which these systems increasingly depend. While this volume focuses on the extended power outages that Black Sky events will create, subsequent studies will explore options for the sector to build resilience against physical damage and other direct effects of Black Sky hazards.

- **Whole Community Planning for incident response and recovery.**

As with other lifeline infrastructure sectors, the water sector is part of a much larger and highly complex system of interdependent infrastructure components, within which water and wastewater utilities both provide

and rely upon services and capabilities that will be vital for saving and sustaining lives in a Black Sky event.

The water sector is also a key component of “whole community” preparedness for such catastrophes. This approach to preparedness, pioneered by the Federal Emergency Management Agency (FEMA) and its Administrator, Craig Fugate, stresses the role that citizens can play in assisting their own survival, and the engagement of “the full capacity of the private and nonprofit sectors, including businesses, faith-based and disability organizations, and the general public, in conjunction with the participation of local, tribal, state, territorial, and Federal governmental partners.”¹⁹



FEMA Community Relations team members Mary Czaplinski and Sandy Hendrix talk with the shelter manager at the American Red Cross shelter at Pleasantville High School. [Source: Liz Roll/FEMA. 10/31/2012]

Whole community planning to help sustain water service in extended blackouts is only beginning in many regions of the United States. This volume will highlight a number of ways in which such planning might go forward through a partnership between the water sector, emergency managers, NGOs and other partners for disaster preparedness. A more detailed analysis of these planning opportunities will be sponsored by EIS Council in follow-on projects and incorporated into the forthcoming NGO playbook.

19 Federal Emergency Management Agency, *A Whole Community Approach to Emergency Management: Principles, Themes, and Pathways for Action* (FDOC 104-008-1), 2011, https://www.fema.gov/media-library-data/20130726-1813-25045-0649/whole_community_dec2011__2_.pdf

- **NGO Support for the Families of Critical Water and Wastewater Personnel**

For Black Sky outages that last many weeks or months, and which may require water and wastewater personnel to not only sustain operations at their own facilities but (through mutual assistance) also do so far from their homes, providing assistance to their families will be an important support mission. Such assistance will be especially vital as the loss of electric power creates cascading infrastructure failures, resulting in severe shortages of food, water, medical care and other basic lifeline services. Given their unique capabilities to provide such services, this is a likely priority for an expanded role for the NGO community, in supporting power restoration from Black Sky events. Follow-on analysis will be conducted of these NGO support opportunities for the water sector as well.

For recovery from Black Sky hazards, the complex interdependencies among lifeline infrastructures mandate preplanned, well-coordinated recovery efforts across those sectors and with contributors to *whole community* preparedness.

2

SECTION TWO

THE NATURE OF BLACK SKY CHALLENGES FOR THE WATER SECTOR



INTRODUCTION

While water and wastewater utilities rely on gravity to help run their systems to the maximum extent possible, electricity powers critical components and functions in water infrastructure. Water systems need power to pump water from underground aquifers, rivers and other sources to treatment plants. Treatment plants require electricity to operate. Once water is treated, electric-powered pumps maintain sufficient pressure in pipes to safely transport and deliver water to customers, and to help sustain sewage flows for sanitation. To treat that sewage, wastewater systems require power for their own pumping and treatment operations.

The number and size of pumping stations (and their associated power requirements) vary with local topography. The more power that a system needs to transport water from lower elevations to higher ones, the greater the demands for pumping and electricity. The overall dependence of the water sector on electric power is striking. The Environmental Protection Agency's *Power Resilience: Guide for Water and Wastewater* emphasizes the risks that this dependence can pose:

An extended power loss can have devastating impacts on drinking water and wastewater utilities and the communities they serve. Inoperable pumps at a drinking water utility can make firefighting difficult and cause local health care facilities and restaurants to close. A loss in pressure can result in contamination entering the drinking water distribution system from surrounding soil and groundwater. For wastewater utilities, losing pumps may lead to direct discharge of untreated sewage to rivers and streams or sewage backup into homes and businesses.¹

Peter Grevatt, Director of the U.S. Environmental Protection Agency's Office of Ground Water and Drinking Water, frames the challenge still more succinctly: "power equals pressure."² Sustaining adequate pressure when the power grid goes down -- potentially for many weeks or even months -- poses a prime challenge for water sector resilience against Black Sky hazards.

1 Environmental Protection Authority (EPA), "Power Resilience: Guide for Water and Wastewater Utilities," December 2015, p. 0-1. <https://www.epa.gov/sites/production/files/2016-03/documents/160212-powerresiliencguide508.pdf>

2 Grevatt, Peter. Presentation to Electric Infrastructure Security (EIS) Council Summit, July 21, 2015, Washington, DC.



Engineers plan repair of Bay Park Waste Water Treatment Plant damaged by the storm surge from Hurricane Sandy.[Source: K.C. Wiley, FEMA. 03/20/2014]

I | THE CONTEXT FOR BUILDING RESILIENCE: PAST DISASTERS AND ONGOING PROGRESS

Long before Sandy struck the United States, hurricanes and other storms had repeatedly highlighted the vulnerability of water and wastewater systems to power outages. The massive blackout that occurred on August 14, 2003, shut down an especially large number of water utilities and disrupted service for millions of Americans. In Cleveland's water system, for example, all four of the utility's major water plants and twelve distribution pumping stations ceased operations, leaving the city with a water crisis that was shared by Detroit and other cities across the blackout zone.³ Hurricane Isabel struck just a few weeks

3 Gilpin, Kenneth. "Blackout Brings Water Shortages to Cleveland and Detroit," *New York Times*, August 15, 2003, <http://www.nytimes.com/2003/08/15/national/15CND-CITIES.html>; Ellermeier, Fred J., et al. "Emergency Power Source Planning for Water and Wastewater," *American Water Works Association*, 2004, p 15.

later and created a 4-day blackout extending from North Carolina to Delaware. Once again, systems with little or no emergency power capabilities failed across the region.⁴ The Derecho Storm of 2012 and other weather-induced blackouts created still further region-wide water and wastewater system disruptions.⁵

A significant number of the water and wastewater utilities hit by these storms responded by installing emergency power generators to sustain operations of major pumping stations and other critical system components.⁶ Many of these utilities also installed onsite fuel storage tanks to operate their generators for at least a day or two, and contracted with private companies to resupply that fuel if the blackout lasted longer. Still other water systems downsized their overall requirements for emergency power, by adopting more energy-efficient pumps and other system components, installing dual drive pumps that can operate using diesel motors or natural gas engines, and adopting other resilience measures.⁷

Pre-Sandy initiatives to prepare for power outages helped utilities sustain operations during Sandy. Most utilities achieved remarkable success in sustaining operations until grid-supplied power was restored, although some major utilities came close to failure.

These storms also prompted water and wastewater utilities to create mechanisms to help each other meet their emergency power needs when disasters struck. Water/Wastewater Agency Response Networks (WARNs) were established to facilitate mutual assistance between utilities, including the sharing of emergency generators, equipment, and personnel to help respond to and recover from emergencies.⁸ WARNs and their members also began advancing a comprehensive approach to emergency preparedness, including plans for

4 Ellermeier, *Emergency Power*, 2004, pp. 15-16.

5 Lau, 2013. *Strengthening Regional Resilience*, NIAC. p. 21.

6 Ellermeier, *Emergency Power*, 2004, pp 15-16.

7 Water Research Foundation and the Electric Power Research Institute, *Electricity Use and Management in the Municipal Water Supply and Wastewater Industries – 4454*, 2013. <http://www.waterrf.org/Pages/Projects.aspx?PID=4454>.

8 AWWA, *Water and wastewater Agency response network*. <http://www.awwa.org/resources-tools/water-knowledge/emergency-preparedness/water-wastewater-agency-response-network.aspx>

emergency operations, staff training programs (especially National Incident Management System training), and initiatives to ensure that critical staff would be available during emergencies.⁹ Federal and state agencies also launched a range of efforts to encourage utilities to strengthen their preparedness for power outages.

These pre-Sandy initiatives helped utilities to sustain operations during the superstorm with far fewer service disruptions than would otherwise have occurred. While electric outages in Sandy contributed to significant spillages of wastewater, most utilities achieved remarkable success in sustaining operations until grid-supplied power was restored to them. The American Water Works Association's (AWWA) Superstorm Sandy After-Action Report (2013) identified a broad range of utility efforts that contributed to this success, including the ability of the WARN members to provide emergency generators to other utilities in need.¹⁰

Nevertheless, as noted in the Introduction to this section, the power outage in Sandy pushed a number of major utilities to brink of failure. In Philadelphia, for example, the water utility had to quickly shut down valves and distribution networks to preserve water pressure when electricity was lost at the Queen Lane Plant. Power was restored when the winds fell below 45 mph, just in time to avoid service disruption during the morning's peak water usage.¹¹ A 2013 report by the National Infrastructure Advisory Council (NIAC), *Regional Resilience*, found that Sandy created similar "near miss" events for utilities across the water sector.¹²

9 Morley, Kevin M. "Evaluating Resilience in the Water Sector: Application of the Utility Resilience Index (URI)," George Mason University, September 2012. pp. 23-30. http://digilib.gmu.edu/xmlui/bitstream/handle/1920/7880/Morley_dissertation_2012.pdf?sequence=1&isAllowed=y

10 AWWA, Superstorm Sandy After-Action Report, 2013, p. 4.

11 NIAC, *Strengthening Regional Resilience*, 2013, p. 105.

12 NIAC, *Strengthening Regional Resilience*, 2013, p. 105.

A | Building on Lessons Learned from Previous Events: Vital but Not Sufficient for Black Sky Resilience

Black Sky outages -- that is, outages lasting a month or more that affect multiple states -- will transform near misses into catastrophic failures, unless the sector greatly strengthens its ability to sustain emergency operations in such events. A broad range of manmade and natural hazards could create long duration, wide area outages. Catastrophic earthquakes in the New Madrid, Cascadia, and other major U.S. fault zones could cause devastating physical damage to the grid that would require months to repair.¹³ Electromagnetic Pulse (EMP) attacks and severe space weather could also cause catastrophic outages, as could terrestrial weather events associated with climate change, combined cyber and kinetic (i.e., physical) attacks, and other threats.

Without expanded preparation, Black Sky outages lasting a month or more will transform near misses into catastrophic failures.



A temporary generator replaces a pump station damaged by Superstorm Sandy floodwaters.

[Source: Rosanna Arias, FEMA. 10/02/2013]

A key starting point to build resilience against such extended blackouts will be to fill the gaps in emergency power capabilities that Sandy highlighted. The

13 See E-PRO Handbook I, pp. 3-73

NIAC and AWWA reports on Sandy identify specific problems that put utilities in jeopardy, including shortfalls in the resupply of diesel fuel for emergency generators. Acting on the recommendations for improvements made by these studies, and by a range of other public and private sector stakeholders in water sector resilience, is essential to prepare for Sandy-level outages in the future. The analysis below examines how these initiatives can be scaled up to meet the more demanding requirements for emergency operations that Black Sky events will create.

Yet, remedying the problems revealed by Sandy will take the water sector only part of the way towards preparedness for outages lasting a month or more. The sections that follow examine how the scope and scale of Black Sky events will create unprecedented requirements for emergency power generators, fuel resupply, and resupply of chemicals to sustain emergency operations. Water and wastewater utilities can then use these requirements to help develop their plans and investment priorities for resilience against Black Sky events.

First, however, strategies to strengthen Black Sky resilience will have to account for a broader problem: that is, the scarcity of resources available for investing in emergency power capabilities and other infrastructure upgrades.



The U.S. Army Corps of Engineers and the National Training Center at Fort Irwin began work on a \$100 million water treatment plant for Fort Irwin and National Training Center Dec. 05. [Source: U.S. Army Corps of Engineers Photo]

II | MEETING THE FISCAL CHALLENGES OF BLACK SKY RESILIENCE

Even after Isabel and other hurricanes revealed glaring shortfalls in the sector's emergency power capabilities, many utilities found it difficult to obtain funding approval for additional standby generators. It will be still more challenging to secure funds for resilience against Black Sky events that have yet to occur. To meet this challenge, sector leaders will need practical, politically viable strategies to build consensus for investments in capabilities and plans for sustained emergency operations.

Water and wastewater utilities face a broad range of funding requirements apart from (and potentially in conflict with) investments in emergency preparedness. Many U.S. cities rely on pipes that are a hundred years old or more. A 2012 report by the AWWA estimates that just to maintain current levels of water service, at least \$1 trillion dollars will be needed to restore existing

water systems as they reach the end of their useful lives and expand them to meet shifting population requirements.¹⁴ Moreover, at least 6 million lead service pipes are in use across the United States. In the aftermath of the Flint, Michigan water crisis, prioritized efforts to replace those pipes could cost an estimated \$300 billion.¹⁵

Still further spending by the water sector will be needed to mitigate the effects of climate change, including persistent drought, rising sea levels, and storm surge risks (which are especially significant for low-lying wastewater systems), and numerous other challenges. According to a 2009 report by The National Association of Clean Water Agencies (NACWA) and the Association of the Metropolitan Water Agencies (AMWA), initial estimates of the cost of these climate mitigation measures through 2050 range from \$488 to \$944 billion.¹⁶

Recommendations to strengthen resilience must account for the brutal fiscal environment confronting the water sector.

These wide-ranging requirements for investment are growing at a time when resources are scarce. Many water utilities face flat or declining revenues due to conservation measures and other reductions in water usage.¹⁷ Total Federal, state and local spending on water and wastewater systems has declined 8% between 2010 and 2014, and shows no sign of reversing.¹⁸ Moreover, a growing

14 AWWA, "Buried No Longer: Confronting America's Water Infrastructure Challenge," 2012, p. 3. <http://www.awwa.org/Portals/0/files/legreg/documents/BuriedNoLonger.pdf>

15 Dolan, Matthew. "U.S. Could Face A \$300B Lead Pipe Overhaul, Agency Warns," Detroit Free Press, 5 Apr. 2016. <http://www.freep.com/story/news/local/michigan/flint-water-crisis/2016/03/04/flint-crisis-could-cost-us-300b-lead-pipe-overhaul-agency-warns/81316860/>

16 National Association of Clean Water Agencies (NACWA) and the Association of the Metropolitan Water Agencies (AMWA), "Confronting Climate Change: An Early Analysis of Water and Wastewater Adaptation Costs," October 2009, p. 4-1, http://www.nacwa.org/index.php?option=com_content&view=article&id=939&catid=8&Itemid=7

17 Johnson Foundation, "Declining Water Sales and Utility Revenues: A framework for Understanding and Adapting," 2012, http://www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/rates/Summit-Summary-and-Declining-Water-Sales-and-Utility-Revenues-2012-12-16.pdf

18 Congressional Budget Office, Public Spending on Transportation and Water Infrastructure, 1956 to 2014, March 2015, <https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/49910-Infrastructure.pdf>.

share of that government spending goes towards operations and maintenance versus capital investments (including funds to upgrade emergency power and broader system resilience).¹⁹ Efforts to build resilience against Black Sky outages will succeed only if they take account of this harsh fiscal landscape and the wide array of sector needs for capital investment.

A | Building Practical Strategies for Progress

The Introduction to this volume identified one way to help strengthen resilience within this difficult fiscal environment: build preparedness for power outages from the bottom-up as well as the top-down. As utilities gradually add to their emergency power capabilities for shorter duration, more frequent outages, they can sustain those investments to gradually build preparedness against more severe events.



Water Plants are a Major Consumer of Electricity

The EPA's 2015 Power Resilience Guide and other documents offer recommendations to the water sector that can help utilities improve their

¹⁹ Capital spending by Federal, state and local governments has declined by an average of 4% per year since 2009. See Eskaf, Shadi. "Four Trends in Government Spending on Water and Wastewater Utilities Since 1956," Environmental Finance Blog, September 9, 2015. <http://efc.web.unc.edu/2015/09/09/four-trends-government-spending-water/>.

capacity for emergency operations.²⁰ However, in order to prioritize and systematically guide such improvements to build Black Sky preparedness, utilities will also need to work from the top-down and develop goals and a playbook for Black Sky operations.

Water and wastewater utilities can also minimize potential conflicts between resilience investments and other priorities by tailoring those investments to meet multiple needs. For example, as utilities launch pipeline replacement projects to reduce leakage and improve system reliability, they can design those projects to also provide more resilient service to hospitals and other customers essential for Black Sky preparedness. Valve replacement projects needed to improve system reliability can also help utilities strengthen their ability to prioritize service to specific pressure zones -- an option for that many utilities may want to consider in planning for sustained emergency operations.²¹ Other system modernization efforts will offer similar opportunities to achieve such “twofers,” as long as utilities first identify the Black Sky priorities that should help guide their modernization efforts.

Pipeline and valve upgrade and replacement projects provide a good opportunity for low cost, synergistic efforts to enhance Black Sky resilience, by designing-in capabilities that increase options for service in long duration power outages.

Measures to increase the energy efficiency of water and wastewater systems can provide additional synergies. In *A Sustainable Future: Energy Management Guidebook for Wastewater and Water Utilities* (January 2008) the EPA recommends that the water sector adopt a systematic approach to reducing energy consumption and energy cost. According to the Guidebook:

Energy represents the largest controllable cost of providing water or wastewater services to the public. Most facilities were designed and built when energy costs were not a major concern. With large pumps, drives, motors, and other equipment operating 24 hours a day, water and wastewater utilities can

20 EPA, Power Resilience Guide, December 2015

21 Black Sky playbook options for prioritizing service to selected pressure zones are examined in Section III of this volume.

be among the largest individual energy users in a community.²²

Investing in more energy-efficient equipment can provide twin benefits for utilities and their customers. During normal operations, the savings created by reduced electricity costs can be used to pay off those investments, cut water and wastewater service charges, or meet other priorities. During blackouts, reductions in energy requirements can help utilities sustain emergency operations. The EPA notes that “When equipment requires less power, generators can run longer while saving fuel.”²³ Limiting requirements for fuel resupply and generator repair/replacement will be especially critical in Black Sky outages.

Improving energy efficiency offers the potential for synergistic benefits: improving resilience for Black Sky scenarios, and reducing operating costs.

More far-reaching investments in water and wastewater power systems may create still greater synergies. Section V of this volume examines how utilities (and especially wastewater plants) can build microgrids to reduce their operating costs, and also facilitate sustained operations in Black Sky outages. As with other efforts to harmonize investments in Black Sky resilience with other utility modernization goals, however, developing a broader understanding of Black Sky goals and requirements will be a prerequisite for progress.

22 Environmental Protection Agency (EPA) and Global Environment and Technology Foundation (GETF), “A Sustainable Future: Energy Management Guidebook for Wastewater and Water Utilities,” January 2008, p. 14. https://www3.epa.gov/npdes/pubs/pretreatment_ensuring_sustainable_future.pdf, See also Water Research Foundation and Electric Power Research Institute, *Electricity Use and Management*, November 2013

23 EPA and GETF, *Sustainable Future*, January 2008.

B | Cost Recovery for Black Sky Investments: Assessing the True Value of Resilient Water Service

Water sector leaders can also help build support for resilience investments by developing a deeper understanding by customers, government officials and sector partners of the value of sustained water and wastewater service in Black Sky events, and help convince them to expand the funds they make available for strengthening water sector resilience.

Federal grant programs are a valuable source of funding for resilience projects but are limited in scale. FEMA's Pre-Disaster Mitigation (PDM) Program provides a key program for resilience investments by the water sector and other infrastructure grant recipients.²⁴ However, for Fiscal Year 2016, only \$90 million is available to help meet the cross-sector needs (and other state and local government mitigation goals) of the entire United States.²⁵ Grants for resilience investments under the EPA's Drinking Water State Revolving Fund and other EPA funding sources are similarly dwarfed by the water sector's trillion-dollar investment needs.²⁶ According to the Drinking Water Infrastructure Needs Survey and Assessment (done with 2007 data and published in 2009), drinking water systems need \$334.8 billion in investments between 2007 and 2037 to install, upgrade, or replace equipment.²⁷ Investments in emergency power for Black Sky days are thus caught in a vise between these infrastructure repair/upgrade requirements, and the intense pressure to keep water prices low.

24 FEMA notes that "Funding for the PDM program is limited; therefore, state and local government officials must make difficult decisions as to the most effective use of grant funds." See FEMA, Pro-Disaster Mitigation Program. https://www.epa.gov/sites/production/files/2015-10/documents/pdm_0.pdf

25 Federal Emergency Management Agency (FEMA), FY-2016 Pre-Disaster Mitigation Grant Program, Fact Sheet. http://www.fema.gov/media-library-data/1455711373912-17d561db31cc299667dc5c60811165d1/FY16_PDM_Fact_Sheet.pdf

26 EPA, "Overview of Federal Disaster Funding Opportunities For Water And Wastewater Utilities, Federal Funding For Water And Wastewater Utilities. October 21, 2015. <https://www.epa.gov/fedfunds/overview-federal-disaster-funding-opportunities-water-and-wastewater-utilities>

27 EPA, What is the Drinking Water Infrastructure Needs Survey and Assessment? <http://water.epa.gov/infrastructure/drinkingwater/dwns/>

The water bills paid by customers provide an additional source of revenue to purchase emergency power generators and meet other preparedness needs. However, utilities will face significant challenges in convincing customers, regulators, and other state and local officials that they should approve rate increases for Black Sky resilience.

One challenge stems from the way water is currently priced in many jurisdictions. As a percentage of household income, the U.S. Environmental Protection Agency reports that U.S. residents pay less for water and wastewater services than most other developed countries.²⁸ Additionally, in the United States, customers pay less for water than for all other utilities. The average four-person household spends about \$50 a month for water, compared with closer to \$150 for electricity and telephone services.²⁹ These low prices for water service reflect not only the historic tendency of U.S. customers to take reliable water service for granted, but also the use of pricing models that do not fully account for required investments in infrastructure. “Full cost pricing” enables utilities to cover the full costs of treatment and delivery to consumers, including expenses related to building, operating, maintaining and replacing water systems – in other words, its true value.³⁰ Utilities and their partners should explore how they can apply this pricing model to support projects that strengthen Black Sky resilience as well as broader modernization requirements.

Water sector leaders should consider inviting regulatory agencies and other government officials to participate in sector Black Sky planning opportunities like the biannual EPRO Water Sector Steering Committee meetings, to give them a solid understanding and foundation for decisions on resilience investment.

28 Duffy, Maureen, The Value of Water, American Water, <http://water.epa.gov/infrastructure/sustain/Water-and-Wastewater-Pricing-Introduction.cfm>

29 Barnett, Cynthia (2014, October 6). “Hey America, It’s Time to Talk About the Price of Water,” Ensia.Com, at <http://ensia.com/features/hey-america-its-time-to-talk-about-the-price-of-water/>

30 Duffy, Maureen, The Value of Water, American Water, http://www.amwater.com/files/ValueofWater_whitepaper_92711.pdf. See also “Charting New Waters: A Call to Action to Address U.S. Freshwater Challenges,” The Johnson Foundation at Wingspread, September 2010. <http://www.johnsonfdn.org/sites/default/files/charting-new-waters/charting-new-waters.pdf>

Water and wastewater system leaders will need to examine how established cost-benefit criteria for assessing infrastructure projects can be best applied to the risks posed by Black Sky events. In comparison with floods, hurricanes and other frequently occurring events, it is difficult to pinpoint the likelihood of a combined cyber/kinetic attack or other Black Sky hazards striking the United States. That difficulty complicates efforts to apply traditional cost-benefit calculations to investments in Black Sky preparedness, especially for manmade threats.

For years, however, the water sector has adopted an “all-hazards” approach to preparedness, and invested in protections against terrorist attacks to poison water supplies and other manmade threats.³¹ A key rationale for doing so: because the consequences of such attacks could be so devastating, prudent investments in strengthening preparedness against them are worth making.

Investing in resilience against Black Sky events falls squarely within this all-hazards approach.

Such events could jeopardize public health and safety on an unprecedented scale. Attacks on the water and wastewater systems that serve critical military bases, defense industrial base assets, and other facilities could also degrade their ability to execute their critical national defense functions.

When regulators and other officials responsible for sector funding decisions assess the value of water and wastewater service, and the societal costs that can be avoided by making targeted resilience investments, they should consider accounting for the sector’s critical role in sustaining lives and supporting U.S. national security in Black Sky events. The Department of Defense and other key beneficiaries of resilient water service should also develop new mechanisms to help utilities recover the costs of making such service possible to Defense installations.

Yet, while increasing the availability of funds for infrastructure projects will be necessary for building Black Sky resilience, those funds will always

31 Morley, K.M. (2010). Advancing the culture of security and preparedness in the water sector. *Journal – American Water Works Association*, 102(6), 34-37; Roberson, J.A. & Morley, K.M. (2006). Water security: Shifting to an all-hazards resiliency approach. *Journal – American Water Works Association*, 98(5), 46-47; Roberson, J.A. & Morley, K.M. (2005). We need to get strategic on water security. *Journal – American Water Works Association*, 97(10), 42, 44.

be in short supply compared to the vast modernization needs that the water sector confronts. Few if any water and wastewater systems in the United States will be able to acquire sufficient standby generators and other infrastructure necessary to sustain normal levels of service in outages lasting a month or more. Instead, utilities will need to develop practical, affordable strategies for Black Sky resilience by determining the bare minimum levels of service that they should seek to sustain in such events, and making the limited, stringently prioritized investments in standby generators, fuel tanks, chemical storage facilities, and other infrastructure necessary to achieve their goals. Water sector partners can then align their plans and capabilities to resupply generators, fuel and chemicals to this critical sector accordingly.

Consideration should also be given to enabling the Federal Government to provide additional assistance to utilities when Black Sky events occur. The NIAC Final Report recommends that DHS and FEMA should examine whether section 406 of the Stafford Act ought to be amended to allow, on a discretionary basis, financial assistance to speed the restoration of privately owned power, water and sewage, telecommunications or other facilities damaged in a disaster where there is a clear public benefit to such action, just as it now allows such contributions to restore publicly-owned or nonprofit-owned facilities. Such assistance could as appropriate, take the form of loans, and in all cases, the recipient would have to reimburse the government for any insurance benefits received. Any such amendment would need to be carefully structured to avoid creating disincentives for critical infrastructure asset insurance, while ensuring that public welfare is adequately protected through timely restoration of critical infrastructure and key resources (CIKR) services. If such clarification is not forthcoming, the NIAC recommends that DHS should explore the possibility of adopting some response measures to benefit critical infrastructure outside of the Stafford Act, relying on the authority of the Homeland Security Act.³²

To help provide the basis for launching these planning and investment initiatives, the sections that follow examine how the infrastructure and resupply requirements for emergency operations in Black Sky events will differ from those in Sandy or any other power outage in U.S. history.

32 NIAC, Final Recommendations, p. 21



The Geostationary Operational Environmental Satellite 13 (GOES-13) captured this natural-color image of Hurricane Sandy at 1:45 p.m. Eastern Daylight Time on October 28, 2012. NASA Earth Observatory image by Robert Simmon with data courtesy of the NASA/NOAA GOES Project Science team.

III | DEFINING CHARACTERISTICS OF BLACK SKY HAZARDS: CLARIFYING THE CHALLENGE

Black Sky outages will differ from Sandy-scale events in two ways, both of which are critical for assessing water sector requirements for emergency power generators and for resupply of fuel and chemicals. The first difference lies in geographic scope. Superstorm Sandy caused power outages across an exceptionally wide area, with an estimated 8,100,000 customers losing power at least briefly over 21 states.³³ ***EMP attacks, coordinated cyber/kinetic attacks,***

33 "After Sandy, Power In N.J. Restored Faster Than Elsewhere Following Previous Major Storms". NJ.com. 16 November 2012. http://www.nj.com/news/index.ssf/2012/11/power_not_so_slow_to_be_restor.html

and other Black Sky hazards may be able to create outages over even broader portions of the United States.

The second (and more significant) defining characteristic of Black Sky outages lies in outage duration. In Sandy, major utilities in the affected region needed two weeks after the Superstorm made landfall to restore electricity service to 95% of their customers. Hurricane Katrina was a more severe event in terms of duration. 23 days after Katrina struck, only 75% of customers had their power restored before Hurricane Rita struck the affected area and created additional outages.

Earthquakes, EMP attacks and other Black Sky hazards can cause outages lasting weeks or even months longer than occurred in Sandy or Katrina, even if electric utilities sustain and expand the wide range of resilience investments that they currently have underway or plan to implement.³⁴ For the purposes of this study, Black Sky outages are defined as those in which 90% of customers in a multi-state region lose power for at least 30 days -- that is, a month or more.³⁵

Taken together, the extended geographic scope and duration of Black Sky outages will create unprecedented requirements for emergency preparedness in the water sector. These requirements include those for 1) emergency power generators; 2) fuel storage and resupply; 3) maintenance; and 4) chemical storage and resupply.

For the purposes of this study, Black Sky outages are defined as those in which 90% of customers in a multi-state region lose power for at least 30 days.

34 Given the scale of Black Sky outages and the cross-sector interdependencies that could lengthen event duration, such outages – without new multi-sector resilience investments – would be far longer, and recovery partial, at best. See, for example, the Congressional EMP Commission Final Report, and EPRO Handbook Volume 1.

35 Stockton, Paul. Resilience for Black Sky Days: Supplementing Reliability Metrics for Extraordinary and Hazardous Events, February 2014, p. 7. http://www.naruc.org/grants/Documents/Resilience_for_Black_Sky_Days_Stockton_Sonecon_FINAL_ONLINE_Feb5.pdf

3

SECTION THREE

TOP-LEVEL GOALS IN BLACK SKY OPERATIONS FOR THE WATER SECTOR AND ITS PARTNERS



Local residents impacted by Hurricane Sandy get water and meals ready to eat from National Guard troops at a Federal Emergency Management Agency (FEMA) Point of Distribution. [Source: FEMA Photo by Jocelyn Augustino]

INTRODUCTION

Given the extraordinary challenges associated with the multi-region, long duration power outages that characterize Black Sky hazards, few if any water and wastewater systems will be able to sustain normal levels of service to all their customers until power is restored. Indeed, many of these systems will be at risk of suffering a complete failure of service in such events, unless the water sector and its external partners develop and implement Black Sky playbooks to guide their emergency plans, capabilities and infrastructure investments to sustain minimalist service levels in outages lasting 30 days or more.

The water sector should consider setting a decisionable range of minimal service levels for Black Sky scenarios, as a basis for utility resilience standards and investments, and interface requirements.

This section focuses on the first step for creating such playbooks: specifying the fundamental, top-level goals that the water sector and its partners should seek to achieve in Black Sky outages. The water sector and its partners should consider adopting two key objectives: 1) that of minimizing unplanned, mass migrations by enabling as many water customers as possible to shelter in place; and 2) sustaining service to facilities and functions most critical to the U.S. economy and national security, especially given the risk that adversaries may attempt to disrupt water service in an intense crisis to disrupt key military base operations and create panic amongst U.S. citizens.



Providing an adequate supply of drinkable water is vital to keeping Americans in their homes.

I | AVOIDING THE “TIPPING POINT”: KEEPING AMERICANS IN THEIR HOMES FOR AS LONG AS POSSIBLE

Unless the water sector and its partners build preparedness against Black Sky hazards, the multi-region, long duration outages created by these hazards could deprive many millions of American of drinking water and essential sanitary services. Such conditions would quickly prompt chaotic, mass flight from communities unable to sustain the lives of their citizens. A fundamental goal for the water sector and its partners should be to avoid this tipping point, and maximize the number of citizens who can remain in their homes or in nearby shelters for as long as possible in Black Sky events.

The analysis that follows begins by examining why mass evacuations represent such a poor option for saving lives in catastrophes. This analysis then examines why providing bottled water and other emergency drinking water services cannot be scaled up to meet Black Sky requirements for sheltering in

place (though delivering emergency water supplies can supplement other life sustaining efforts). Instead, the only way that the water sector and its partners can help prevent unplanned mass migrations is to sustain reduced, minimalist levels of water and wastewater service until power is restored.

A | Lessons from Past Events: Why Averting Unplanned Mass Migration is So Critical

Hurricanes and other natural hazards have highlighted the logistical and operational management problems inherent in evacuating large populations during a disaster. Governors (who in many states have primary responsibility for issuing evacuation orders) are especially aware of the pitfalls associated with mass movement. The Governors Guide to Mass Evacuation (2014) warns that “poor handling of a large evacuation has the potential to be a disaster unto itself and risks becoming the unwanted legacy of a governor’s administration.”¹



In Some Cases Evacuation is Necessary, But the Goal Following a Black Sky Event is to Maintain Shelter in Place.

The inept evacuations in Hurricanes Katrina and Rita spurred efforts by emergency managers, NGOs and their partners to improve preparedness for

1 National Governors Association, Governors Guide to Mass Evacuation, 2014, pp. 2-4. <http://www.nga.org/files/live/sites/NGA/files/pdf/GovGuideMassEvacuation.pdf>

such operations.² The DHS/FEMA Mass Evacuation Incident Annex (2008) marked an especially important step forward. The Annex provides a concept of operations for Federal-level mass evacuation support of state, local and tribal authorities, and clarifies Federal Department roles and responsibilities to execute such operations.³ A growing number of cities and states are also refining their evacuation plans, especially in states such as Florida where hurricanes and other natural disasters frequently strike.⁴



New York Army National Guard soldiers assist residents impacted by Hurricane Sandy at Long Beach City Hall, N.J. for evacuation to shelters [Source: U.S. Army photo by Col. Richard Goldenberg, New York National Guard]

However, evacuation problems in Hurricane Irene in 2011 and Hurricane Sandy in 2012 indicate that even the most basic prerequisites for such operations are lacking in many regions.⁵ Self-evacuation by citizens fleeing an event are especially problematic. For example, the minor East Coast earthquake in August 2014 caused the Washington, D.C. workforce to flee en masse, overwhelming

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- 2 Wagman, David. "Exit Strategy: Evacuation lessons learned from Hurricanes Katrina and Rita," *Homeland 1*, November 15, 2005. <http://www.homeland1.com/evacuation/articles/390294-Exit-Strategy-Evacuation-lessons-learned-from-Hurricanes-Katrina-and-Rita/>
 - 3 FEMA, Mass Evacuation Incident Annex, June 2008, https://www.fema.gov/pdf/emergency/nrf/nrf_massevacuationincidentannex.pdf. See also FEMA, Evacuating Yourself and Your Family, February 12, 2012, <http://www.ready.gov/evacuating-yourself-and-your-family>
 - 4 State of Florida, Mass Migration Annex, February 2012, <http://www.floridadisaster.org/documents/CEMP/2012/MASS%20MIGRATION%20ANNEX.pdf>; State of Texas, Mass Care Annex, March 12, 2015, <https://www.txdps.state.tx.us/dem/documents/planState/annexc.pdf>.
 - 5 National Governors Association, Governors Guide to Mass Evacuation, 2014, pp. 2-4. <http://www.nga.org/files/live/sites/NGA/files/pdf/GovGuideMassEvacuation.pdf>

public transit, highways, and bridges, and other transportation nodes and rendering city plans for such evacuations moot.⁶

FEMA Administrator Craig Fugate emphasizes that that wide-area, long duration power outages could create vastly greater (and near-insurmountable) evacuation challenges. Fugate warns that in a cyberattack on the grid, “large regions of the United States could go dark.” A 7.7 New Madrid earthquake, an EMP attack or other Black Sky hazards could cause equivalent blackouts.

Fugate notes that in such an outage loss of water service would create especially immediate threats to saving and sustaining life in the crisis. However, he dismisses the option of evacuating a city such as New York City to save its population. With so many people to evacuate, [you] “can’t move ‘em fast enough.”⁷ Evacuating such a large city would be even more difficult in a Black Sky event due to the disruption that a Black Sky event would inflict on road, rail and air transportation. Those disruptions would stem from the loss of power for gas pumps and other supporting infrastructure, as well as (as in an earthquake or EMP event) direct damage to transportation networks. Moreover, while Fugate rejects the option of evacuating even a single metro area -- New York City -- as impractical, multiple cities across entire regions of the United States could be in similar need of evacuation in a Black Sky event.

Even if that many people could be moved or self-evacuated, where would they go? Under FEMA’s National Mass Care Strategy, the American Red Cross and the Federal Emergency Management Agency (FEMA) will co-lead the mass care portion of Emergency Support Function #6 (ESF-6) of the National Response Framework. The American Red Cross and other Non-Governmental Organizations (NGOs) are ramping up plans and capabilities to shelter citizens more effectively than was done in Katrina and Rita.

Evacuating a major city like New York to save its population after a water system failure is not a credible option.

With so many people to evacuate, [you] “can’t move ‘em fast enough.”

Craig Fugate, Administrator of FEMA

6 National Governors Association, *Governors Guide to Mass Evacuation*, 2014, p. 4. <http://www.nga.org/files/live/sites/NGA/files/pdf/GovGuideMassEvacuation.pdf>

7 Ted Koppel, “Lights Out,” Random House, 2015, Large Print Edition, p. 142

However, the sheltering requirements for Katrina-scale hurricanes would be dwarfed by those in a Black Sky event. There is no practical, affordable way to build sufficient (and sufficiently survivable) mass care facilities for the tens of millions of citizens who would lose water and wastewater service if Black Sky hazard were to strike today. Instead, FEMA Administrator Fugate recommends a better preparedness strategy: “Keep the water on.” To achieve that goal, he emphasizes that:

“We need to have enough power to pump, treat, and distribute water through the system. You have to keep the water system up, and you’ve got to then focus on the water treatment system. Backing up sewage is just about as bad. Those two pieces will buy you enough time to look at what your alternatives are. Basically, people have to drink water, they have to eat, that waste has to go somewhere, they need medical care, they need a safe environment.”⁸

Even if very rapid mass migration were feasible, where would people go?

National strategies for mass care are designed to address relatively local disasters, not multi-region breakdowns of most or all lifeline infrastructures.

Keeping the water on in outages lasting 30 days or more will require most water systems to drastically reduce the level of service they provide. As Section IV will examine in greater detail, utilities have a range of options to set minimalist, sustainable service levels appropriate for their own system architecture and circumstances. Utilities can also build on their existing emergency operations plans by adopting a variety of more stringent curtailment options to reduce emergency power requirements and their needs for fuel/chemical resupply. For example, some water systems may choose to curtail service to high elevation, low population density pressure zones.

Shelters can play an important supplementary role in meeting the needs of customers affected by these service reductions. NGOs and emergency managers should collaborate with water utilities to pre-plan for the resulting community sheltering requirements. They will also need to ensure that the shelters themselves are supported with prioritized water and wastewater

8 Kopple, op cit.

service (and other critical services). Section IV will address these resilience requirements as well.

On a broader state and regional basis, NGOs and emergency managers should also continue to improve mass sheltering capabilities to meet the needs of citizens whose water and wastewater systems cease functioning in a Black Sky event. Again, however, the top-level goal of the water sector and its partners should be to minimize the number of customers who will be forced to leave their communities, and create a more manageable scale of requirements for evacuation and sheltering in wide area, long duration outages.

B | Providing Bottled Water and Other Emergency Drinking Water Services: Valuable but Not Sufficient to Enable Sheltering in Place during Black Sky Outages

Deliveries of bottled water and other temporary drinking water supplies in an emergency offer a crucial, frequently employed means to enable families to shelter in place when water service is disrupted in short duration events. Emergency water delivery operations can also be invaluable in longer duration events such as the 2015-6 water crisis in Flint, Michigan, when an extended disruption is limited to a small geographic area and emergency water logistics operations can be targeted accordingly.

Black Sky events would create a vastly greater challenge for emergency water delivery plans and capabilities than any disaster in U.S. history. In fact, strategies for relying on emergency water represent a classic example of resilience options that are valuable for normal crises, but that cannot be scaled up for catastrophic events; they will inevitably fall short and serve no more than as a backup for other Black Sky playbook initiatives.

1. Current Approaches to Emergency Water Services

Statutory requirements have helped drive significant progress by water utilities and their Federal and state partners in planning to provide emergency water supplies when disasters strike. The Safe Drinking Water Act (SDWA) was amended by the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Bioterrorism Act) to address emergency water supplies. The Bioterrorism Act directs EPA to conduct “a review of the methods and means by which alternative supplies of drinking water could be provided in the event of destruction, impairment or contamination of public water systems” (42 U.S.C. 300i-4 (b)).⁹



An American Red Cross volunteer provides water for residents displaced by North Dakota Flooding [Source: Patsy Lynch/FEMA. 07/05/2011]

State primacy agencies and community water systems also have significant responsibilities for emergency water. In particular, 42 U.S.C. 300i-2, provides that “Each community water system serving a population greater than 3,300 shall prepare” an emergency response plan that includes actions, procedures, and identification of equipment which can obviate or significantly lessen the impact of terrorist attacks or other intentional actions on the public health and the safety and supply of drinking water provided to communities and

9 Executive Order 1265 (November 18, 1988,) also requires the EPA Administrator to take lead responsibility to “develop, in coordination with the Secretary of Defense, plans to assure the provision of potable water supplies to meet community needs under national security emergency conditions, including claimancy for materials and equipment for public water systems.” EPA, Planning for Emergency Drinking Water Supply, June 2010, p. 2, https://www.epa.gov/sites/production/files/2015-03/documents/planning_for_an_emergency_drinking_water_supply.pdf

individuals.¹⁰ Increasingly, water systems have moved beyond this initial focus on terrorism to take an “all hazards” approach to build emergency drinking water plans.¹¹

A growing number of guides support this utility planning, and provide a starting point to assess Black Sky options to meet emergency drinking water requirements. The most comprehensive and useful guide for providing such emergency service is the EPA report on Planning for Emergency Drinking Water Supply (2011). The report recommends that for planning purposes, emergency managers and their partners be prepared to provide one gallon per person per day for drinking as well as food preparation and personal hygiene. [Water required for fire suppression or other non-drinking water services vital for disaster response operations is not included in this estimate].¹²

The EPA study identifies a broad range of practical, proven ways to meet these emergency drinking water needs, from large-scale bottled water deliveries to National Guard reverse osmosis purification units that can take raw water from rivers and other sources and make it potable (i.e., drinkable). The study also proposes much-needed improvements in planning and exercising for water emergencies, and in family preparedness to have adequate water on hand for the first few days of an event.¹³ Utilities, emergency managers, and other partners should continue to advance these initiatives on a nationwide basis.

Absent minimal water system service to major population centers, the geographic scope of Black Sky events would overwhelm traditional emergency water approaches.

However, some recommendations that are valuable for water sector resilience against short-duration outages will be of little value in Black Sky events. The development of emergency interconnections to adjoining systems provides a case in point. Emergency interconnections between utilities already provide

10 EPA (2010), p.3.

11 Preparedness, Emergency Response, and Recovery CIPA Working Group, All Hazards Consequence Management Planning for the Water Sector, November 2009, http://www.wef.org/uploadedFiles/Access_Water_Knowledge/Water_Security/Water_Security_PDFs/All-HazardCMPNovember2009FINAL.pdf

12 EPA, p. 7.

13 EPA, pp. 30-3.

resilience backup source of water for systems in New York, New Jersey, and the San Francisco Bay area.¹⁴ However, interconnections will be of no value for Black Sky outages. In a multi-state blackout lasting a month or more, all adjacent water systems within the outage area will be affected, and will not be able to assist each other unless their emergency power capabilities are able to provide for sustained operations in such severe events.

Other typical emergency drinking water strategies offer greater potential promise for long duration power outages. However, as Administrator Fugate has warned, not all emergency plans and capabilities can be effectively scaled up for catastrophic events. The following section examines specific challenges in leveraging traditional approaches to emergency water service for Black Sky events.

2. Scaling Up for Black Sky Events: Bottled Water and Mobile Treatment Units

The EPA notes that the primary approach to providing post-disaster water supplies in the United States is to bring bottled water into the affected area.¹⁵ In the 2014 water crises in Toledo, Ohio (2014),¹⁶ Flint, Michigan, and other events, state, local and federal emergency managers have been able to collaborate effectively with a range of private and public sector partners (most notably, state National Guard organizations) to meet human hydration needs. However, these events were much smaller in terms of geographic scope and affected population than would be created by Black Sky hazards.

To scale up emergency water service for more severe events, the U.S. Army Corps of Engineers (USACE) would play a key role. USACE is responsible for large-scale deliveries of emergency water under Emergency Support Function No. 3, Public Works and Engineering.¹⁷ The Corps' capabilities are impressive. USACE has been preparing to provide emergency water service for up to 1

14 EPA (2011), p.11.

15 EPA (2010), p. 22.

16 Henry, Blade. July EPA notes found Toledo's water crisis plan lacking, The Blade, August 9, 2014. <http://www.toledoblade.com/local/2014/08/09/EPA-s-July-notes-said-city-s-water-crisis-plan-is-lacking.html#vbiBLdqG2FmXqdw.99>

17 FEMA, Emergency Support Function #3, January 2008. <https://www.fema.gov/pdf/emergency/nrf/nrf-esf-03.pdf>

million people per day for a total of seven days.¹⁸ More recently, the Defense Logistics Agency (DLA), the U.S. Armed Services, and other Department of Defense components have also been greatly strengthening their capacity to provide emergency drinking water, through emergency water deliveries and by mobile assets for onsite water treatment in contingency operations in the United States and abroad.¹⁹

However, Black Sky events will quickly exceed the capacity of even these Federal capabilities.

A recent series of water sector and EPA-sponsored exercises and workshops examined the emergency water requirements that severe storms and other catastrophes would create. In 2010, one such seminar examined the potential sector impact of storm-induced flooding in the Sacramento-San Joaquin Delta, which provides drinking water to approximately 25 million people in urban southern California and the San

In Black Sky outages, emergency water deliveries alone will never approach the levels needed to enable enough Americans to shelter in place and avert reduce the scale and catastrophic consequences of unplanned mass migrations

Francisco Bay Area.²⁰ The seminars found that due to the flooding of electric substations and the destruction of levees and other water infrastructure caused by such a storm, California cities would need to be supplied with massive amounts of emergency drinking water until the infrastructure was repaired. Trucking-in the necessary amount of bottled water would require the Army Corps of Engineers and other suppliers to deliver 4,000 tractor trailer loads of bottled water per day for over 6 months.²¹ Doing so would be entirely impractical and unsustainable.

Other Black Sky hazards could create still greater requirements for emergency water service. The risk of a New Madrid earthquake provides a

18 Senior Leadership Seminar, p. 26.

19 For compressive overview of U.S DOD emergency water capabilities and planning, see Joint Publication 4-03, Joint Bulk Petroleum and Water Doctrine, 11 January 2016, http://www.dtic.mil/doctrine/new_pubs/jp4_03.pdf

20 Senior Leader Seminar, "Sacramento Valley & Bay Delta Flood Scenario," pp-14-28.

21 Ibid.

case in point. The New Madrid Fault Zone runs near the Mississippi River from Iowa and Illinois to Mississippi and Alabama. A recurrence of the 7.7 earthquake that occurred in 1812 (which could strike at any moment) would cause massive damage to grid, water, and wastewater infrastructure. Studies conducted by the Central United State Earthquake Consortium (CUSEC) in June 2014 found that large portions of an eight state region would lose electric power for many months, due to shaking-induced physical damage to power generation, transmission, and distribution systems (especially high voltage transformers, and substations). An estimated 400,000 breaks and leaks in natural gas lines would also disrupt the flow of fuel to gas-generating plants that survived, further delaying the restoration of electric power to water systems and other critical infrastructure.²²

To meet the resulting needs for emergency water service, mobile water treatment units would provide an important alternative to bottled water delivery in cities such as Chicago, which have access to lakes and other sources of raw water. However, the largest units currently in production can provide only 1 million gallons per day.²³ These treatment units are in very short supply and would need to be paired with extensive distribution systems.²⁴ Some water utilities also have small emergency treatment units, which typically have a maximum production rate of between 10-30 thousand gallons per day. That could be very helpful for meeting emergency water needs for a localized event in a small community. For Black Sky events, they would provide (almost literally) a drop in the bucket.

The New Madrid scenario highlights an additional problem for relying exclusively on emergency water deliveries: the disruption of ground transportation networks on which USACE and other providers would rely.

22 New Madrid Seismic Zone Catastrophic Earthquake Response Planning Project. Impact of New Madrid Seismic Zone Earthquakes on the Central USA, Vol. 1, pp.vi, 46-89, at <https://www.ideals.illinois.edu/bitstream/handle/2142/14810/ImpactofNewMadridSeismicZoneEarthquakeso%20theCentral%20USAVol1.pdf?sequence=3>

23 Estimate based on the EPA finding that a person must consume 2.5 quarts a day (0.625 gallons) of water from all sources. United States Environmental Protection Agency, Water Facts, June 2004. http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_waterfacts_web.pdf

24 E-mail communication to the author by Kevin Morely, Security & Preparedness Program Manager, American Water Works Association, October 19, 2015

While indirect effects of any Black Sky hazard would cause serious disruptions of ground transportation, a major earthquake would have a uniquely severe impact. Thousands of roads, bridges, railroad tracks, and other infrastructure components would be damaged or destroyed. Gas stations would lose power for their pumps and would be difficult to resupply. As deliveries of drinking water falter, highways would be clogged with vehicles carrying citizens to areas where they hoped water would be available.

Finally, even if deliveries of bottled water and other emergency water supplies could meet hydration requirements in a wide-area, long duration outage, the requirement would still exist to provide for some basic level of sanitary service. The 2011 earthquake in Christchurch, New Zealand, highlighted the critical public health and disease prevention role of sustained sewerage operations in catastrophic events, and the difficulties of relying on chemical toilets and other backup options if sewerage halts.²⁵ These difficulties would be still greater in the wide area, long duration outages created by Black Sky hazards. Sustaining minimalist water flows required for sanitary service, especially in dense urban environments, will be crucial for averting mass migration even if emergency drinking water requirements are successfully met.

3. Emergency Water Deliveries as a Supporting Component of the Black Sky Playbook

Despite these limitations, public and private sector emergency water providers should continue to expand their plans and capabilities to meet hydration needs in two categories of operations. First, as in the Flint water crisis, emergency water deliveries can provide an essential service in water system disruptions of narrow geographic scope or limited duration. As emergency water providers scale up their ability to operate, their value for larger-scale events will grow accordingly.

While emergency water delivery operations alone can never meet the hydration needs that Black Sky events will create, they could provide a key supplement for service reduction strategies in the water sector's playbook.

25 Ian McLean, et al, Review of the Civil Defense Emergency Management Response to the 22 February Christchurch Earthquake, 29 June 2012, pp. 97-105, <http://www.civildefence.govt.nz/assets/Uploads/publications/Review-CDEM-Response-22-February-Christchurch-Earthquake.pdf>

Second, even if their capabilities will never be adequate to meet all water needs in a Black Sky event, emergency drinking water suppliers can play an important supplementary role. Just as community shelters can help meet the needs of citizens affected by reductions in water service, so too can emergency water providers help those citizens shelter in the face of service curtailments. In particular, expanded emergency water capabilities will be vital to help limit evacuations from the lower population density zones and other areas that will likely face curtailed water service in a Black Sky event.



This tornado shelter for 400 campers at the Iowa State Fairgrounds outside Des Moines, IA. When not in use as an emergency shelter, the large multi-purpose building is used by both the fairground sta and campers for restrooms, showers, a laundry area, o ces, and meeting space. [Source: FEMA. 07/24/2004]

Government agencies, NGOs and the private sector can partner with the water sector to pre-plan for such supplementary services as part of their Black Sky playbooks. As water and wastewater utilities set reduced service goals and refine their plans to curtail their operations until the electric subsector can restore power, utilities will be able to share those plans with emergency water providers. In turn, those providers (including USACE and DLA) will be able to account for those anticipated service reductions in their own playbooks. Section IV will further examine these collaborative playbook opportunities.

Emergency water providers will also need to prepare for an additional challenge: that of a significant number of water system failures. The harsh fiscal reality is that not all systems will be equally willing and able to make the investments in generators and other infrastructure necessary to sustain their operations for 30 days or more. Sector partners who supply generators, fuel and chemicals will also find it enormously difficult to sustain all 160,000+ systems in the United States over such long periods, especially given the disruptions that

Black Sky hazards may inflict on their supply chains and distribution networks. If the water sector is to achieve a top-level goal of minimizing unplanned mass migrations, the sector's playbook must account for the uneven progress that water and wastewater systems Sector-Specific Plan (2015), issued by the EPA and the Department of Homeland Security (DHS), provides a valuable foundation for maximizing the benefits of Black Sky resilience initiatives.²⁶ The plan notes that from a nationwide perspective, the water and wastewater systems of the United States share a common structural characteristic: a relatively small number of systems each serve exceptionally large numbers of customers.



Steam Generation Requires Considerable Quantity of Water

4. Water Systems

Figure 1 depicts the distribution of U.S. water systems in terms of the size of the populations they serve. There are approximately 153,000 Public Water Systems (PWS) in the United States.²⁷ Of these, approximately 51,000 are Community Water Systems (CWS) that serve people year-round in their residences, versus systems at campgrounds and other locations that serve

26 Department of Homeland Security (DHS) and Environmental Protection Agency (EPA), Water and Wastewater Systems Sector-Specific Plan, 2015, <https://www.dhs.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf>. Additional guidance useful for shaping the water sector's Black Sky playbook is provided in Critical Infrastructure Partnership Advisory Council (CIPAC) Water Sector Strategic Priorities Working Group, Roadmap to a Secure and Resilient Water Sector, May 2013, <http://www.asdwa.org/document/docWindow.cfm?fuseaction=document.viewDocument&documentid=2516&documentFormatId=3187>

27 Public Water Systems are defined as those that provide water for human consumption through pipes or other constructed conveyances to at least 15 service connections, or serve an average of at least 25 people for at least 60 days a year. Sector Specific Plan (2015), p. 3.

transient and non-transient customers.²⁸

The disparity between these systems will be crucial factor for achieving the top-level goal of maximizing the number of U.S. citizens who can shelter in place during a Black Sky event. The vast majority of CWS -- 83 percent -- are categorized as small or very small systems. They serve only 8 percent of all U.S. citizens who get their water from a CWS.²⁹

At the other end of the spectrum, only 17 percent of CWS are categorized as very large, large, or medium systems. Yet, this relatively small number of systems serves 92 percent of the U.S. population that gets water from a CWS.

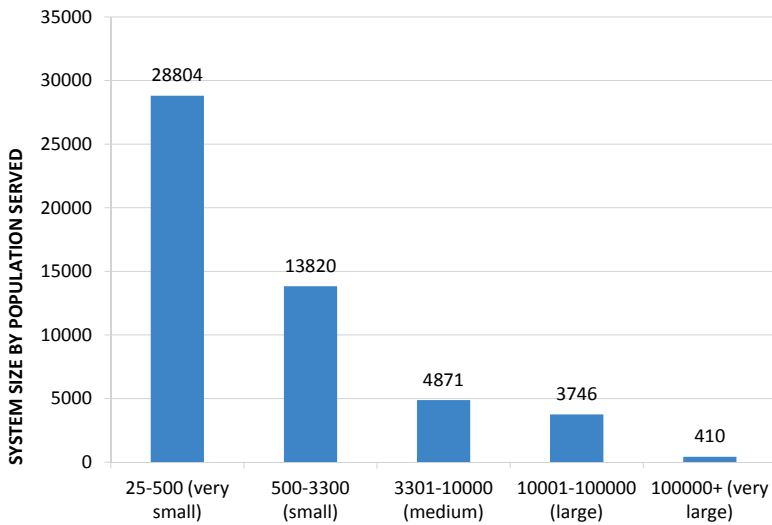


Figure 1 | Number of Community Water Systems and System Size³⁰

28 Categories other than CWS: 1) Non-Transient Non-Community Water Systems (NTNCWS), which are public water systems (PWS) that are not a community water system but still regularly serves at least 25 of the same people more than six months of the year (e.g., schools, factories, office buildings, and hospitals that have their own water systems); and 2) Transient Non-Community Water System (TNCWS)—a PWS that serves transient consumers. Transient consumers represent individuals who have the opportunity to consume water from a water system but who do not fit the definition of a residential or regular consumer. Examples include gas stations or campgrounds where people do not remain for long periods. There are more than 51,000 CWSs, more than 18,000 NTNCWSs, and approximately 84,000 TNCWSs in the United States. See Sector Specific Plan (2015), p. 3.

29 Sector Specific Plan (2015), p. 4.

30 Department of Homeland Security (DHS) and Environmental Protection Agency (EPA), Water and Wastewater Systems Sector-Specific Plan, 2015, <https://www.dhs.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf>

The 410 very large systems (those serving 100,000 or more customers) offer an especially leveraged opportunity to maximize the impact of Black Sky preparedness initiatives. If the CWS in major urban areas can sustain reduced levels of service to enable most of their customers to shelter in place, the benefits for averting unplanned mass migrations would be enormous. Focusing on the small number of very large systems also bounds the planning and logistics problems that water sector partners will confront. For government agencies and private contractors responsible for supplying generators, fuel and chemicals in Black Sky events, being able to target their operations on a few hundred of the largest CWS (versus the more than 40,000 small and very small systems) would significantly narrow their challenge.

Yet, building the Black Sky resilience of such smaller systems would also have enormous benefits. For small and very small systems that have ready access to rivers, lakes and other surface sources of “raw water,” even limited investments in emergency power capabilities and expanded storage for fuel and chemicals could enable these systems to sustain reduced levels of service for significant periods. Over time, such initiatives could help the water sector meet its top level goals over increasingly broader regions of the United States.

Strategies to maximize sheltering in place will also have to account for the surprises (and requirements for operational flexibility) that Black Sky hazards will entail. For example, Los Angeles and many other cities lie hundreds of miles away from their primary sources of water, and depend on electric-powered pumps and other equipment to convey that raw water to city treatment plants. Los Angeles is fortifying the Los Angeles Aqueduct against catastrophic earthquakes, developing new local water sources, and taking other measures to reduce the risk of interruption to the city’s water supply. Nevertheless, when sector leaders and emergency managers make real-time decisions on which systems can be

A key finding of this analysis: The need for definition and implementation of a coordination team to lead whole community support during Black Sky recovery.

Prioritized support plans will need to respond quickly as events unfold.

This highlights the critical need to plan and train for real-time, wide coordination of the overall recovery process across the vast number of cross-sector interdependencies.

effectively sustained during a Black Sky event, Mother Nature (or adversaries launching coordinated attacks on energy and water infrastructure) will also get a vote. Plans for prioritizing support for utility sustainment will need to be adjusted accordingly as events unfold. Indeed, this is only one example of the critical need to plan and train for real-time, wide-area coordination of the overall recovery process across the vast number of cross-sector interdependencies. Definition and implementation of a coordination process that would meet this need is a key finding of this analysis.



Activated Sludge Process for Sewage Treatment

5. Wastewater Systems

Wastewater is predominantly treated by publicly owned treatment works (POTWs), although there is a small number of private facilities such as industrial plants. As with drinking water, there are relatively few very large wastewater utilities as compared to the number of smaller utilities. Figure 2 depicts the distribution of these wastewater systems in terms of population served. Only 382 POTWs serve cities with populations of more than 100,000; 2,288 POTWs serve between 10,001 and 100,000 people; 2,598 POTWs serve populations between 10,000 and 3,301; and 11,050

With only several hundred out of the more than 15,000 U.S. waste water systems serving large city populations, focusing resilience initiatives on the relatively small number of large-scale wastewater systems will provide an especially efficient way of strengthening Black Sky preparedness

POTWs serve fewer than 3,301 people.³¹

Again, as with water service, focusing resilience initiatives on the relatively small number of large-scale wastewater systems will provide an especially efficient way of strengthening Black Sky preparedness. But smaller systems that are able to make sufficient investments in emergency power and supplies of fuel and chemicals necessary to sustain their operations can make important contributions to overall sector resilience.

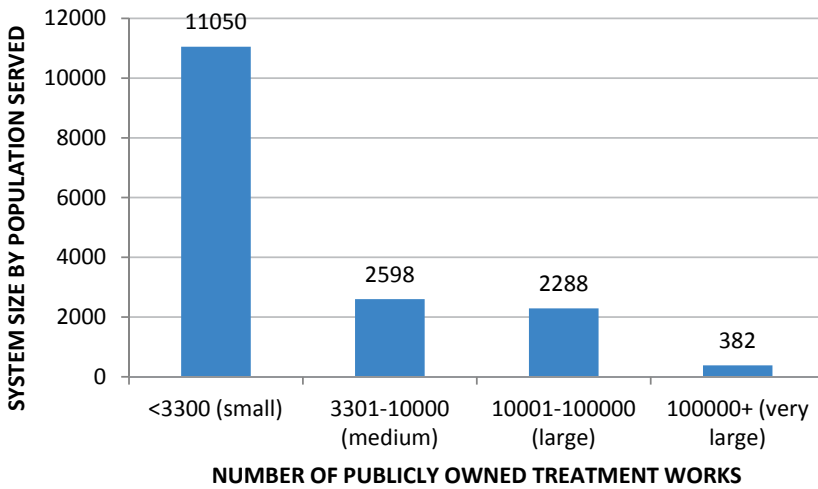


Figure 2 | Number of Publicly-Owned Treatment Works and System Size ³²

31 Sector Specific Plan (2015), p. 6.

32 Department of Homeland Security (DHS) and Environmental Protection Agency (EPA), Water and Wastewater Systems Sector-Specific Plan, 2015, <https://www.dhs.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf>



II | NATIONAL AND HOMELAND SECURITY AS A TOP LEVEL GOAL IN THE WATER SECTOR PLAYBOOK

The 2010 edition of the Water Sector-Specific Plan notes that, in addition to identifying higher-consequence and higher-priority utilities according to the size of the populations they serve, water and wastewater systems can also be assessed in terms of the “critical customers” they serve, including key defense installations and Level-1 trauma centers and other major medical facilities.³³ Sustaining service to critical customers should also be considered for inclusion in minimalist goals for the water sector’s Black Sky playbooks. First, however, the sector’s top level goals should be broadened to account for critical customers,

33 DHS, Sector-Specific Plan, p. 30.

particularly given the risk that adversaries will seek to degrade water systems to achieve key political and military effects in a crisis.

The imperative to provide water to hospitals has been a long-standing focus of emergency planning for the water sector.³⁴ The same is true of sustaining service for fire suppression, emergency operations centers, and other facilities and functions essential for disaster response. Until recently, however, far less attention has focused on the need to ensure that military bases have the water and wastewater system support they need to execute their critical national defense missions. Utilities and the DOD should work together to intensify that focus, and shape their baseline resilience goals accordingly.

Adversaries may strike the water sector (and the electric systems that power it) as an indirect means to degrade and disrupt U.S. national defense.

The key reason to do so: precisely because Defense installations are so dependent on water and wastewater service to operate, adversaries may strike the water sector (and the electric systems that power it) as an indirect means to degrade and disrupt U.S. national defense.

Secretary of Defense Ash Carter has highlighted the risk that adversaries will employ a deeply asymmetric strategy in future conflicts, and not only attack U.S. forces deployed abroad, but also strike the installations and supporting infrastructure on which these forces rely. The DOD Mission Assurance Strategy, which Secretary Carter issued in 2012 while serving as Deputy Secretary of Defense, notes that:

The Department of Defense's ability to ensure the performance of its Mission-Essential Functions (MEFs) is at growing risk. Potential adversaries are seeking asymmetric means to cripple our force projection, warfighting, and sustainment capabilities by targeting critical Defense and supporting civilian capabilities and assets.... on which our forces depend.³⁵

34 Centers for Disease Control and Prevention and American Water Works Association, Emergency water supply planning guide for hospitals and health care facilities (Atlanta: U.S. Department of Health and Human Services, 2012), <http://www.cdc.gov/healthywater/pdf/emergency/emergency-water-supply-planning-guide.pdf>

35 Department of Defense. (2012). Mission Assurance Strategy, p. 1.

Water and wastewater systems, the power grid and other civilian-owned and operated critical infrastructure constitute especially important supporting assets, and are prime targets for adversary nations to attack.

General Martin Dempsey, U.S. Army, Chairman of the Joint Chiefs of Staff, provides the strategic context for this threat. “In the future,” he emphasizes, “our homeland will not be the sanctuary it has been.” General Dempsey notes that Defense installations in the United States play an increasingly important role in supporting warfighting operations abroad. Given the dependence of these installations on civilian-owned critical infrastructure, it is prudent to assume that “our critical infrastructure will be threatened.”³⁶

Sustained service to mission-critical defense installations should be recognized as a fundamental priority as utilities develop minimal service goals addressing an EMP attack or a coordinated kinetic/cyber strike. New funding mechanisms should be an important consideration in cross-sector utility/DOD interface discussions.

Minimalist goals for water and wastewater service in an EMP attack or a coordinated kinetic/cyber strike against the water and electric sectors, must account for this threat. DOD and the utilities that serve it should recognize the foundational importance of the water sector to defense installations and the mission essential functions they support.

In particular, the national security imperatives for the water and wastewater sector should be included as an important priority as utilities size and define their investments in backup power and plan for sustaining emergency operations in Black Sky outages. In addressing these important interface requirements, utilities should examine opportunities for new funding mechanisms in partnership with DOD.

36 Dempsey, Martin E. (2012, 16 May). “JCS Speech.” Speech at 2012 Joint Warfighting Conference and Exposition, Virginia Beach, VA. Joint Chiefs of Staff, p. 6; <http://www.jcs.mil/Media/Speeches/tabid/3890/Article/7832/gen-dempseys-remarks-and-qa-at-the-2012-joint-warfighting-conference-exposition.aspx>

4

SECTION FOUR

SETTING MINIMALIST SERVICE GOALS FOR BLACK SKY EVENTS, AND DEVELOPING EMERGENCY PLANS FOR SUSTAINED OPERATIONS





Water Purification Plant

INTRODUCTION

Based on the top level objectives that the water sector and its external partners adopt, the next step in developing a Black Sky playbook for water and wastewater systems will be to establish the minimalist, “rock bottom” levels of service that those systems will seek to maintain in a long duration outage. Water and wastewater systems can then choose between a variety of specific options to achieve these service reductions, and help the maximum number of customers shelter in place for as long as possible.

This section examines ways in which utilities can cut back on their usual service levels to help meet their Black Sky objectives. This section also examines 1) the internal requirements that these reduced service options will entail for utilities, including investments in infrastructure and revised emergency planning; and 2) the external requirements these options will create for water sector partners, especially emergency managers and NGOs.¹

¹ Section V examines the internal and external requirements for emergency generators, fuel resupply, and chemical resupply.

Part I of this section examines the “spectrum of service” along which water and wastewater systems can seek to position themselves in long duration outages, ranging from near-normal service (which would entail the most demanding requirements for emergency generators and sustained fuel/chemical resupply) to total loss of service. The most promising and sustainable options for Black Sky service lie between these two extremes of the spectrum. Part A also outlines the reduced levels of service that utilities can provide to help their communities avoid the tipping point, both for drinking water and for sewerage, fire suppression, and other critical non-drinking water services.

Part II analyzes a key option to implement such service reductions: that is, cutting back on the pressure maintained in water system pipes. Utilities will typically need less pumping capability if they no longer seek to maintain their usual pressure levels. With lower pumping requirements, systems will not need to sustain as much emergency power generation – a significant advantage in long duration outages.

However, low pressure (defined by the EPA as below 20 pounds per square inch) increases the risk that contaminants will seep into pipes and reduce the quality of water below drinking water standards. Part II examines these risks and highlights implications for internal water sector planning and emergency operating capabilities. This analysis also examines potential external requirements for water sector partners to facilitate reduced pressure operations – in particular, provisions for emergency waivers of state water pressure standards.

Part III analyzes another prime option for curtailing service: cutting back on the number of pressure zones that will continue to receive water in a Black Sky event. In systems with major variations in elevation, sustaining water service to very high-elevation pressure zones may require an unsustainable amount of emergency power. Part III explores decision criteria (including elevation, customer criticality, and population density) to help prioritize sustainment of service across pressure zones. This analysis also examines emerging best practices in developing emergency curtailment procedures, and briefly reviews the internal water sector requirements that this option will entail for additional control valves and other infrastructure investments.

Part IV briefly highlights an additional option: that of cutting back on water and wastewater treatment operations. If systems drastically reduce such treatment, they can also slash their requirements for chemical resupply

and emergency power for lifts and other electric-powered assets at treatment facilities, and facilitate sustained delivery of non-potable water.

Of course, all such options that reduce water quality below drinking water standards (or entirely halt service to selected pressure zones) will create severe problems for meeting hydration needs. Part V summarizes the external requirements that reduced service levels will create for emergency managers, NGOs, the National Guard, and other organizations that will need to be prepared to meet drinking water needs for affected populations.



I | BLACK SKY SERVICE LEVELS: THE SPECTRUM OF OPTIONS

Maintaining water service during an extended blackout is not an “all or nothing” proposition. Between the extremes of total loss of service (nothing) and uninterrupted, normal operations (all), water systems can provide reduced levels of service that would be enormously valuable for helping citizens shelter in place until electric utilities restore power. Figure 3 illustrates the spectrum of service that water systems might provide in long duration power outages.

Near Normal	Reduced Service Black Sky Options	No Water Service
Sustain distribution system pressure at 20 psi or greater	Reduce distribution system pressure below 20 psi, but still support: <ul style="list-style-type: none"> • Fire services • Sanitation Services • Other non-potable services 	<ul style="list-style-type: none"> • No fire service • No sanitation service
Maintain pressure in virtually all service zones	Reduce service to selected pressure zones	<ul style="list-style-type: none"> • No drinking, bathing, washing • No system pressure
Water continues to meet all drinking water standards	Reduce water quality <ul style="list-style-type: none"> • Emergency waivers of selected regulations • Self-treatment by customers • Other options 	<ul style="list-style-type: none"> • System integrity concerns

Figure 3 | Spectrum of Water Service/Degree of Disruption

A | Near-Normal Service

The left end of the spectrum represents the least disrupted (and most difficult to sustain) levels of emergency service. Extraordinarily well-prepared systems may be able to sustain near-normal service: they will be able to continue to provide water that meets drinking water standards across virtually all pressure zones, at pressure levels above 20 pounds per square inch (psi), for the entire duration of the power outage.

However, to sustain normal service in Black Sky outages lasting 30 days or more, water systems would have to meet monumental requirements for emergency power and treatment chemical storage/resupply. Even if utilities have sufficient emergency power generators installed at the start of the outage to help treat and deliver potable water across their service areas, they will need access to replacement generators as extended use causes their original ones to

burn out. Those generators will require sustained resupply of fuel to operate. Resupply of chlorine, anhydrous ammonia, or other chemicals will also be essential if utilities are to continue to meet drinking water standards.

As will be discussed in Section V, water sector partners (including government agencies and contractors) will face enormous difficulties in meeting such replacement and resupply requirements in a Black Sky event. Prioritizing external support operations can help maximize the number of U.S. water sector customers who can shelter in place. However, for the vast majority of water systems, it will be impractical to sustain near-normal operations for 30 days or more.

B | Reduced Water Service: Black Sky Options

The next category along the spectrum, reduced water service, will be more practical for many water utilities to adopt as their Black Sky preparedness goal. Maximizing the number of customers who can shelter in place will require at least limited sustainment of two types of service: 1) service for fire suppression, sewerage and other critical functions apart from drinking water and 2) drinking water service – potentially delivered over fewer pressure zones or at reduced quality (thus requiring further treatment for potability by adequately prepared customers).

1. Services Other Than Drinking Water

While meeting human hydration needs presents the most obvious imperative for avoiding the tipping point in Black Sky events, past water emergencies in Elk River, West Virginia (2014), Christchurch, New Zealand (2010), and other events have also highlighted the need to sustain the flow of water to meet other community needs – regardless of whether that water also meets all Federal and State water quality regulations. Utilities and their public sector partners should consider these non-drinking functions as part of their rock bottom requirements for sustaining service in Black Sky outages. Then, building on this foundation, they can consider a range of options to also meet emergency drinking water needs. Key non-drinking functions for sustained water service include:

- Fire suppression
- Other emergency functions and critical services
- Sewerage/sanitation/support for wastewater operations
- Prevention of pipe breakage/facilitation of water system restoration



Maintaining Minimum Fire Flow is a Crucial Post-Disaster Requirement to Prevent Further Damage

a. Fire Suppression

Sustaining flows of even non-potable water will be enormously valuable for fighting fires that break out during extended power outages. Fire trucks have very limited abilities to draft water from ponds, rivers and other “raw water” sources. If trucks can draw on hydrant-supplied water, even at pressure levels not sufficient to prevent contaminants from seeping in, their ability to support firefighting operation will be vastly more efficient and effective.

Fire Departments in the San Francisco Bay area, Los Angeles basin and other cities at risk of catastrophic earthquakes have developed detailed contingency plans to fight fires if water distribution systems are too severely damaged to maintain pressure to hydrants. In blackouts caused by EMP events, cyberattacks and other Black Sky hazards, where pipeline breakage will be limited, the ability of water utilities to maintain flows of water will be similarly vital for fire suppression.

The imperative to sustain water flows for fire suppression will also exist even when water is so contaminated that states must issue a “do not use” order.

Sustaining flows of water for firefighting will be important when water is so contaminated that states must issue a “do not use” order. The state of

West Virginia issued such an order in the Elk River event in January 2014, when chemicals severely contaminated the source of water for Charleston. However, while the water could not be made drinkable, the state accepted the recommendation by the West Virginia American Water Company that the system continue to take in water from the River to sustain fire protection.²

Sustaining flows of water to for firefighting will be important in Black Sky events as well. So, too, will be need to provide water sufficient for the fire suppression sprinklers that are required in all hospitals, police stations, office buildings, emergency operations centers, military bases, and other key facilities in a Black Sky event.

b. Cooling for Critical Functions and Facilities

Water is essential for heating, ventilation, and air conditioning (HVAC) systems upon which hospitals and other key Black Sky facilities rely. Their computers centers, communications equipment rooms, power control centers, and a vast array of other electronic-heavy systems will also shut down unless utilities provide water to help cool them.

Water below drinking water standards can still meet these needs; with no water, critical facilities and functions will grind to a halt precisely when they are most needed. Indeed, such cascading failures will occur even if emergency managers can provide facilities with drinking water. During Katrina, for example, hospitals had to evacuate because the failure of their water supply brought down their HVAC units.³

These same non-drinking water requirements will also be vital for military installations and other facilities that perform national security functions. The DOD is intensifying its efforts to strengthen the availability of emergency power

With no water to sustain HVAC systems or provide minimal flows for sewerage, critical civil and military facilities and functions will grind to a halt precisely when they are most needed.

2 Markham, Peter et al. After Action Review: Emergency Response to January 9, 2014, Freedom Industries Chemical Leak, p. 14. <http://www.governor.wv.gov/Documents/After%20Action%20Review.PDF>

3 Zane et al., "Hospital Evacuation Decision Guide," p. 14.

on military bases so that if grid service is disrupted, those bases can still execute their critical defense missions (that is, provide for “Mission Assurance”).⁴ But Defense installations also depend on water and wastewater services – not just for potable water, but for all of the other water requirements necessary to support base operations. As with non-Defense facilities, water service is essential for fire suppression sprinklers on military bases. Additionally, water service is vital to support HVAC systems, including computer room air conditioning units (CRACs) and other systems to cool the electronic equipment on which Defense installations depend.

Measures to improve the availability of emergency power at military installations will have very limited value for Mission Assurance unless they are paired with initiatives to meet these critical water service needs. Ideally, of course, utilities will be able to sustain water service that meets drinking water standards. However, if that is not possible during a long duration, Black Sky outage, sustaining water service below that level could still have significant national security benefits.



Loss of Electricity May Cause Degraded Sewage Treatment

c. Support for Sewerage, Sanitation, and Wastewater System Functionality

Unless water utilities can sustain the flow of water through their distribution systems, sewage collection systems will clog up with solids and eventually cease

4 Office of the Assistant Secretary of Defense for Energy, Installations and Environment, “Energy Initiatives,” <http://www.acq.osd.mil/ie/energy/power.shtml>

functioning. Once pipes are blocked in this fashion, extensive, time-consuming repair operations will be needed to restore system functionality. Conducting such operations in a Black Sky environment would be prohibitively difficult; even after the event is over, restoration timelines would be far longer than if water flows had been maintained.

The dependence of wastewater systems on adequate water flows also has significant implications for the availability of drinking water. Many thousands of water systems take in their raw water for treatment from rivers. In some of these rivers, especially larger ones, treated sewage flows into the rivers upstream from the intakes for drinking water treatment. The failure of wastewater systems can leave raw water so polluted that even fully-operational treatment facilities will be unable to process it to sufficient levels of purity for drinking.

Even if they have adequate power, wastewater systems will be unable to function unless water systems sustain an adequate flow of water for sewerage, a good use of water that falls below drinking quality.

The need to avoid such a disruption to drinking water supplies provides a powerful impetus to ensure that wastewater facilities have adequate emergency power to function in a blackout. Even if they have adequate power, however, they will be unable to function unless water systems sustain an adequate flow of water for sewerage -- regardless of whether or not that water meets drinking water standards.

d. Preventing Pipe Breakage/Facilitating Water System Restoration

Unless emergency power generators can sustain at least some pressure in water pipes, those pipes will be at increased risk of breaking due to ground collapse around them, especially in the many thousands of systems that rely on old and corroded piping. Detecting where pipe breakages have occurred throughout a major city's distribution system would be an enormous undertaking (and indeed, would not be practical at all in the midst of a Black Sky event). Repairing or replacing those broken pipes in a Black Sky event would be equally impractical. The net result: if all pressure in a water system is lost, the time required to restore service will be vastly greater than if minimal pressure prevents system damage.

Recharging water into empty pipes can also risk causing “water hammer” effects that can inflict further damage. In the Elk River contamination event, West Virginia’s After Action Review noted “shutting down the plant and then restarting it would have been a prolonged, difficult process, keeping customers out of water for any use (including sanitation) for a substantial period of time.”⁵



MTA New York City Transit crews repair water main.
[Source: Marc A. Hermann / MTA New York City Transit. 4/8/2015]

Precisely because water utilities go to such great lengths to avoid complete depressurization of their systems, very little data exists on the damage to water infrastructure that such an event would cause. Nevertheless, ensuring that water flows continue -- regardless of whether the water meets drinking water standards -- will be critical for accelerating system restoration.

2. Drinking Water

Only a relatively small number of water utilities will adopt a Black Sky goal of sustaining “near normal” drinking water service -- that is, providing water that fully meets Federal and state drinking water standards across virtually all pressures zones, at pressure levels above 20 pounds per square inch (psi), for the entire duration of the power outage.

For utilities that cannot realistically aspire to sustain near-normal drinking water service, bottled water and other traditional strategies for emergency water

5 Markham, Peter et al. After Action Review: Emergency Response to January 9, 2014, Freedom Industries Chemical Leak, p. 3. <http://www.governor.wv.gov/Documents/After%20Action%20Review.PDF>

service will not be adequate to meet the needs of major urban areas (and most smaller communities) in Black Sky events. As noted in Section III, multi-state power outages lasting a month or more will render these traditional options impractical and unsustainable as the primary means to enable citizens to shelter in place.



The EPA's study on Planning for Emergency Drinking Water Supply (2011) reaches a similar conclusion. Contributors to the study reached shared recognition that "traditional approaches may not work after a catastrophic event." Instead, the study urged the development of "more creative approaches" to meet emergency water supply needs, including flexibility in meeting water quality regulations and options for household purification of water (i.e., "point of use treatment").⁶ The section that follows examines how utilities and their partners should consider adopting such options to provide reduced drinking water service.

[a. Emergency Waivers of Water Quality Regulatory Requirements](#)

Some states have already pioneered the option of providing for temporary waivers of certain water quality regulations when disasters strike.⁷ In anticipation of Black Sky events, when utilities will find it increasingly difficult to sustain emergency power to treatment facilities and pumping stations to maintain pipeline pressure above 20 psi, and when chemical resupply will pose significant challenges, utilities and their state partners should consider pre-planning for the

6 EPA (2011). p. 37

7 EPA (2011) p. 8.

delivery of water that meets only the most crucial regulations for public health.

One promising way to provide for such reduced service would be to have water utilities focus on meeting only acute exposure standards, and temporarily halt monitoring and treatment for contaminants associated with chronic, long-term health risks. The National Primary Drinking Water Regulations (NPDWRs) and the Maximum Contaminant levels (MCLs) and approved treatment techniques established under the Safe Drinking Water Act (SDWA, Public Law 93-523) provide a starting point for utilities and their public sector partners to reach consensus on which specific monitoring and treatment regulations should remain in place during Black Sky events. More stringent, state-specific MCLs should also be considered in this analysis. The resulting minimalist service requirements could then be included in the water sector's Black Sky playbook, and taken into account in developing Federal and state-specific emergency waivers.⁸



Technician Checking Water Quality at the Source

Another option to reduce drinking water service in Black sky events is to halt water treatment operations designed to improve the aesthetic qualities of water, including appearance, taste, and odor. Utilities and their partners should consider pre-planning for the waiver of secondary standards for such non-health related factors as part of their overall preparedness efforts.

In all such discussions, the EPA, state agencies, the Association of State Drinking Water Administrators, and other water sector associations will be

8 United States Environmental Protection Agency, "Drinking Water Standards and Health Advisories Table," June 2007. https://www3.epa.gov/region9/water/drinking/files/dwsha_0607.pdf

critical for consensus building on waiver triggers and specific provisions for regulatory relief. The EPA Emergency Planning study offers a number of additional recommendations on how such regulatory efforts might go forward.⁹

b. Household Treatment: Boiling Water and Other Options

In past events where utilities could no longer provide water that met acute exposure standards, boil water notifications and other point of use treatments by customers have proven to be an extremely valuable alternative to the delivery of bottled water and other emergency water options. Scaled-up point of use strategies could provide an important component of broader plans for reduced Black Sky service – but only if a number of stringent requirements are met to make these strategies feasible.

Boiling water has offered a prime means for self-treatment by customers in past outage events. When the Derecho struck, for example, the West Virginia Department of Health and Human Resources issued a statewide boil-water advisory for any water system that experienced low pressure from a loss of power.¹⁰



Boil Water Advisory Notice

The protocols and procedures for boil water operations are also well established. Water systems and their government partners issue precautionary boil water advisories when the water system experiences a loss in positive water

9 EPA (2011), pp. 38-9.

10 Morley, Kevin (2012). "A Lesson in Resilience from Derecho." American Water Works Association, Vol. 104, Issue 9, September 2012. Pg. 20. <http://connection.ebscohost.com/c/articles/88432534/lesson-resilience-from-derecho>

pressure, often caused by a serious break in water mains or blackout-induced losses of pumping capabilities. As noted above, the loss of positive water pressure can allow contamination to enter the distribution system. Mandatory boil water notices are issued when contamination is confirmed in the water system. Customers are instructed to boil the water to kill bacteria and other organisms in the water until the issue is resolved and the notice can be lifted.¹¹

Many water systems provide information for their customers on how to boil water to make it safe for drinking when these systems and their government partners issue boil water advisories.¹² However, in Black Sky outages, lack of fuel may make boiling water impractical for many customers.

- Electric stoves will be useless for boiling water unless emergency power generators and sustained diesel supplies enable them to operate in a long duration blackout.
- Relying on gas stoves will also be problematic. As discussed in Volume I of this Handbook, natural gas transmission systems are increasingly dependent on electric-powered compressors and other components that depend on electricity. Long duration, wide area outages will seriously disrupt gas supplies unless the Oil and Natural Gas (ONG) sector develops and implements its own Black Sky playbook.
- Stoves fueled by propane provide a viable option for boiling water in short duration outages. However, in Black Sky events, onsite supplies in many households will run short, and outage-induced disruptions of supply chains and ground transportation systems will hobble contractor resupply operations.

To hedge against the loss of fuel supplies, water systems and their partners should strengthen the preparedness of their communities to employ treatment options other than boiling water. Many systems already provide their customers with information on how to treat contaminated water with household liquid

11 Pennsylvania American Water, Boil Advisory. <http://www.amwater.com/paaw/Customer-Service/Water-Quality-Reports/page24469.html>

12 DC Water, What to do during a Boil Water Advisory. https://www.dewater.com/education/WhatToDo_BWA.cfm

bleach or other disinfectants.¹³ The American Red Cross has also identified a range of other treatment options apart from boiling water, including purification tablets and manual filters.¹⁴

The water sector and its external partners (including emergency managers and NGOs) should strengthen the preparedness of communities to use treatment methods apart from boiling water. Regardless of treatment method, however, ensuring that non-potable water continues to flow will be a prerequisite for such emergency measures to succeed, and should be a prime consideration in developing the water sector's Black Sky playbook.

Helping customers treat potentially non-potable water limits their communities' need for scarce emergency drinking water, and avoids the potentially catastrophic need for rapid evacuation.

C | Total Loss of Service

The total loss of all water service marks the far end of the spectrum of emergency service. The only "benefit" of adopting this level of service as a target for Black Sky operations: it requires no water system investments to achieve. If water utilities settle for having zero resilience against long duration outages, either explicitly or tacitly (by failing to invest in sufficient emergency power), their preparedness requirements will be minimal.

However, the ability of these utilities to help their citizens shelter in place during a Black Sky event will be similarly low. Communities would lose much of their ability to fight fires and meet other critical non-drinking water requirements for water service. Sewage collection and sanitation functions that depend on water system flows would break down. Such flows would be unavailable to support self-treatment of water to meet hydration needs. And

13 Ibid.

14 International Red Cross, Household Water Treatment and Safe Storage in Emergencies, 2008, <http://www.ifrc.org/Global/Publications/disasters/142100-hwt-en.pdf>

with a total loss of distribution system pressure, pipe breakage could greatly delay restoration of service.

Some water systems (including ones categorized by DHS and EPA as small or very small)¹⁵ may be unable to afford sufficient emergency power capabilities to stave off total loss of service in a Black Sky outage. Others will be at risk of not receiving the external partner support they need for the resupply of generators and fuel necessary to sustain minimal distribution system pressure.

To meet the needs of citizens who will not be able to shelter in place due to total loss of water service, emergency managers and NGOs responsible for mass care should coordinate with the water sector to determine where those services losses are most likely to occur, and develop targeted mitigation plans accordingly.



The American Red Cross has set up shelters around the State of North Dakota in anticipation of evacuees that may have to leave their home in areas that are flooded.

[Source: Patsy Lynch/FEMA.03/26/2009]

However, maximizing the number of citizens who can shelter in place must remain a key Black Sky playbook goal. To achieve that goal, the largest possible number of water systems should meet their internal requirements to provide for reduced levels of service, including emergency plans and infrastructure investments necessary to implement them. Sector partners will also need to consider possible external requirements for supporting these water system initiatives.

15 Very small and small systems are those that serve populations between 25-500 and 501-3,300 people, respectively. DHS, Water Sector-Specific Plan, 2010, p. 8.

Black Sky Service Levels: Findings and Recommendations

Maintaining the flow of water that meets drinking water quality requirements will always be the “gold standard” for setting emergency power goals. If utilities have sufficient generators and fuel to sustain drinking water service during an outage, doing so will obviate the need to provide emergency water supplies or issue boil water notifications, and support HVAC operations and all other uses for water apart from drinking. Maintaining sufficient pressure to prevent contaminants from leaking into pipes will also avoid the delays in service restoration that will otherwise be needed for system decontamination.

However, in long duration outages, even the best-prepared water utilities will find it increasingly difficult to maintain water pressure at 20 psi or above, given the difficulties they will face in acquiring replacement generators, fuel, and treatment chemicals as the blackout continues. Utilities should not only treat reduced-pressure, non-potable water service as a likely problem to occur, they should also adopt such reduced service as a practical goal for emergency operations in a Black Sky event, and size and structure their emergency power investments to sustain the flow of water even if it is undrinkable.

The analysis that follows examines three basic ways to curtail service in Black Sky events and make that service more sustainable:

- Reduce the pressure maintained in water system pipes
- Cut back on the number of pressure zones that will still receive service
- Reduce water quality level



II | REDUCING WATER PRESSURE

Lowering the pressure that water utilities seek to maintain in their distribution systems offers a practical, relatively straightforward way to reduce requirements for emergency power in a Black Sky event. Where emergency power generators operate key lifts and pumps, reducing the amount of time they operate (and allowing pressure to fall accordingly) will reduce their requirements for diesel fuel resupply.

Over the course of a long duration outage, shortening generator run times will also help slow the pace of generator burnout and reduce requirements for replacement generators. Cutting back on use of generators for pumps not critical for maintaining minimal pressure levels may offer similar benefits. For certain system piping configurations, emergency power generators may also be operated intermittently and cyclically across the

Many states require public water systems to maintain a minimum pressure of 20 psi to reduce the risk of drawing contamination into the distribution system.

system to maintain pressure. Thames Water in the UK, for example, has a large looping system and their plans call for operating emergency generators cyclically to maintain minimum pressure levels.

Internal Water Sector Requirements

Water systems will need to conduct significant planning and analysis to determine how to implement pressure reduction operations in ways that maximize savings in emergency power requirements, and that also meet critical fire suppression needs and other minimalist service and infrastructure preservation goals. Many of these systems will also need to make significant investments in generators and fuel storage tanks to sustain even reduced-pressure operations. As Section V notes, tens of thousands of U.S. water systems have little or no onsite emergency power generation capacity. Many of them have not even pre-arranged for contractors or government agencies to install generators when an outage occurs. Section V examines options to deal with these gaps; filling them will be an essential water sector requirement for reduced pressure operations.

External Partner Requirements

Even if utilities cut back on the number and operating times of generators used to sustain emergency service, contractors and other external partners will still need to provide for fuel and generator resupply and for generator maintenance. For outages lasting 30 days or more, that will remain a demanding (though somewhat more manageable) requirement at reduced pressure levels.

Equally significant will be the partner requirements to deal with the impact of reduced pressure on water potability. As briefly discussed above, low pressure (defined by the EPA as below 20 psi) increases the potential that contaminants will back-flow or back siphon into the water distribution system. Accordingly, many states require public water systems to maintain a minimum pressure of 20 psi in their distribution system because a pressurized system (>20 psi) is less likely to draw contamination into the distribution system through pipe cracks or cross-connections.¹⁶

¹⁶ US EPA Drinking water Bluebook, p. 11. https://www.fedcenter.gov/_kd/go.cfm?destination=ShowItem&Item...

States should consider planning in advance to issue emergency waivers of these pressure requirements, and thereby facilitate water system planning to operate at reduced levels. Government-industry discussions should also go forward to further clarify where “knees in the curve” exist for minimal pressure levels, including for 1) preventing pipe breakage or infiltration; and 2) possible implications for self-treatment of water by customers and requirements for emergency water supplies.



Utility worker fixing broken watermain



Water Distribution By Uses, Cleveland Water [Source: www.clevelandwater.com]

III | LIMITING THE GEOGRAPHIC SCOPE OF DISTRIBUTION SERVICE, AND PRIORITIZING DISTRIBUTION TO CRITICAL CUSTOMERS

Water systems have another potential means to reduce water service, and emergency power requirements, in a sustainable way. Systems can cut back on the number of pressure zones that they serve with potable water, or (if they are also using pressure reduction strategies) water that no longer meets drinking water standards.

Utilities with extraordinary emergency power capabilities and assured sources of fuel resupply may seek to sustain water distribution to all customers, even those at high elevations or in low-population areas that require the greatest number of pumping stations to reach.

However, many other water systems should consider adopting a less ambitious and more sustainable goal of sustaining service to only a limited number of pressure zones. They should also examine criteria for prioritizing sustained service for specific zones in a long duration outage -- for example, zones serving higher versus lower population densities, or serving a cluster of critical facilities. In turn, providing these plans as external requirements to emergency managers could help guide priorities for replacement generators and fuel resupply.

System topography and design will dictate whether and how utilities will be able to halt service to some zones in favor of sustaining it to others. However, over the longer term, new opportunities may emerge to develop engineering options for such prioritized service, and to expand on long-standing plans to provide emergency service to hospitals and other vital customers. The analysis that follows provides:

- Background information on multi-zone emergency service
- Zone-Based Emergency Service Options
- Topography Factors
- Other Criteria for Prioritizing Service Between Pressure Zones

Water systems should consider prioritizing sustained service for high population zones or zones supporting critical facilities in a long duration outage. Planning for such decisions in advance, and providing them to emergency managers as an external requirement, can help guide priorities for replacement generators and fuel resupply.

A | Emergency Service in Multi-Zone Systems: Background

Water distribution systems are typically divided into pressure zones designed to equalize positive water pressure across the system. This can include, for example, addressing variations in elevation from lowest-lying to highest areas, and the need for pumping stations to build pressure to force

water uphill to water storage tanks and water towers. In many larger systems, pressure zones can operate as stand-alone systems, but also have some degree of interconnection to other zones in order to provide for reliable service when system components fail.

The water utility in Cleveland, Ohio illustrates one common way that distribution systems are divided into pressure zones. To provide water over the system's 640-square-mile service area, Cleveland Water has an extensive distribution system that includes 4 primary pump stations, 11 secondary pump stations, 22 towers and tanks, and nearly 5,200 miles of underground water mains. Lake Erie (the source of raw water for treatment) lies at the lowest elevation of the system; in general, the greater the distance customers are from the Lake, the higher their elevation. The large pumps located at each of the system's four water treatment plants can push water to only a certain elevation before water pressure drops below required thresholds. To counter that loss of pressure, Cleveland Water uses a combination of pumps, towers, and storage tanks and inter-zone pressure valves to sustain adequate pressure in the four major pressure zones.¹⁷

Surface water systems serving communities across the United States are often similar to the Cleveland Water model. Approximately 12,000 surface water systems, serving a total of over 200 million customers, face similar requirements to pump water from lakes or rivers up to treatment facilities and then to their various pressure zones.¹⁸

Systems with other water sources and topographies are structured differently. In cities such as Los Angeles, where major reservoirs and other water sources are located in hills above system customers, gravity helps maintain the flow to lower-altitude distribution zones. Such gravity-aided flows can help distribution systems maintain pressure to some service zones if pumps fail in a blackout (though in the case of Los Angeles, severe drought is reducing reservoir levels at an alarming rate).¹⁹

17 Cleveland Water, Water Distribution. <http://www.clevelandwater.com/your-water/water-distribution>

18 Data provided on October 26, 2015, by Kevin Morely, Security & Preparedness Program Manager, American Water Works Association.

19 Department of Water Resources, California Data Exchange Center – Reservoirs. <http://cdec.water.ca.gov/cdecapp/resapp/getResGraphsMain.action>

Approximately 40,000 “groundwater systems” (serving more than 80 million customers) are entirely dependent on electricity to pump water from groundwater wells. The Suffolk County Water Authority, the largest groundwater supplier in the United States, has 50 well fields, 256 pumping stations, and 64 elevated water storage facilities that serve 43 different pressure zones.²⁰ During the Sandy blackout, the Authority was able to maintain service to the vast majority of its customers because it had installed backup generators at key pumping stations and other facilities (though two backup generators suffered catastrophic failures during the event, and the Authority experienced significant delays in acquiring replacements from FEMA and other sources).²¹



Scientist Gathering Water Data

B | Zone-Based Emergency Service Options

While scaling up investments in emergency power capabilities provides one way to build preparedness against Black Sky outages, other potential opportunities stem from the division of water distribution systems into separate pressure zones. If pumps fail in a power outage, large water tanks and other

20 Suffolk County Water Authority, SCWA Introduces Strategic Plan 2025. http://www.scwa.com/strategic_plan/; additional information provided by Philip Thompson, Mechanical Supervisor, Suffolk County Water Authority, November 10, 2015.

21 Thompson, op cit.

elevated storage facilities provide at least short-term sources of water pressure for the distribution zones they serve. As backup power generators begin to fail, interconnections between pressure zones can also enable distribution systems to temporarily mitigate such disruptions.

A range of other options could also help multi-zone systems achieve the baseline Black Sky goal of enabling as many customers as possible to shelter in place until power is restored. For example, Seattle has means for establishing temporary connections between pressure zones to allow bypassing of certain areas and improve the provision of service to selected service zones. However, ensuring the availability of an adequate number of operable valves is essential for isolating parts of the system, circumventing sources of pressure loss, and prioritizing the delivery of service to certain areas in a community. Field exercises may be necessary to determine a system's valve requirements.²²

If pumps also fail, elevated storage facilities could provide short-term water pressure for the distribution zones they serve. As backup power generators fail, interconnections between pressure zones could temporarily mitigate disruptions.

C | Topography Factors

In many multi-zone utilities, differences in the elevation of these zones, and in the distance between them and the water treatment plants on which they rely, will make it difficult to sustain equal pressure across the system during a long duration blackout. Plans for emergency water and wastewater service should take these variations into account before an event occurs.

Washington, DC and several neighboring jurisdictions in the National Capitol Region (NCR) exemplify the need for such advance planning. In a

²² EPA (2011), p. 9.

major power outage, emergency power generators and fuel stored onsite will enable DC Water and other systems supplied by the Washington Aqueduct to pump sustained flows of treated water to areas where elevation is below 70 feet above sea level. As long as the Washington Aqueduct and its treatment facilities are resupplied with emergency generator fuel and treatment chemicals within seven days of the outage (and thereafter as the blackout continues), supplies of potable water could continue to customers below that 70-foot elevation.



Varying Topography Imposes Variations in Emergency Services

Customers at higher elevations, including most of the Northwest quadrant of the city, would lose water for drinking, fire suppression, and movement of waste within roughly 48 hours of grid failure.²³ (Adoption of water quality and pressure Black Sky protocols, as reviewed above, could significantly extend these standalone operation times).

Of course, even if water flows can be maintained to lower-elevation pressure zones, the loss of service to customers at higher elevations would be extremely disruptive. Participants in an NCR workshop in 2015 explored the potential consequences and mitigation options for such a disruption of service in a 10-day

In the nation's capital, Washington D.C., as long as adequate emergency generator fuel and treatment chemicals are resupplied throughout the outage, potable water service will continue, though only to customers below a 70-foot elevation.

23 National Capital Region (NCR) Energy Workshop Series, Participant Workbook, p. 39.

regional power outage during a severe winter storm scenario. They found that “water for human hydration, fire suppression, and movement of human waste would be the primary concern within the first 48 hours of the event,” and that “given the scope of this scenario, there are no effective water or wastewater response strategies.”²⁴

However, the participants did identify some options to mitigate the loss of service to higher-elevation customers (and to broader areas as the outage lengthened). Many of these options would be valuable for other major, multi-zone water systems as well. They include:

- **Coordinating shelter plans with water distribution nodes:** Prior to an incident, determine which shelters are closest to pre-planned water distribution nodes, and ensure that information is included in pre-scripted messages to the public
- **Firefighting using water at reduced pressure:** Alter firefighting tactics to use available water, and as a last resort, be selective in choosing fires to combat
- **Shelter-based sewage options:** As a fallback measure, use portable latrines and other emergency measures to move human waste.²⁵

D | Other Criteria for Prioritizing Service Between Pressure Zones

While topography will impose variations in emergency service between high and low-elevation zones in many systems, some utilities are also exploring a more targeted option: that is, to sustain service to high priority customers and pressures zones while allowing other zones to lose service.

This approach could help water systems strategically allocate replacement generators and fuel as supplies run short in a Black Sky event, and also pre-plan and publish external requirements to cross-sector partners to meet the

²⁴ NCR AAR, p. 7.

²⁵ NCR AAR, p. 8

emergency needs of customers in zones that will no longer receive water.

In fact, many water utilities and their emergency management partners already have criteria to prioritize customers for emergency water service. These criteria are not yet optimized for the cross-sector requirements water companies will be asked to support during a Black Sky event, including support for power restoration and restoration of other critical infrastructure functions. However, these criteria serve as a valuable starting point for analysis of prioritization options. Typical criteria include:

Sustaining service only to high priority customers and pressures zones could help water systems strategically allocate replacement generators and fuel as supplies run short in a Black Sky event.

- **Population served:** Higher density, larger population areas of service would be the priority for sustaining distribution system flows
- **Health Care:** Hospitals and other healthcare facilities, especially major regional hospitals or ones with Level 1 trauma centers;
- **Schools**
- **Relocation/mass care facilities**

A growing number of systems use these criteria to determine where to provide for redundant pipelines to critical facilities. For example, to hedge against the disruption of the primary feed to a hospital, utilities can lay pipes from a different pumping station to provide for greater supply resilience. Hospitals and other high-priority facilities can also partner with local water utilities to adopt other emergency plans and capabilities, including drilling their own groundwater wells, installing very large-capacity storage facilities, and providing for emergency pumping of water from nearby reservoirs.²⁶ For most water systems, however, these facility-specific strategies will have little or no value for sustaining service to high-population zones and providing for large-scale sheltering in place.

26 Gregory Welter, Steven Bieber, et al, "Cross-sector Emergency Planning for Water Providers and Healthcare Facilities," *Journal of the American Water Works Association*, January 2010, pp. 70-75.

A more promising potential strategy is to shut down the flow of water to lower-priority pressure zones in favor of sustaining service to higher ones. Many water utilities with multiple pressure zones are able to shift water to zones at risk of low pressure. Typically, this function is provided by inter-zone pressure valves that make adjustments on an automatic basis (often supported by SCADA systems, whose vulnerability must also be addressed).

However, in regions where earthquakes are a prime hazard, utilities have also developed the ability to conduct targeted service shutdowns to halt the flow of water to portions of the distribution system that suffer severe pipe damage. The Portland Water Bureau, for example, has manually operated valves that can shut down any section of the system and leave others open, thereby helping to maintain at least minimum pressure levels in less damaged sections and facilitate the gradual restoration of service to all zones as repairs are completed. The Water Bureau is now installing large valves that can be remotely closed via electronic controls and provide for still more effective emergency operations.²⁷

In earthquake-prone regions, utilities can often halt flow to zones that suffer severe pipe damage to maintain at least minimum pressure elsewhere. Utilities might adopt a similar approach for Black Sky outages to sustain pressure in critical zones when generators, fuel, and consumables run low.

Utilities might adopt a similar approach not only to isolate portions of a system that are severely damaged, but also -- in a Black Sky outage when replacement generators and fuel supplies run low -- to sustain minimum pressure in the most critical zones within a distribution system.

Such an approach would entail demanding operational requirements and (for many systems) the construction of new valves and control mechanisms. Prioritizing the flow of water to hospitals or other specific facilities will be even more difficult, due to the large number of water valves that would need to be turned off between the water treatment plant and the facility in question.²⁸

27 Data provided by Chris J. Wanner, Director of Operations, Portland Water Bureau, October 14, 2015.

28 Based on data provided by Jack Moyer, Carolinas/Tennessee Water Security and Preparedness Area Market Sector Leader, AECOM Technical Services, October 22, 2015.

However, the growing installation of SCADA systems could help ease the challenges of conducting such operations, as long as power can be supplied to these controls in a blackout and they are hardened against EMP, cyber attacks and other Black Sky hazards.

As utilities develop plans to modernize their distribution systems and replace aging valves and other infrastructure, they should explore how the targeted sustainment of service to selected portions of those systems could help maximize the number of customers who are able to shelter in place in a Black Sky outage. Targeting specific zones for sustainment before an event occurs, and accounting for that strategy in emergency water and wastewater plans, could contribute to region-wide planning for mass shelter/care in extended outages.



Maintaining Water Supply for Fire Suppression is Vital to Disaster Recovery

IV | REDUCTIONS IN WATER TREATMENT

Current water quality standards involve a wide range of requirements. Some, like clarity and odor, provide for enhanced utility of drinking water, but have little or no impact on the safety of the water. A number of water utilities and their public sector partners have begun to explore options to cut back on chemical resupply requirements by determining which treatment operations are non-essential. Those discussions should continue.

Discussions should also go forward as to how utilities might pair reductions in water treatment with other Back Sky playbook service reductions. Reduced pressure operations provide a case in point. By lowering the pressure of water distribution system below 20 psi, utilities may be able to cut their requirements

Leading water utilities are beginning to work together with regulators and other stakeholders to explore near-high end Black Sky protocols for targeted reductions in water quality

for emergency power and fuel resupply, and thereby make their operations more practical to sustain in long duration outages. However, such reductions may allow contaminants to enter the system to an extent that the water no longer meets drinking water standards. If utilities know that will be the case in a Black Sky event, they may want to significantly cut back on water treatment levels, and reduce their requirements for power at treatment plants and for chemical resupply.



Representatives from Sectors Collaborate Closely to Identify Requirements

V | PLANNING FOR PUBLIC HEALTH AND SAFETY: KEY EXTERNAL REQUIREMENTS FOR WATER SECTOR PARTNERS

The foregoing analysis identified a number of requirements that emergency managers, NGOs, and other organizations responsible for mass care will need to meet if water utilities significantly reduce their levels of service in a Black sky event. Most important, if utilities can identify in advance the pressure zones where they are most likely to curtail service, and can assess how significantly water pressure reductions will affect water quality, emergency managers can build the plans and capabilities necessary to assist affected customers when Black Sky hazards strike. Similar (but larger scale) external partner requirements will exist for meeting the needs of communities whose water systems cannot afford the emergency power capabilities necessary to sustain even reduced levels of service.

Drawing on best practices from systems engineering methodologies, the best way forward would be for individual water and wastewater systems to clearly specify the requirements they believe that reductions in water service will entail for emergency management agencies in their states and localities. These agencies can then work with NGOs and other providers of mass care to develop their own Black Sky playbooks to sustain communities at greatest risk of losing service in Black Sky events.²⁹

Black Sky events will also require much broader consequence management planning and capabilities. Wide area, long duration outages will not only affect the water sector, but will also cause cascading failures across communications, transportation, and other lifeline sectors as well. The National Response Framework and the Power Outage Incident Annex provide a foundation on which to build cross-sector preparedness to respond to and recover from such catastrophic events. However, much more remains to be done to ensure that response operations can be conducted in a whole of Nation, closely integrated way across the full range of sector-specific Emergency Support Functions. Handbook III will examine these challenges and propose playbook options to meet them.

29 As Section V will emphasize, a similar process of identifying external support requirements will apply to contractors and agencies responsible for supplying replacement generator, fuel and chemicals in Black Sky events.

5

SECTION FIVE

EMERGENCY POWER AND CHEMICAL RESUPPLY: WATER SECTOR AND PARTNER REQUIREMENTS



A U.S. Army Corps of Engineers' employee services a generator before it is returned to the warehouse. [Source: Liz Roll/FEMA.11/20/2012]

INTRODUCTION

To sustain even reduced service levels in long duration outages, water and wastewater systems will face significant internal requirements to strengthen their emergency power capabilities. Utilities will also need extended support from partner organizations responsible for providing replacement generators. The section that follows recommends how the water sector's Black Sky playbook (and those of its partners) can account for such internal and external requirements.

Part I focuses on both sets of requirements for emergency power generators. Part II examines fuel resupply requirements. Part III sets the stage for follow-on analysis of chemical resupply requirements. Part IV examines minimalist service goals for Black Sky events and developing emergencies. To conclude, Part V discusses emergency power and chemical resupply for the water sector.



Engineers Discussing Emergency Power Requirements

I | REQUIREMENTS FOR EMERGENCY POWER GENERATORS

Utilities can sometimes sustain their operations in brief blackouts without emergency power generators. To tee up an assessment of generator requirements for Black Sky events, this analysis begins by reviewing these sustainment options, and explains why they will fall short in long duration outages. The analysis then examines:

- The Current Emergency Power Generation Capacity of the Water Sector, and Key Gaps to Fill
- Emergency Generator Options for Black Sky Resilience
- Improving Just in Time Generator Installation Plans and Capabilities: Benefits for Sandy-Scale Power Outages
- Generator Requirements in Black Sky Events: Static Versus Dynamic Assessments
- Limited Supplies of Emergency Power Generators: The Enormous Mismatch with Black Sky Requirements

A | Emergency Generators: Essential for Black Sky Resilience

Even without using emergency power generators, storage of treated water in elevated tanks can help many water utilities maintain pressure to operate for up to 24 hours or somewhat longer. However, such storage strategies will be completely inadequate in Black Sky outages

Other traditional hedges against power interruptions will be similarly unable to sustain even reduced service in wide area, long duration blackouts. A significant number of water and wastewater systems rely on redundant power feeds to provide resilience against blackouts. If one line goes down, another line can still provide electricity. While useful as a hedge against power interruptions caused by tornados or other localized events, multiple feeds will be ineffective in the very wide area outages that Black Sky hazards will create.

Still other water systems seek to strengthen their resilience by maintaining connections with other systems that can provide water in an emergency. These system interconnections (and the redundant access to water supplies that they offer) have proven valuable not only in small-scale power interruptions, but in other events that have disrupted the primary supply of water to a utility.¹ Again, while helpful in small-scale outages, such interconnections will offer little value in wide area blackouts.

Prioritized restoration of power falls into a similar category, at least for the present. The EPA's Power Resilience Guide recommends that water and wastewater systems ensure that they are on the priority power restoration list maintained by their local electric utilities. The Guide also recommends that to further accelerate restoration, these systems should inform electric utilities of the locations of their critical components that depend on power.²

However, given the extensive damage that earthquakes and other Black Sky hazards will inflict on high voltage transformers and other difficult-to-replace grid components, power restoration to even the highest priority customers

1 Berahzer, Stacy I. et al. "Interconnections Between Water Systems as an Incentive for Asset Management," *Water Asset Management International*, 8:3, 07-12, October 2012. <http://www.efc.sog.unc.edu/reslib/item/interconnections-between-water-systems-incentive-asset-management>

2 EPA, *Power Resilience Guide*, December 2015, p. 1-4.

could take a month or more. Over the longer term, opportunities will emerge for electric utilities to create secure power enclaves to help sustain (or much more rapidly re-establish) electric service to water systems and other essential facilities in such catastrophic events³ Until then, however, prioritized restoration will offer a resilience option only against much less severe outages.

Finding: Water and wastewater systems will only be able to sustain operations in Black Sky events if they have (or can quickly get installed) the emergency generators needed to pump water to treatment plants, conduct treatment operations, transport and deliver water to customers, and help sustain sewage flows for sanitation until grid-supplied power is restored. Wastewater systems will face equivalent imperatives for emergency power to sustain their own pumping and treatment operations.⁴

Internal water sector requirement: For water and wastewater utilities to meet these requirements, they will first need to clarify how the wide geographic scope and extended duration of Black Sky outages will shape their needs. The Black Sky playbook for the water sector as a whole will also need to account for the sector's current emergency power capabilities, in order to help identify overall shortfalls in Black Sky preparedness and assess their implications for internal and external partner support requirements for emergency generators.

3 Power enclaves as an option for water sector resilience are examined in Section IV.

4 Thompson, Paul, "Security and Preparedness: Storm -Related Power Outages: Are You Ready?" AWWA Journal, Vol. 104, No. 1, pp. 22-26, April 2012. http://www.jstor.org/stable/jamewatworass.104.4.22?seq=1#page_scan_tab_contents

B | Current Emergency Power Generation Capabilities in the Water Sector: Key Gaps

Sandy helped spur a growing effort by water and wastewater utilities to assess their emergency power needs, and install emergency power generators or add to the number that they have in place across their systems. This progress provides an invaluable foundation for building preparedness against wide area outages lasting a month or more. However, not all utilities have acted on the lessons from Sandy and other blackouts. On the contrary: tens of thousands of water sector utilities do not yet have generators in place, and may not even have pre-arranged for their “just in time” installation when a power outage strikes.

The DHS’s Sector Resilience Report: Water and Wastewater Systems (July 2014) offers an overview of existing sector emergency power capabilities. The report is based on assessments of 2,661 sites across all 16 critical infrastructure sectors, including 134 water treatment facilities and 96 wastewater systems. DHS found that 87 percent of the assessed water treatment facilities and 88 percent of the assessed wastewater systems have an alternate or backup source of power.⁵

However, utilities vary enormously in terms of the number of customers that they serve, from the 28,000 systems that DHS categorizes as “very small” (serving populations of 25-500) to the 410 “very large” systems that serve populations above 100,000.⁶ The DHS report does not assess how many larger systems lack emergency power generators, and what resulting size of the U.S. population will lose water service in a blackout. There is also no indication of the coverage provided by these backup power sources both in terms of critical sites with generators and available fuel supply. Most utilities would require multiple generators at their treatment plants and at pumping stations throughout their service areas to sustain operations in a Black Sky event. These factors will be critical for assessing overall Black Sky generator requirements and developing

5 DHS, Sector Resilience Report: Water and Wastewater Systems, July 2014., p 1-2, 9-10. <http://infragard-nd.org/wp-content/uploads/2014/07/FY12-OCIA-SRR-Water-and-Wastewater-Treatment-Systems-PDM14178-7JULY14.pdf>

6 Department of Homeland Security (DHS) and Environmental Protection Agency (EPA), “Water Sector Specific Plan: An Annex to the National Infrastructure Protection Plan,” 2010, p. 8, <https://www.dhs.gov/xlibrary/assets/nipp-ssp-water-2010.pdf>

strategies to fill the shortfalls in existing emergency power capabilities.

The best available nationwide survey of emergency power preparedness is provided in a 2012 study by Dr. Kevin Morley. Morley surveyed a representative cross section of 50 water utilities of various sizes, ranging from utilities in major urban areas serving populations of 100,000 or more down to those serving fewer than 10,000. Key findings:

- Twenty five percent of the surveyed utilities would be unable to sustain critical operations for more than 48 hours in a blackout. Translated into population served by the 50 surveyed systems, nearly 6.4 million customers would potentially have compromised water service within 48 hours.
- Of that group, 5 utilities serving nearly 4.5 million customers have zero in-house capability for emergency power.⁷

Applying these percentages to the approximately 155,000 public water systems in the United States,⁸ an estimated 38,000 water systems would be unable to sustain critical operations for more than 48 hours. A similar extrapolation of the 2012 survey data suggests that thousands of other utilities have no emergency power capability at all, leaving tens of millions of additional customers at risk of immediate service disruptions even in very brief outages.

The percentage of utilities investing in emergency power has almost certainly increased since 2012, though no nationwide data exists to quantify that improvement. Two related factors have helped spur this growth: 1) Sandy harshly illuminated the importance of emergency power for many water utility owners and operations, and 2) post-Katrina initiatives by WARNs, the EPA, USACE, and other public and private organizations have encouraged emergency power preparedness across the water sector.

However, it is also possible that the 2012 survey understated the nationwide shortfalls in emergency power capability. That survey gathered data primarily from utilities that had joined WARNs, and hence were already focused on

7 Morley, Kevin. "Evaluating Resilience in the Water Sector: Application of the Utility Resilience Index, George Mason University," September 2012, p. 67. http://digilib.gmu.edu/xmlui/bitstream/handle/1920/7880/Morley_dissertation_2012.pdf?sequence=1&isAllowed=y

8 EPA, "Information about Public Water Systems. <https://www.epa.gov/dwreginfo/information-about-public-water-systems>

preparing to sustain service in blackouts and other disruptive events. The thousands of utilities that are not part of a mutual assistance network were underrepresented in the study. Those systems may be less likely than WARN members to treat emergency power as a priority, creating a challenge of unknown proportions for: 1) requests for USACE and other generator providers to install generators in a crisis; and 2) requirements for emergency managers to provide drinking water and mitigate the cascading failures in hospitals, fire suppression capabilities, and critical facilities and functions.

Finding: The absence of even rough assessments of the number of water and wastewater systems that have minimal emergency power capabilities (defined as the ability to sustain critical operations for 48 hours in a blackout) creates significant planning challenges for building preparedness against power outages.

Internal water sector requirement: Water sector associations should conduct a nationwide survey of their water and wastewater systems' members to help develop an initial assessment of emergency power capabilities, which would be refined and made more comprehensive over time to clarify crisis requirements for generator installation and consequence management operations.

C | Emergency Generator Options for Black Sky Resilience

For water and wastewater systems that lack emergency power capabilities, or want to expand them for greater resilience against extended blackouts, two approaches are most commonly employed. Utilities can purchase, install, and maintain generators at their key pumping stations and other critical system nodes. Alternatively, to avoid the expense and maintenance burdens of having onsite generators, utilities can adopt a “just in time” strategy of relying on contractors or government agencies to provide and install generators when a power outage strikes (or, in the case of an approaching hurricane, when they believe an outage is at significant risk of occurring).⁹

Given the scale of Black Sky outages, plans to provide, transport, and install emergency power generators during an event will fall disastrously short of sector requirements.

Many water and wastewater utilities have adopted the latter option because it is much less expensive. A large percentage of the over 40,000 U.S. community water systems that are rated as very small (serving populations between 25-500) or small (501-3300) will continue to find it difficult to afford their own emergency power systems.¹⁰ Yet, even very large utilities in the water sector (including the Blue Plains Advanced Wastewater Treatment Plant in Washington, DC), rely on just in time delivery of backup power generators, because they view that strategy as offering an especially cost-effective way to meet their emergency power needs.

But, just in time strategies are only effective if adequate supplies of generators are available to meet utility needs, and if emergency managers and private contractors are willing and able to deliver them. Previous hurricanes have

9 For a systemic review of emergency generator options, see EPA, Power Resilience: Guide for Water and Wastewater Utilities, December 2015, pp. 3-1 to 3-8. <https://www.epa.gov/sites/production/files/2016-03/documents/160212-powerresiliencguide508.pdf>

10 For details on these rating categories and numbers of utilities within them, DHS and EPA, Water-Sector Specific Plan: An Annex to the National Infrastructure Plan, 2010, p. 8. <https://www.dhs.gov/xlibrary/assets/nipp-ssp-water-2010.pdf>

revealed significant shortfalls in the effectiveness of generator providers in meeting water sector requests for assistance. For example, the AWWA report on Sandy identified a number of instances where generator requests from key facilities were denied, despite the critical role that water and wastewater systems play in saving and sustaining lives.¹¹

The sections that follow examine a number of initiatives that are helping to remedy these problems for Sandy-scale events and, also for less severe (and more frequent) power interruptions. However, even with such improvements, the extraordinarily wide area and long duration of Black Sky outages will jeopardize the effectiveness of just in time strategies for many water and wastewater utilities. The severity of Black Sky events will also require utilities that already have their own generators to rethink their emergency power needs, since long duration outages will cause those generators to break down in growing numbers.

D | Improving Just in Time Plans and Capabilities: Benefits for Sandy-Scale Power Outages

The AWWA report recommended that FEMA and other emergency management agencies grant a higher priority to providing generators to the water sector in emergencies. That proposal stems from a key problem revealed by Sandy. There was limited recognition that drinking water and wastewater utilities represent a critical lifeline sector essential to community continuity and recovery. The cascading economic and environmental impacts of an operational issue are not well recognized, so preventive actions to mitigate risk of failure were not consistently rated high priority. This resulted in the following challenges for utilities: lack of support for backup power and fuel requests, difficulties for utility personnel trying to access their facilities to assess and/or repair damage, and a lack of coordination among response partners.¹²

11 AWWA, Superstorm Sandy After-Action Report, p. 6.

12 AWWA, Superstorm Sandy After-Action Report, 2013. p. 6.



Members of the Memphis District Emergency Power Planning and Response Team airlift an emergency generator to place on top of a water storage tank at the Port Sulphur (Louisiana) Water Plant [Source: Photo by Memphis District]

To minimize such problems in future disasters, a growing number of water and wastewater utilities have been strengthening their relationships with local and state emergency managers and ensuring that emergency power needs -- and the benefits of sustained service -- are better understood. Many local and state emergency operations centers (EOCs) are also providing seats for water sector representatives to help prioritize and facilitate sector requests for generators and other types of assistance. Other critical infrastructure sector components that require sustained water service in emergencies, including hospitals, fire and police departments, and EOCs themselves, are natural advocates for ensuring that water utilities have the backup power they need.

Finding: Making water and wastewater systems a top priority for the installation of backup generators will prevent potentially devastating consequences in Sandy-scale events. For more severe outages, including those created by Black Sky hazards, embedding water sector personnel in EOCs and taking other steps to strengthen sector coordination with emergency managers will offer broader incident response and recovery benefits as well.

Internal water sector requirement: The water sector should continue to advance stakeholder outreach efforts to specify its critical requirements for external support from local, state, and Federal emergency managers in their disaster response plans.

External partner requirements: At the national level, the FEMA/DOE Power Outage Incident Annex (POIA) to the National Response Plan should be updated to elevate the overall priority assigned to meeting water and wastewater system emergency power needs.¹³ Utility leaders should also work with emergency managers to ensure that local, state and regional plans, including the Regional Catastrophic playbooks, should pre-identify specific utility requirements to be supported in extreme events (including Black Sky outages).¹⁴ In addition, to help ensure the effective implementation of these plans, utilities should work with emergency managers to develop exercises that can help identify and overcome impediments to generator delivery.

Two other initiatives are underway that will also help strengthen support for utilities that rely on just in time strategies. The Water and Wastewater Response Networks (WARNs) are leading one such effort. For over a decade, the water sector has been pursuing a “Utilities Helping Utilities” concept to establish mutual aid networks, under which water and wastewater utilities can obtain emergency power generators and other types of assistance from their counterparts who can provide such aid.¹⁵ As these networks continue to grow, and their utilities have more generators available to deploy, WARNs will be vital for filling the gaps between generator supply and demand that past hurricanes have revealed. There are 50 WARNs in the United States – 49 state WARNs and a National Capital Region WARN – and two WARNs in Canada.¹⁶

USACE is also taking steps to address the problems for just in time delivery revealed by Sandy. During that superstorm, USACE personnel were severely delayed in their generator installation efforts by the failure of facilities to have

13 The POIA has not yet been released. For a description of the Annex, including its focus on prioritizing government support operations for critical infrastructure, see p. 8, Statement of Christopher P. Currie, Director, Homeland Security and Justice, Preliminary Observations on DHS Efforts to Address Electromagnetic Threats to the Electric Grid, U.S. Government Accountability Office, July 22, 2015, p. 8. <http://www.gao.gov/assets/680/671971.pdf>.

14 On Regional Catastrophic Playbook planning and preparedness goals, see <https://www.fema.gov/fy-2011-regional-catastrophic-preparedness-grant-program>

15 Morley, Kevin, Utilities helping Utilities: An action plan for mutual aid and assistance networks for Water and Wastewater Utilities, American Water Works Association, March 2006. <http://www.awwa.org/Portals/0/files/resources/water%20knowledge/rc%20emergency%20prep/rc%20warn%20resources%20pdf/WARNactionplan.pdf>

16 AWWA. WARN in Brief. <http://www.awwa.org/Portals/0/files/resources/water%20knowledge/rc%20emergency%20prep/rc%20warn%20resources%20pdf/WARNOverview2014APR.pdf>

already assessed their emergency power requirements, and to have made advance preparations to connect USACE generators to their own power systems.

USACE's Emergency Power Facility Assessment Tool (EPFAT) enables water and wastewater utilities to enter and store the information on their generator requirements and required connection materials. By ensuring that USACE already has this data available when a blackout strikes, utilities can significantly reduce the time that USACE will need to install generators at critical pump stations and other system nodes.¹⁷ Water and wastewater utilities can further accelerate generator installation by making the pre-event investments in transfer switches, control points, and other hook-up equipment necessary to connect emergency generators to their electric systems.¹⁸

Finding: The WARN and EPFAT initiatives will be extraordinarily valuable for helping make just in time strategies more viable for Sandy-scale events, as well as the less severe outages that utilities more frequently encounter.

Internal water sector requirement: Water and wastewater utilities should continue to expand their mutual assistance efforts, and ensure that they have provided the data necessary for USACE to accelerate generator installation. As discussed below, they should also examine whether and how these initiatives might be scaled up to meet the far greater challenges (and more severely disrupted environment) that Black Sky hazards will create.

17 U.S. Army Corps of Engineers, Emergency Power Facility Assessment Tool, <http://epfat.swf.usace.army.mil/>

18 EPA, Power Resilience Guide, p. 3-6.

E | Generator Requirements in Black Sky Events: Static Versus Dynamic Assessments

The wide area impact and month or more duration of Black Sky outages will produce unprecedented requests for the just in time delivery of emergency generators. This will be true not only for water and wastewater utilities, but across other critical infrastructure sectors as well, creating an intense and difficult to manage competition between high-priority facilities for emergency power.

Gustav, Rita, Ike, and other hurricanes spurred hundreds of calls from the water sector for emergency power generators. During Gustav for example, the blackout drove over 300 generator requests from the water sector.¹⁹ However, the power losses created by Gustav were concentrated in just a handful of states (primarily Louisiana and immediately adjacent areas). A combined cyber/kinetic attack, EMP strike, or other Black Sky event could easily double or triple the geographic scope of the power outage created by Gustav. Water sector requirements for the installation of power generators would multiply accordingly.

Moreover, these greatly increased water sector requests would also compete against many hundreds (and more likely, thousands) of similar requests from other critical infrastructure sectors. During Sandy, emergency managers received urgent calls for the installation of emergency generators from hospitals, fuel terminals, nursing homes, apartment towers, and a wide range of other facilities. Black Sky outages will produce an unprecedented wave of such cross-sector requests.

Extended Outage Duration: An Even More Severe Challenge for Meeting Generator Needs

The long duration of Black Sky outages will also lead to the breakdown of emergency generators from extended use. The resulting requirements for multi-

19 Curtis, Thomas, Deputy Executive Director, American Water Works Association. Letter to U.S. Environmental Protection Agency. (2011, February 4).

sector replacement generators will exacerbate potential shortfalls in generator supplies, both for utilities with just in time strategies for emergency power and for those that already have standby generators in place.

Emergency generators are typically expected to serve only occasionally, and for a limited number of hours for any single use, even though many are engineered to operate for a total of 10,000 hours or longer (the equivalent of over a year) on a periodic basis. Sandy demonstrated that when critical infrastructure owners need to continuously operate their emergency generators, those generators will start breaking down, first by the dozens and then at an accelerating rate as the blackout continues.

Maintenance problems contribute to these failures. Unless water utilities or their contractors adequately maintain and test their emergency generators, at loads consistent with actual emergency operations, those units will fail. Long duration events will require the development of new maintenance strategies, since maintaining generators during an extended outage presents unique challenges. Emergency generators typically operate on a periodic basis; when they are not in service, utilities can perform routine maintenance on them while grid-supplied power sustains operations. Moreover, many generator providers require that maintenance be performed only by their own personnel or specified contractors. Sandy produced so many calls for repairs that maintenance crews were stretched thin.

The AWWA report on Sandy found water and wastewater utilities were not always able to get timely replacements for generators that broke down, contributing to wastewater spills and other system failures during the blackout. In part, the failure to meet water sector replacement needs reflected the low priority that some emergency managers assigned to the sector. Raising that priority in disaster plans will help utilities sustain their emergency operations in extended outages.

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Unless water utilities or their contractors adequately maintain and test their emergency generators, they will fail.

The more difficult problem lies in the overall, cross-sector demand that Black Sky events will create for replacement generators (over and above initial generator installation requests). During Sandy, the USACE and other providers were inundated with requests for replacement generators from “lifeline” infrastructure facilities beyond the water sector, including public health and safety, communications, and transportation assets, as well as apartment towers, nursing homes, and other facilities essential for sheltering in place. In the health sector alone, generators at New York University’s Langone Medical Center stopped functioning only days after Sandy made landfall, as did the fuel pumps for backup generators at Bellevue Hospital.²⁰ In longer duration outages, such breakdowns will become ubiquitous and will create immense, simultaneous demand for the installation of replacement generators across multiple infrastructure sectors.²¹



The water treatment plant in Beach Haven, N.J. being run by U.S. Army Corps of Engineer generators three weeks after Hurricane Sandy hit. [Source: Liz Roll/FEMA. 11/20/2012]

20 McNeal, Gregory S. “UPDATED: NYU Hospital Without Power, Evacuation Underway, Bellevue Hospital with only 2 Hours of Power Left,” *Forbes*, October 29, 2012. <http://www.forbes.com/sites/gregorymcneal/2012/10/29/nyu-hospital-without-power-evacuation-underway/#6d196de44c03>

21 Wentland, William. “Backup Generators are the Bad and Ugly of Decentralized Energy,” *Forbes*, April 15, 2013. <http://www.forbes.com/sites/williampentland/2013/04/15/backup-generators-are-the-bad-and-ugly-of-decentralized-energy/>

Finding: As power outages extend beyond the first week of an event, an increasing number of generators will burn out and require replacement. Water and wastewater utilities should not base their assessments of generator requirements solely on what they will need for emergency operations at the outset of an event. As became apparent in Superstorm Sandy, generator burnout will become a growing problem as they operate beyond a week, and – in a Black Sky event – will greatly contribute to the mismatch between multi-sector demands for generators and available supplies for water and wastewater utilities.

Internal water sector requirement: Utilities should develop dynamic (versus static) assessments of their generator requirements, and account for likely replacement requirements over time. Current guidelines that help utilities assess their emergency power needs, including the J100-10 (R-13), “Risk and Resilience Management of Water and Wastewater” and EPA’s Power Resilience Guide, should be updated to encourage and support dynamic assessments for long duration outages.²² A number of water utilities that experienced generator failures during Sandy have made such assessments and increased their stockpiles of generators since that event. Other utilities might consider adopting a similar approach.

22 American National Standards Institute (ANSI) and American Water and Wastewater Association (AWWA), J100-10 (R-13), “Risk and Resilience Management of Water and Wastewater Systems,” <http://www.awwa.org/store/productdetail.aspx?productid=21625>; EPA (2015), Power Resilience Guide; Electricity Use and Management in the Municipal Water Supply and Wastewater Industries, <http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001433>; Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability (FEMA P-1019), <https://www.fema.gov/media-library/assets/documents/101996>; EPA, “Is your water or wastewater system prepared? What you need to know about generators,” September 2009.

F | Limited Supplies of Emergency Power Generators: The Enormous Mismatch with Black Sky Requirements

Just in time strategies for the installation of emergency generators will only be effective if adequate supplies exist to meet utility requests. Supply issues will also be crucial for utilities that already have generators in place, but will need replacements as an outage continues.



Water and Wastewater Plants Require Emergency Power To Continue to Function After a Black Sky Event

Ongoing improvements in contractor and government capabilities to provide generators (including those programs managed by the USACE) will help increase the likelihood that both sets of utility requirements can be met in typical power outages. However, in multi-state Black Sky outages that last a month or more, generator suppliers will be unable to meet the demand not only from the many hundreds or even thousands of affected water and wastewater systems, but also from other critical infrastructure sectors and essential facilities.

Two factors will contribute to this mismatch between water utility requests for generators and the ability of providers to fulfill them: 1) the limited total number of generators in public and private sector inventories; and 2) the logistical challenges of installing such large numbers of generators, given severe disruption of transportation systems that Black Sky hazards are likely to create.

1. Generator Inventories

WARNs provide an especially important and reliable source of generators for the water sector. As the number of participating utilities continues to grow, the inventory of generators available to support systems in need will expand as well. However, no estimate exists of the number of generators within that overall inventory. Moreover, in Black Sky events, many of the utilities that are prepared to assist neighboring utilities will also be in the outage footprint, limiting their ability to meet requests for help (and potentially in need of replacement generators themselves as an outage continues). Both public and private sector generator providers will need to help fill the resulting gaps in generator supplies.

a. Public Sector Providers

State agencies provide an additional public sector source of emergency generators that could be made available to the water sector. In Florida, for example, both the Florida Rural Water Association and the Florida Division of Emergency Management maintain generator pools for distribution as needed.²³ Many other states lack such programs. As with the WARN inventory, however, no estimate exists of the number of generators that state agencies are prepared to provide to the water sector or other essential systems and facilities.

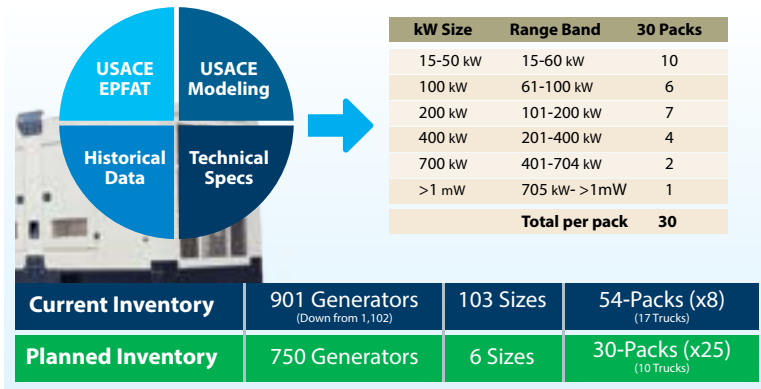


Figure 4 | FEMA Power Pack Inventory

23 EPA, Power Resilience Guide (2015), p. 3-3.

Better data is available on Federal assets. FEMA provides a key source of generators for the water sector. To meet generator requests, FEMA has pre-positioned eight “power packs” located at strategic locations throughout the country. These packs currently consist of 54 generators, ranging in size from 15 kilowatts (kw) to 800kw. USACE is transitioning to having 25 packs with 30 generators in each, for a total planned inventory of 750 generators.¹⁴² The USACE is responsible for maintaining, deploying and installing those generators, once a determination is made by FEMA to deploy. Figure 4 depicts this transitioning Power Pack inventory.”

FEMA also maintains approximately 400 generators in an “at-large pool” spread across the 10 FEMA Regions of the United States.²⁴ FEMA can also contract with private vendors to supply additional emergency generators. However, as will be discussed below, Black Sky events will create massive demands on private sector inventories and put FEMA in competition against many other customers (including water and wastewater systems) for generator delivery. Figure 5 is a map showing the 10 FEMA regions and the six mobile emergency response support locations that serve each.



Figure 5 | The 10 FEMA Regions, and their 6 mobile emergency response locations.

24 Data provided by Mr. Pete Navesky, USACE, January 2016.

Some other Federal departments and agencies, most notably the Department of Defense, also maintain significant inventories of emergency power generators. These generators are needed to help Departments sustain their critical missions and operations in a blackout, rather than to help meet the needs of the water sector.

That leaves the FEMA and power pack and “at-large” inventories as the key Federal inventories of generators for water and wastewater systems. Their combined total of generators: 1,150. This Federal inventory represents a valuable and much-needed asset to support water sector resilience against hurricanes and other traditional hazards. However, for EMP events, combined cyber-kinetic attacks, or other Black Sky events that could create sustained power outages over major portions of the United States, a substantial percentage of the 160,000+ water and wastewater utilities in the United States could require emergency power assistance. A Federal inventory of barely over a thousand generators would need to help meet those support requirements, plus respond to urgent requests from other critical infrastructure sectors and key facilities.

Moreover, note that within these Federal generator pools, a very small number of generators are sized to serve loads of 1 megawatt (MW) or larger. Many lifts and other critical nodes in major water and wastewater systems will require generators on that scale to sustain emergency operations. However, each of the 30-pack generator pools to be maintained by USACE includes only a single 1MW generator, with a total nationwide capacity of 25 such generators.

Some water and wastewater systems are configured to enable load-splitting -- that is, the use of two or more smaller generators to meet the emergency power requirements of a large-load pump or other system component. Load splitting can help mitigate the need for generators of 1MW or larger. However, from a sector-wide perspective, the shortfall in Federal inventories needed to serve water and wastewater systems (and also meet other critical infrastructure requirements) lies not only in overall numbers of generators, but also in the tiny percentage of those generators that can serve the larger loads that many systems will require.

b. Private Sector Providers

The private sector will be essential for filling the resulting gap between generator supplies and potential water sector requests for assistance. Many water and wastewater systems that rely on just in time installation strategies

have already signed contracts with private vendors, or have reserved portable generators from a rental pool during storm seasons in their region.

These arrangements work well in limited area, short duration outages that produce a relatively small number of requests for assistance. Black Sky events however, will create a tidal wave of simultaneous calls for support.

Once again, data limitations complicate efforts to quantify the gap between private sector supplies of generators and the potential demand for them. No estimate exists of the nationwide pool of vendor inventories that might be utilized in a Black Sky event. As a starting point to develop such an estimate, the Electric Infrastructure Security Council (EIS) conducted a survey of the largest generator vendors in the United States. This initial survey focused on vendor ability to provide the large (1 MW and larger) generators, given the extraordinarily small numbers of such generators maintained by the public sector.

The survey found that the total inventory for all infrastructure-grade (1MW and larger) generators available from the largest firms combined is estimated at 6,332 MW. The vendors also estimated the utilization rate of these assets at 60-70%, meaning that only about 2,652 MW is actually available for use at any given time. Broken down further, 1,475 MW of this capacity lies in the category of 5-25MW (nearly 90% in the form of 25 MW turbines). This leaves only 1,977 MW of capacity in the 0.8 MW to 2.25 MW generator size range, which will be a much closer fit with water sector needs for heavy load generators than 25MW turbines.²⁵

Very large wastewater systems can require up to 20 MW of emergency power to function. Systems in the transportation sector and other critical infrastructure sectors across the United States can entail still greater loads for emergency operations, creating a Black Sky environment where too many high-priority generators users are chasing too few generators -- especially as generators begin to burn out through extended use.

25 Electric Infrastructure Security Council (EIS), National Emergency Power Commission (NEPC) – White Paper, February 2016, p. 5.

Finding: Insufficient data exists to quantify the extent of the gap between available generator supply and Black Sky demand to fully understand the implications for water sector (and multi-sector) resilience in extended power outages. However, based on preliminary assessments, enormous shortfalls are likely to emerge in the availability of emergency generators for water and wastewater utilities, both for just in time installation and for replacement generators as Black Sky outages continue for a month or more.

Internal water sector requirement: Water sector associations should support a broad, nationwide effort to assess the size of emergency power inventories within WARNs, in state and Federal agencies, and in the private sector. In line with the preliminary survey conducted by EIS Council with major generator vendors, this analysis should also examine inventories in terms of specific load classes (including loads well below 1 MW).

A broader understanding of generator requirements will also be necessary to support water sector resilience planning. Together with the analysis of dynamic, over-time requirements for generators by water and wastewater systems, an analysis of overall, multi-sector requirements should also be conducted either by FEMA, USACE, and some other entity with broad responsibilities and expertise on emergency power requirements and responsibilities. The EIS Council proposal for a National Emergency Power Council (NEPC) calls for just such a net assessment to provide a basis for new policy and planning initiatives to strengthen Black Sky preparedness.

2. Logistical Challenges

Shortfalls in the supply of generators poses only one of the problems that water and wastewater utilities will confront in meeting their just in time power requirements, or in receiving replacements as their existing generators burn out. Additional problems will result from the logistical difficulties of transporting these generators in a Black Sky event, and the technical requirements for installing them when they arrive.

a. Generator Movement

The same Black Sky hazards that can create extended, wide-area power outages will also disrupt the transportation and communications sectors on

which generator movement depends. Catastrophic earthquakes exemplify this risk to generator resupply operations. In the Capstone 14 New Madrid exercise, which the Central United States Earthquake Consortium (CUSAC) conducted in June 2014, experts in seismic effects modeling concluded that a 7.7 earthquake along the new Madrid seismic zone (which roughly parallels the mid- and lower Mississippi River) would:

Create multi-month power outages over significant portions of an eight state region, due to shaking-induced physical damage to power generation, transmission, and distribution systems (especially high voltage transformers, and substations). An estimated 400,000 breaks and leaks in natural gas lines would also disrupt the flow of fuel to gas-generating plants that survived. With the resulting disruptions to the power grid and to fuel supplies for power generation, immense requirements would emerge for emergency power generators by the water sector and other critical infrastructure sectors.



FEMA is setting up an Incident Support Base at Maxwell Airforce Base in Alabama to stage generators, water, Meals Ready to Eat (MRE), and other supplies that Alabama emergency management can direct where the need is and get them there quickly. U.S. Army Corps of Engineers personnel fuel and test the generators before deployment. [Source: Tim Burkitt/ FEMA.04/30/2011]

Over three thousand bridges (including many spanning the Mississippi) would need repair before utilities could use them to move replacement components for the grid. Other road, rail and airport infrastructure would be similarly disrupted. Public and private sector providers of generators for the water sector, and the trucking companies on which they depend, would face extraordinary difficulties in delivering generators to water and wastewater utilities.

Gasoline pipelines and other infrastructure necessary to fuel delivery trucks would suffer massive damage.

Thousands of cell towers and other communications nodes would be destroyed, complicating efforts by generators suppliers and their multi-sector sector customers to manage and coordinate distribution operations.²⁶

Many other Black Sky hazards could create equivalent disruptions to transportation and communications sectors, stemming from the loss of electricity to them and also from the direct damage to sector components that the hazards would inflict. EMP attacks, for example, would damage microelectronics in communications systems unless they are shielded against EMP effects. Multi-sector cyberattacks (as occurred in in the simultaneous attacks on phone and electric distribution systems in Ukraine in 2015) could also affect not only the water and electric sectors, but also communications and transportation systems needed to support generator delivery operations.²⁷

b. Installation

The EIS Council survey of generator vendors asked them to identify additional problems in meeting cross-sector demands for emergency power, over and above supply limitations. The top two challenges that they noted were the availability of adequate cabling and trained personnel to install generators at water utilities and other customers.

A notional example of these installation requirements helps illuminate the difficulty of meeting them in a Black Sky event. In order to connect a 2 MW rental generator to a main switchboard that is not prepped, an engineer needs 6 sets (18 total cables) of 500 MCM SOOW cabling. Even if the generator is only 250 feet from the switchboard, it would still require 4,500 feet of cable, more than 4/5 of a mile. Additionally, depending on how prepared a facility is to receive a generator, the installation can require between 4-60 hours of labor to complete a single installation.

26 New Madrid Seismic Zone Catastrophic Earthquake Response Planning Project, "Impact of New Madrid Seismic Zone Earthquakes on the Central USA, Vol. 1, pp.vi, 46-89, at <https://www.ideals.illinois.edu/bitstream/handle/2142/14810/ImpactofNewMadridSeismicZoneEarthquakeso%20theCentral%20USAVol1.pdf?sequence=3>

27 Assante, Michael, "Confirmation of a Coordinated Attack on the Ukrainian Power Grid," Industrial Control Systems SANS Blog, January 9, 2016. <https://ics.sans.org/blog/2016/01/09/confirmation-of-a-coordinated-attack-on-the-ukrainian-power-grid>

The EPFAT program and other initiatives can reduce emergency power installation time requirements for water and wastewater utilities. Pre-purchasing and storing of cabling can also accelerate generator hook-up operations. Nevertheless, as in Sandy, significant customization will often be necessary to install generators at specific utilities. James Balocki, who served as the USACE leader for Task Force Power in Sandy, noted that generators installed in that event were specific to the various power situations they encountered. “This is not a one-size-fits-all situation where we rolled up with 75 generators in the back of a van and started dropping them off and hooking them up,” notes Balocki. “Every one of the generators had to be specially matched and connected, to safely provide temporary power.”²⁸

The National Emergency Power Commission (NEPC) Initiative will be an essential tool for national recovery from Black Sky hazards. Its three parallel missions: a greatly expanded supply of suitable emergency generators; emergency fuel distribution; and tech support.

These customization requirements created significant delays in the installation of generators during Sandy, including to the Kinder-Morgan fuel terminal and other top-priority recipients. However, in Sandy, USACE provided approximately 335 generators.²⁹

Finding: “Just in time” strategies for acquiring emergency power will need thorough revamping and reassessment. Many water and wastewater systems do not have emergency power generators or fuel tanks in place to sustain emergency operations. Instead, they either have contracts with private companies to install the required power infrastructure when a blackout occurs, or will rely on emergency management agencies or the (USACE to do so. Such “just in time” strategies offer a highly cost-effective approach to

28 Castagna, Joanne, “Engineers assist with emergency unwatering, temporary power and debris removal,” *Civil and Structural Engineer Magazine*, January 2013. <http://cenews.com/article/9168/u-s-army-corps-responds-to-hurricane-sandy>

29 Ibid.

preparedness against typical power outages. However, in Black Sky events, an enormous number of the more than 160,000 water and wastewater systems in the United States may require standby generators to sustain emergency operations. Water utilities will be competing for access to generators against hundreds (and more likely, many thousands) of other facilities requesting in extremis support, including nursing homes, health care institutions, and other priority needs.

Internal water sector requirement: The water sector should build strategies to address the enormous mismatch that will emerge in Black Sky events between the number of water and wastewater systems requesting just-in time installation of emergency generators, and available supplies. Individual utilities should also reach out to their generator providers to assess the degree to which those providers are at risk of being overwhelmed by demand in Black Sky events.

As one conclusion from this analysis, the new National Emergency Power Council (NEPC) initiative will be an essential tool for national recovery from Black Sky hazards, with its three parallel missions: A greatly expanded supply of suitable emergency generators (with specifications designed for Black Sky scenarios); emergency fuel distribution; and tech support.³⁰

In addition, installation of new generators of the required power level at unprepared facilities is complex, requiring uncommon, highly skilled, specialized knowledge. In a Black Sky environment, new installations would perforce be the exception, not the rule. In fact, where water and wastewater systems are unable to allocate resilience funds to acquire essential generators, a crucial, highly recommended fallback position is to undertake the far less expensive effort to build-in electrical connection / control points, to make it feasible to bring in generators at need, if available. Indeed, just transporting such generators is in itself challenging, requiring careful planning even under ordinary conditions. Typical lifts may need two 500KW generators, each with its own tractor trailer and a fueled weight approaching 20 tons.

30 The NEPC initiative is a new, explorative effort jointly hosted by DHS and EIS Council, with participation of a wide range of federal and state government agencies and lifeline utility corporations and associations. For more information, write to chris.beck@eiscouncil.org.



Under Black Sky conditions, fuel resupply to the water sector will be critical to maintaining emergency power.

II | EMERGENCY FUEL RESUPPLY IN BLACK SKY EVENTS

Even for water and wastewater utilities that have already installed generators, and have contracted with local fuel companies to resupply them in an emergency, storm-induced blackouts have frequently produced breakdowns in fuel distribution. NIAC's Regional Resilience report found that in Sandy, fuel availability became a critical challenge for water utilities and helped create significant risks for cascading consequences.³¹ Meeting these challenges for Black Sky hazards will present a much more difficult problem.

31 NIAC (2014), p. 107.

A | The Nature of the Fuel Resupply Challenge

Black Sky hazards will exacerbate the mismatch between supply and demand by disrupting the flow of fuel to distributors who serve the water sector. In Sandy, the blackout halted the operations of the Linden terminal of the Colonial Pipeline and additional transportation and distribution nodes for liquid fuels across the Northeast United States.³² Catastrophic earthquakes and other Black Sky hazards would create outages of at least as great a geographic scope, and also inflict physical damage on storage tanks, pipelines and other infrastructure that will slash the availability of fuel for emergency generators just when it is most vital.

In conjunction with the installation of emergency generators, both the NIAC study and the AWWA report on Sandy recommend that emergency managers elevate the priority of water sector requests for fuel resupply.³³ Doing so is vital. Many water utilities have onsite fuel storage capacity to operate their generators for 48 hours or less, and will quickly run out in a Black Sky outage.

Expanding this onsite storage will present difficult regulatory and cost recovery challenges for many utilities. The only challenge more difficult: sustain fuel resupply operations sufficiently over the course of a Black Sky outage. The average consumption of a 2MW generator is 75 gallons of diesel per hour and 3,600 gallons per day if it is run continuously for 24 hours. The average fuel tanker truck holds 9,000 gallons, meaning a new truck is needed for every 2MW of power every 2.5 days in order to maintain operation.

Moreover, water and wastewater utilities are not the only important customers for fuel resupply. Nursing homes, cell communications towers, and many hundreds or even thousands of other facilities have limited storage. Existing fuel resupply contractors and public sector providers, such as the Defense Logistics Agency (DLA), will face immense challenges in meeting even a small portion of this demand in wide-area outages, and in prioritizing deliveries across water utilities and other infrastructure essential for saving and sustaining life.

32 US Department of Energy, Comparing the Impacts of Northeast Hurricanes on Energy Infrastructure (2013), http://www.oe.netl.doe.gov/docs/Northeast%20Storm%20Comparison_FINAL_041513c.pdf

33 Ibid; AWWA (2013), p. 6.

And while new initiatives like the National Emergency Power Council are now beginning to move forward, with plans for greatly expanded, advance planning for extensive emergency fuel distribution intended for Black Sky hazards, the extraordinary levels of need will limit sustainable supply levels. Building Black Sky protocols at water and wastewater facilities that allow for operation with greatly reduced power will be vital to assure sustained service with these limited emergency fuel supply levels.

B | A Possible External Requirement: Setting Design Standards for Sustained Emergency Operations

Determining the length of time that water and wastewater systems must operate in a blackout, at whatever level of service that utilities decide to provide, is critical for assessing emergency power requirements and planning to preserve public health and safety (especially for multi-region events). Yet, very few states have specified requirements for duration of emergency service other than for maintaining minimum water pressure beyond 48 or 72 hours.

There is a reason for this gap. If state legislators or other authorities mandate that water utilities be able to sustain even minimum service levels for weeks to months, at least an implicit requirement would emerge for backup generators and fuel resupply on a scale unprecedented in the civilian economy. Meeting such requirements in many jurisdictions will be politically (if not fiscally) impossible.

But accounting for the risk of long duration outages can also help prioritize investments in emergency power and help set the “design standard” that utilities should be prepared to meet in blackout operations. Expectations in terms of outage duration will be especially important for identifying and preparing to meet fuel requirements. In addition, accounting for event duration will be vital for developing plans to save and sustain lives when Black Sky events strike.

1. Federal Regulations

The Federal government has not established a specific period over which water or wastewater systems must be able to function on emergency power.

(FEMA recommends that in general, critical assets should be able to self-sustain their operations for 72 hours, which is the benchmark set in National Electric Code Article 708 for such assets. But that is merely a recommendation. In fact, there are no federal standards or agreed-upon practices within the water infrastructure sector to govern readiness, response to security incidents, and recovery. The EPA lacks authority to require water infrastructure systems to implement specific security improvements or meet particular security standards, including for capabilities required to sustain operations during long duration blackouts.³⁴

The Public Health Security and Bioterrorism and Response Act does require drinking water utilities to identify plans, procedures, and equipment that can be implemented or utilized in the event of a terrorist or intentional attack, or that can obviate or significantly lessen the impact of a terrorist or other intentional attack, on the utility. The Act calls for utilities to develop Incident-Specific Emergency Action Procedures (EAPs), including for electrical power outage response.³⁵ The Bioterrorism Act also calls for coordination with Local Emergency Planning Committees. Coordination between the water and the local emergency management agencies (EMAs) will be critical during large emergencies as the local and/or state EMA can activate Emergency Operations Centers (EOCs) to coordinate response activities for the water sector as discussed previously.³⁶

To help water utilities develop such plans and coordinating mechanisms, the EPA has issued detailed recommendations and voluntary guidelines.³⁷ The EPA also provides extensive decision support tools to help water sector owners and operators assess their emergency power requirements. Again, however, use of

34 Copeland, Claudia (2010, December 15). Terrorism and Security Issues Facing the Water Infrastructure Sector (CRS Report No. RL32189). Congressional Research Service. Pg. 5-6. <https://www.fas.org/sgp/crs/terror/RL32189.pdf>

35 Large Water System Emergency Response Plan, p. 5

36 EPA, Coordination of the Water and Emergency Services Sectors: An Important Step to Better Response, February 2012, p. 2. https://www.epa.gov/sites/production/files/2016-03/documents/coordination_of_the_water_and_emergency_services_sector.pdf

37 (EPA) U.S. Environmental Protection Agency (2003, July). Large Water System Emergency Response Plan Outline: Guidance to Assist Community Water Systems in Complying with the Public Health Security and Bioterrorism Preparedness and Response Act of 2002, Office of Water (4601M) EPA 810-F-03-007. Pg. 2. <http://www.epa.gov/watersecurity/pubs/erp-long-outline.pdf>

these decision tools is purely voluntary, and no EPA or other Federal standards exist to mandate the length of time that water and wastewater systems must be able to function on emergency power.

2. State Standards

State and local governments have primary authority to determine requirements for emergency power operations. States typically require comprehensive plans for water and wastewater systems to assess future system needs (e.g., capacity) and how those needs will be met. The elements of those comprehensive plans are defined by the state. Many of these plans include requirements to identify hazards to which the system could be subjected, and how the utility will address those hazards -- including those that could result in long duration power outages.³⁸ A growing number of them also specify minimum pressure levels that must be maintained throughout those outages. Rarely, however, do states define long duration outages in terms of the number of days that systems must be able to operate.

New Jersey offers a case in point. In many respects, New Jersey administrative code provides standards that are well suited to clarify emergency power requirements. The state specifies that “drinking water systems must provide auxiliary power for source and treatment facilities that are primary components of the system and are necessary to continue effective operation of the system. Auxiliary power is also required for pump stations in pressure zones without storage.” New Jersey also provides detailed guidance on minimum pressure requirements. N.J.A.C. 7:19-6.7(a), N.J.A.C. 7:10-11.10(d)1, and N.J.A.C. 7:10-12.37(b)) require systems to “sustain minimum pressures of at least 20 pounds per square inch at street level, in all parts of the distribution network, under all required flow conditions.” Consequently, “auxiliary power sufficient to maintain minimum pressure shall be provided, continuously, including during a power outage.”³⁹

38 (NIST) National Infrastructure Security Council (2015, February 11). “Disaster Resilience Framework 75% Draft for San Diego, CA Workshop,” DHS, Pg. 22. http://www.nist.gov/el/building_materials/resilience/upload/Framework_LineNumbered_75-25_11Feb2015.pdf

39 New Jersey Environmental Infrastructure Finance Program (2013). “Auxiliary Power Guidance and Best Practices.” Pg. 3-4. <http://www.nj.gov/dep/watersupply/pdf/guidance-ap.pdf>

What is missing from these otherwise detailed requirements is a specific minimum length of time that emergency power must be able to sustain water and wastewater service. New Jersey and other states require water systems to self-sustain for the duration of an “extended” outage. However, beyond such generalities, no state or locality in the United States has yet set a design standard for the period for which emergency powered operations must be able to operate.

Anticipating potential requirements for extended emergency power operations will be critical for building water system resilience against Black Sky hazards, which can produce multi-region blackouts lasting a month or more. As Superstorm Sandy demonstrated, emergency power generators that operate for extended periods and begin to approach their mean time before failure will begin to break down, and need to be replaced on increasingly large scales -- across multiple infrastructure sectors and in hundreds of hospitals, EOCs, nursing homes and other facilities in a wide-area outage. Ensuring that adequate replacement generators can be accessed and installed in this demand-heavy environment will present a significant challenge. So, too, will be the task of securing fuel to power them.

External Partner Recommendation: In addition to specific requirements to maintain water pressure and other design parameters, stakeholders concerned with sector resilience should also begin to discuss anticipated outage durations, and seek consensus on requirements for blackouts lasting far longer than the 72-hour benchmark endorsed in the National Electric Code Article 708. Ideally, these stakeholders would also include the full range of those who contribute to system resilience and those who must plan against service interruptions, including 1) water and wastewater utilities; 2) those who help determine the availability of funding for investments in emergency power (including regulators and local officials); 3) emergency planners who are responsible for allocating fuel, backup generators, and potable water in long duration outages; and 4) hospitals, defense installations, and other key facilities that depend on sustained water and wastewater service.



Continuous chemical resupply is critical to the water sector.

III | TREATMENT CHEMICAL RESUPPLY IN LONG DURATION OUTAGES

Wide area blackouts lasting a month or more will also threaten the ability of water systems to restock the chemicals they need for water purification. Water treatment plants use over 10 different chemicals to meet water quality standards promulgated by the EPA and state regulators. Many systems rely on chlorine, for example, because it is so cost-effective for destroying dangerous pathogens.

Wastewater systems also depend on chemicals for water treatment. The EPA notes that unless adequately treated, wastewater can contain enteric bacteria, viruses, and protozoan cysts. Disinfecting wastewater by using chlorine and other chemicals plays an essential role in inactivating and destroying them for many wastewater plants.⁴⁰

40 EPA. 1999, September. "Wastewater Technology Fact Sheet Chlorine Disinfection," Office of Water, Washington, DC. http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_chlo.pdf

Water utilities typically stock enough of these essential chemicals onsite to operate 24-72 hours. However, a growing number now store supplies of some chemicals sufficient to sustain operations for multiple weeks. American Water, for example, generally designs facilities for 30-day of chemical storage except where the quality of the chemical degrades too quickly or where safety concerns exist for large-scale storage. The individual state Departments of Environmental Protection (DEPs) often have permitting requirements for how much chemical should be stored on site. The Recommended Standards for Water Works published by the Great Lakes - Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers recommends building sufficient space for at least 30 days of storage of supply for many chemicals.⁴¹

Black Sky power outages will disrupt the transportation systems and other infrastructure essential for chemical deliveries, and impede the broader chemical supply chain on which water and wastewater systems depend. The longer the duration and wider the footprint of the blackout, the greater these disruptive effects are likely to be on the chemical resupply system.

A | Internal water sector requirement: Planning for reduced treatment levels

As recommended in Section III, water utilities and their public sector partners should seek consensus on the specific cutbacks in water treatment operations that should be made in Black Sky events, and pre-plan for emergency waivers to allow for the delivery of water that meets only the most critical public health requirements.

Current water and wastewater treatment requirements for water clarity, odor and other aesthetics will not be critical to maintain in the “triage” environment of Black Sky operation.

41 Water Supply Committee of the Great Lakes--Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. "Recommended Standards For Water Works: Policies for the Review and Approval of Plans and Specifications for Public Water Supplies," 2012. <http://10statesstandards.com/waterrev2012.pdf>



Water Quality Drives Chemical Use at Water and Wastewater Plants

The same is true of treatment for chronic (i.e., long-term) risks to public health. As a key strategy in developing Black Sky treatment protocols, utilities may find that defining non-ideal but safe treatment levels will be highly conducive to minimizing the variety and quantity of chemicals needed. Evaluating and ultimately implementing this strategy – as for most Black Sky strategies – will require careful coordination with state and Federal regulators and other stakeholders.

B | Internal water sector requirement: Increased onsite storage

Another strategic option for the water sector to mitigate this additional Black Sky risk is to store more chemicals onsite. This approach has clear advantages for assured supply and, even if expanded storage quantities fall below predicted needs for extreme duration scenarios, it would minimize the resupply frequency for stored chemicals.

For chlorine and other toxic chemicals however, this strategy entails significant safety and security problems, as well as investments to manage them. All forms of chlorine (which include chlorine gas, hypochlorite solutions, and other chlorine compounds in solid or liquid form) are highly corrosive and toxic. The Clean Air Act requires facilities handling large quantities of chlorine and other toxic or flammable chemicals to submit risk management plans (RMPs). For chlorine, facilities storing 2,500 pounds or more onsite must

submit an RMP detailing worse case scenarios and what response measures are in place in the event of a chemical release. Approximately 2,000 water treatment and wastewater treatment plants that use chlorine in their operations fall into that category and are required to have RMPs and meet other Federal and state safety and security requirements.⁴²

The infrastructure and other costs associated with safely storing these chemicals reinforce the incentives for water utilities to minimize onsite storage, and rely instead on frequent resupply. Increasing storage capacity to sustain treatment operations in a long duration blackout without resupply might be technically possible for many utilities, but prohibitively expensive.

Further, this approach – if it becomes the primary strategy for assured treatment – can only address well-defined outage durations. While any Black Sky hazard will likely involve blackouts of a month or more, actual durations are difficult to project, especially given likely geographic variability. Depending exclusively on onsite storage risks having insufficient inventory for longer-than-projected outages.

C | External water sector partner requirement: Strengthening the treatment chemical supply chain

A third option is to strengthen the resilience of chemical production, remote storage, and distribution systems against the disruptive effects of wide-area, long duration outages.

This strategy requires a multi-level review of requirements to strengthen the full supply chain for essential chemicals. For distribution, for example, it will require prioritized chemical delivery plans that minimize state, regional, and nationwide threats to public health and safety, and that are designed for a disrupted, Black Sky environment.

42 Leeann Sinpatanasakul, "Chlorine Gas is a Major Risk Across the Country, but Needn't Be," Center for Effective Government, October 8, 2013;

As one important consideration, this strategy will require extending the “umbrella” of whole community support to include critical supply chain assets, and coordination with associated government and NGO partners. For example, distribution planning would likely require coordination and participation of National Guard forces for chemical truck convoying, road clearing, and remote storage site security, and tie-in of critical supply chain stakeholders to a national emergency communication system.

D | The Need for Further Analysis

Given the mix of advantages and disadvantages, developing a balanced combination of all three strategies for sustained treatment chemical supply provides important flexibility, allowing utilities facing different challenges to develop a combination balanced for their own situation.

As a key enabler, a sensitivity analysis will be needed to evaluate the performance and cost of each of these approaches – minimized treatment levels, increased onsite storage, and a strengthened supply chain – relative to typical utility parameters. Once developed, this analysis can then function as a tool to help local utilities to assess their own, optimum balance among the three approaches.

Analysis will also be required to determine the external requirements each of these three strategies imply for cross-sector support, as well as coordination with these external sectors to ensure assumptions on their support are integrated into their own Black Sky protocols. For example, best-case distribution and delivery support from National Guard forces may limit the resupply frequency, mandating minimum onsite storage levels.



Breakdown in waste water treatment can result in severe pollution of potential water sources.

IV | THE IMPORTANCE OF WASTEWATER RESILIENCE IN BLACK SKY OUTAGES

Sewage collection systems are typically designed to rely on gravity to the maximum extent possible. However, especially for larger wastewater utilities, electricity is essential to power lift stations and key treatment system components. For utilities that rely on energy-intensive technologies such as mechanical aerators, blowers, and diffusers to keep solids suspended and to provide oxygen for biological decomposition, treatment accounts for the largest share of energy use.⁴³

Operation of wastewater treatment plants requires large amounts of electricity, ranging from one megawatt for a medium-sized city to 20 megawatts for the largest urban systems.

43 EPA and State and Local Climate and Energy Program, p. 3

Electricity is also essential for the computers, telemetry, and industrial control systems on which an increasing number of wastewater utilities rely.

The net result: wastewater treatment plants require large amounts of electricity for the operation of pumps and process equipment. A typical medium-sized city wastewater treatment facility with an average daily flow of 20 million gallons per day (MGD) may require approximately one megawatt of power. The very largest systems, such as Los Angeles Sanitation's Hyperion Water Reclamation Plant, require 20 megawatts of power or more.⁴⁴ However, even most smaller septic systems depend on electricity to move liquid sewage from septic tanks into drain fields. All of these system components will require sustained emergency power in a Black Sky outage.

Cross-water sector interdependencies provide a further challenge for sustaining wastewater operations in long duration blackouts. Unless water utilities can sustain the flow of water through their distribution systems, whether potable or not, sewage collection systems will clog up with solids and eventually cease functioning. Once sewerage is blocked in this fashion, extensive and time-consuming repair operations will be needed to restore system functionality. The dependence of the wastewater sector on water service provides is still another impetus to drive investments in emergency power for water utilities.

Unless water utilities sustain the flow of water through their distribution systems, whether potable or not, sewage collection systems will cease functioning.

Many water utilities, in turn, depend on effective wastewater services to meet their own drinking water standards. The intakes for water systems in Washington, DC, St. Louis, and of dozens other urban areas lie downstream from the pipes that release treated wastewater from other towns and cities. If a power outage causes wastewater systems upstream to fail, and sewage flows into rivers and lakes on which water utilities rely, the raw water taken in by those utilities can become too polluted to treat up to drinking water standards. Long duration, region-wide power outages will be especially likely to cause such cascading failures from wastewater to water systems.

44 Adel Haagekhalil, DGUP Background Information, November 30, 2015.

Loss of wastewater service will also cause cascading failures in other critical facilities and functions. As sewage backs up into homes, offices, and facilities critical for maintaining public health and safety (including hospitals and police stations), those facilities will quickly become difficult to use and ultimately become uninhabitable. The disruption of health care services will present especially significant challenges as sewage spills into streets and spreads pathogens to the local population.

Emergency managers, however, can take steps to mitigate some of these effects of disrupted wastewater service. When the 2011 earthquake in Christchurch, New Zealand, caused widespread breakage of sewerage pipes and other system components, emergency workers were able to stave off a looming health crisis by deploying over 38,000 chemical toilets. Workers also installed hundreds of large-scale chemical toilet waste tanks around the city.⁴⁵

Emergency managers in Oregon, Washington State, and other seismic zones are currently studying lessons learned from these Christchurch response operations to build preparedness in their own regions. Their preliminary conclusion: no practical options exist to mitigate the public health threats that region-wide disruptions of wastewater service will create. These threats will be equally severe if wastewater service is halted by Black Sky induced power outages from other natural or manmade hazards, unless 1) wastewater systems have adequate emergency power to maintain at least minimal service, and 2) water utilities can maintain sufficient flow of water to keep sewage collection and other wastewater system elements unclogged and functional.

As sewage backs up into homes, offices, and facilities critical for maintaining public health and safety and military bases, they will become uninhabitable.

The disruption of health care services will present especially significant challenges as sewage spills into streets and spreads pathogens to the local population.

45 Bill Noell, Pattle Delamore and Partners and Rob Meek Christchurch City Council, A Day in the Life of an Earthquake Sewer Recovery Operation. <http://www.pdp.co.nz/documents/2012NoellMeek1.pdf>



Water Treatment Plant

Loss of wastewater service would have equally disruptive effects on base operations over time. Backup power in key facilities will also have little value if their wastewater service goes down. Loss of wastewater service can quickly create threats to public health, and, over time, render hospitals, nursing homes, EOCs and other key facilities uninhabitable and incapacitated. The same is true of many DOD facilities that execute mission essential functions (MEFs).

A | Developing Black Sky Requirements for Wastewater System Operations

As with water systems, requirements for emergency operations by wastewater systems are set by state governments rather than by the EPA. State standards for wastewater systems frequently parallel those established for water utilities. New Jersey's requirements are typical in this regard. N.J.A.C. 7:14A-23.13(h) requires that auxiliary power must be provided for all treatment facilities in New Jersey that can "continue essential system operations throughout the duration of an extended power outage."⁴⁶ This language suffers from the same open-ended ambiguity as the standards for water system operation. As with

46 New Jersey Environmental Infrastructure Finance Program (2013). "Auxiliary Power Guidance and Best Practices." Pg. 3-4. ;<http://www.nj.gov/dep/watersupply/pdf/guidance-ap.pdf>

water utilities, wastewater system owners and operators should partner with emergency managers and other stakeholders to provide more specific targets for the duration of emergency operations, especially given the difficulty of mitigating the consequences of system failure.



Aerial View of a Sewage Treatment Plant

In two other respects, however, the New Jersey standard provides a valuable model for other states to consider adopting. First, while the standard leaves outage duration open-ended, New Jersey provides a comprehensive frame of reference for establishing emergency power requirements:

A system's auxiliary power must have sufficient "capacity" to meet the specified service standard for the duration of the power outage (capacity in this context is defined as adequately sized generators) sufficient fuel storage (or reliable access thereto), service parts (i.e., oil and oil filters for generators, or other key components) and qualified technicians to ensure viable operation).⁴⁷

Second, New Jersey's standards make a crucial point regarding the expense of meeting emergency power capacity requirements. The standards note that "While the cost of installing auxiliary power can be significant, the additional cost of a unit(s) designed for extended operation may actually be cost-effective compared with the increased maintenance costs and the implications of failure of an overworked unit."⁴⁸

47 New Jersey Environmental Infrastructure Finance Program (2013). "Auxiliary Power Guidance and Best Practices." Pg. 3-4. <http://www.nj.gov/dep/watersupply/pdf/guidance-ap.pdf>

48 Ibid.

The implications of failure extend not only to a wastewater system's emergency power generators, but also to the cascading consequences of system failure for public health and for other infrastructure sectors.

B | Unique Resilience Challenges and Opportunities for Wastewater Systems: Findings and Recommendations

Finding. It will be extraordinarily difficult to mitigate the catastrophic effects of the loss of wastewater service in an extended, wide area blackout. Accordingly, sustaining wastewater operations will be at least as important as keeping water utilities functional in Black Sky outages.

Recommendation: Given the interdependencies between wastewater and water services, emergency power requirements for both of these sector components should be considered in a holistic fashion for Black Sky events, as well as on a utility-specific basis. Discussions of emergency power requirements (including prioritized fuel resupply) should also be informed by analysis of the cascading failures that an extended loss of wastewater would entail for critical facilities and disaster response/consequence management operations.



Water and Wastewater Plants Require Emergency Power To Continue to Function After a Black Sky Event

V | EXTERNAL REQUIREMENTS

A | Emergency Power Support

A critical, external requirement for the water sector is cross-sector support for emergency power needs in a long duration, Black Sky hazard. As the sector develops internal requirements that can reduce but not eliminate their need for emergency power and fuel, without external support they will not be able to sustain adequate service to allow large populations to shelter in place throughout the length of Black Sky-induced outages.

Without external support, the water sector will not be able to sustain adequate service to allow large populations to shelter in place throughout the length of Black Sky-induced outages.

The consequence of a failure to develop external assistance to the water sector for Black Sky hazards: unsupportable mass migration, with catastrophic consequences, and severe implications for national continuity.

Building and implementing an effective plan for external support for emergency generation should therefore be a critical national objective.

Such support requirements will not, it should be noted, be static requirements. While a range of guidelines is available to help assess (initial) emergency generator needs, existing guidelines pay little attention to the likely evolution of generator requirements over the course of a widespread, long duration blackout. However, as briefly noted in the Section I of this volume, generator burnout will be a significant factor in Black Sky outages.

Accounting for generator replacement needs will be critical for building utility and sector-wide preparedness, and for determining “how much emergency power is enough.”

During Sandy, the breakdown of emergency generators in hospitals and nursing homes provided a prime focus of concern for emergency managers, and highlighted the broader cross-sector problems that water utilities and other critical infrastructure service providers will face. Only days after the Sandy blackout began, generators at New York University’s Langone Medical Center stopped functioning, as did the fuel pumps for backup generators at Bellevue Hospital.⁴⁹ In longer duration outages, such breakdowns will become ubiquitous and will create immense, simultaneous demand for acquisition, transport, and installation of replacement generators, especially large, megawatt-class replacement generators, across multiple infrastructure sectors.⁵⁰

The consequence of a failure to develop external assistance to the water sector for Black Sky hazards: unsupportable mass migration, with catastrophic consequences, and severe implications for national continuity.

49 McNeal, Gregory S. “UPDATED: NYU Hospital Without Power, Evacuation Underway, Bellevue Hospital with only 2 Hours of Power Left,” *Forbes*, October 29th, 2012.

50 Wentland, William. “Backup Generators are the Bad and Ugly of Decentralized Energy,” *Forbes*, April 15, 2013, at <http://www.forbes.com/sites/williampentland/2013/04/15/backup-generators-are-the-bad-and-ugly-of-decentralized-energy/>

One reason that emergency generators failed during Sandy is that they are typically expected to serve only occasionally, and for a limited number of hours. While many are engineered to operate for a total of 10,000 hours or even more on a periodic basis (the equivalent of over a year), Black Sky outages will require continuous operation. Such sustained operations will also greatly complicate maintenance activities. Sandy illuminated the cumulative result of these factors: when critical infrastructure owners operate generators in this mode, generators will break down, first by the dozens and then on a rapidly growing scale as the blackout continues.

Sandy illuminated an additional challenge for the water sector: as systems without generators asked emergency managers to help provide and install them, and as generators that were already in service began to break down, utility requests for generators were not always treated as a priority. The American Water Works Association (AWWA) Superstorm Sandy After-Action Report found requests for priority on generator [and fuel] supply “were in some cases not accepted or denied if ‘not immediate need.’” The Report goes on to note that:

“This occurred in several instances, even when water service to a regional hospital was in potential jeopardy because one generator failed and a second unit required maintenance following several days of 24-hour operation. Emergency operations center personnel failed to recognize that elevating the power needs of the facility to “immediate need” would be in the best interest of the community and, more importantly, the patients served by the hospital. Supporting the maintenance of system status and preventing service from degrading should receive priority consideration in relation to systems that have already been completely compromised.”⁵¹

However, the emergency managers and other authorities responsible for allocating backup generators during Sandy faced competing demands for support. Requests for generators not only mounted as the outage continued, but spread across multiple infrastructure sectors, including communications cell towers, transportation nodes, oil and gas systems, as well as apartment towers and other facilities. USACE alone received requests for generators at over 335 sites during Sandy in New York and New Jersey, with many more requests flowing to other private and public sector providers.

51 AWWA Sandy report p. 6

Further complicating the tasks for prioritizing these requests, many of the most urgent focused on infrastructure nodes that had not previously been identified as having system-wide significance, and whose criticality only emerged as Sandy's effects accumulated. "Surprise" requirements for emergency power were especially prominent in the energy sector. At the Kinder-Morgan fuel terminal, for example, the USACE had to immediately respond to an unanticipated, top-priority requirement to install a purpose-built power generator to help resolve the regional liquid fuel crisis exacerbated by pipeline failures.⁵²

Equivalent surprises occurred in the healthcare sector. Increasingly, dialysis and other crucial services are provided in small, widely distributed facilities, as opposed to being centralized in hospitals. Many of these small facilities lack adequate emergency power. The same is true of nursing homes and other care facilities, all of which created unanticipated, high priority demands for the installation and replacement of emergency generators during the Superstorm.⁵³

These escalating demands for generators in Sandy revealed underlying challenges for sustaining water service in blackouts.

The AWWA Report is correct to emphasize that serious disruptions stemmed from the failure of some emergency managers to recognize the importance of supporting water and wastewater service during the Superstorm.

However, an additional lesson from Sandy is that as a blackout continues, requests for generators will escalate across multiple critical infrastructure sectors, putting assistance to the water and wastewater systems in competition for limited resources against other urgent needs. Long duration outages will also reveal and raise the criticality of infrastructure nodes that were not apparent on "blue sky" days, and that had not been anticipated as potentially urgent targets for supplemental emergency power. Prioritizing competing, cross-sector requests for emergency generators will present major challenges for

52 <http://www.defense.gov/news/newsarticle.aspx?id=118464>

53 After Hurricane Sandy: Lessons Learned for Bolstering the Resilience of Health Systems and Services," Kostas Research Institute for Homeland Security, November 14, 290013, <http://www.northeastern.edu/kostas/wp-content/uploads/2013/08/Health-Systems-and-Services-Resilience.pdf>; U.S. Army Corps of Engineers, "USACE ESF#3 and Hurricane Sandy Response, 11 April, 2013, http://www.samesanfrancisco.org/wp-content/uploads/2013/04/SAME_SF_USACE_Sandy_Perspective_Crary_041113.pdf

emergency managers in future events, especially as sustained outages widen the gap between available resources and overall demand for backup power.

Black Sky events will exacerbate all of these problems. In outages lasting a month or more that cover multi-state regions, many more water and wastewater utilities than in Sandy will either: 1) request the installation of generators because they have none or not enough of their own; or 2) need replacement generators for those that have broken down. The same will be true of owners/operators of other infrastructure sectors competing for dwindling backup supplies.

B | Preparedness for Emergency Power Support: Findings and Recommendations

a. Finding: Emergency Generator and Fuel Support

In Black Sky events, generators will break down due to extended use, and the challenge of maintaining the ones that are still functioning will escalate as wear and tear on them accumulates.

Recommendation: Establish a National Emergency Power Council. The first steps that have been taken toward developing a National Emergency Power Council (NEPC) should be encouraged, and followed up by full establishment of such a Council tasked with addressing limited emergency generator supply, generator maintenance and burnout, and generator fuel at critical facilities and lifeline infrastructures.

To address these problems, as well as the closely related problem of adequate emergency fuel and fuel deliveries in a disrupted Black Sky environment, NEPC stakeholders should consider three taskforces, operating as part of the Council:

i. Emergency Generator Taskforce

Tasking:

- Assess, at top-level, emergency generator requirements as a function of time during extended duration, Black Sky events, as required for nationwide critical facilities and lifeline infrastructures serving high

density populations. Include estimated optimum regional distribution of these assets, to address critical facility and lifeline infrastructure needs, associated with Black Sky hazards. Over time, this assessment should be continually refined, by working closely with a wide-spectrum government and corporate process. (See the following recommendation, below).

- Based on the top-level needs assessment, acquire an adequate inventory of appropriately sized, EMP-protected generators designed for long duration, continuous operation. The inventory should include provisions for storage, maintenance and logistics support. As refined requirements become available, supplement this procurement as required.
- Acquire an adequate inventory of highly configurable, flexible interface units, designed to simplify physical and electrical connection of generators in physically and electrically constrained facilities.
- Preplan a range of options for real-time transportation and installation of generators in Black Sky disrupted environments, to include appropriate logistics support, security, road clearing, and other requirements.
- Coordinate with lifeline utilities to enable them to synergistically acquire their own generators as part of an NEPC-coordinated procurement.
- Maintain an updated, Black Sky-protected database of contact information for personnel at critical facilities that may require NEPC support during Black Sky events.

ii. Fuel Distribution Taskforce

Tasking:

- Evaluate emergency fuel needs associated with Black Sky Hazards.
- Pre-plan to maintain undisrupted access to adequate fuel sources during a Black Sky event.
- Preplan for extensive, nationwide emergency fuel distribution capable of indefinite continuity, to include adequate logistics support, security, road clearing, and other requirements for disrupted environments, for the vehicle fleets.

iii. Tech Support Taskforce

Tasking:

- Develop a national and regional emergency generator maintenance and support plan for the generators.
- Evaluate likely failure modes for existing generators, and newly acquired generators, under stressful, continuous operation for extended durations.
- Evaluate size and optimum regional distribution of tech support teams to address critical facility and lifeline infrastructure needs. This should include an assessment of likely needs for both remote and in-situ support to critical facilities and lifeline infrastructures.
- Develop recommended, user-capable maintenance plans for different generator types.
- Preplan a capability for providing remote failure assessment and maintenance support.
- Preplan coordination with providers for emergency transportation support for tech support personnel.

b. Finding: Refined, broadly coordinated assessment of generator requirements is needed

Given the complexity and interdependencies of lifeline infrastructures, and the requirements of other critical national resources, critical facilities, and different vital emergency support sectors, a carefully refined, prioritized assessment of cross-sector generator requirements will be needed to supplement the “top level” initial assessment of the NEPC team.

Recommendation: Initiate a broad, cross-sector, ongoing evaluation of detailed emergency generation requirements.

This evaluation should be developed, as required, for specific urban areas, states, and FEMA regions. Specific actions to take:

- In its March 2015 report, “Executive Collaboration for the Nation’s Strategic Infrastructure,” the National Infrastructure Advisory Council’s (NIAC) recommended establishment of a Strategic Infrastructure Executive Council (SIEC) to focus on national critical infrastructure priorities. The Council’s scope would include four strategically vital sectors: water, transportation, communications, and finance. The SIEC

should be established and tasked with responsibility to initiate and oversee the assessment of prioritized, cross-sector emergency generator requirements. Appropriate private and public sector representation from the water sector will be essential to help guide that effort, including representation from the Water and Wastewater Agency Response Networks (WARNs) and other partners with programs and expertise on emergency power.⁵⁴

- The FEMA and Department of Energy (DOE) are with their public and private sector partners to develop a cross-sector Power Outage Incident Annex (POIA) to the Response and Recovery Federal Interagency Operational Plans. FEMA regions, beginning with Region 5 (Illinois and adjacent states), will also develop region-specific plans for extended outages.⁵⁵ These regional POIA plans should assess and prioritize cross-sector requirements for emergency generators and emergency fuel, match those requirements up against the FEMA Generator Inventories located in Atlanta, Fort Worth, and other regional storage centers, and conduct a gap analysis to inform acquisition and emergency management initiatives.
- The USACE is the Federal coordinator for emergency power within Emergency Support Function #3 (ESF-3), Public Works and Engineering.⁵⁶ As such, USACE is especially well-positioned to conduct cross-sector assessments of priority emergency power requirements. The Corps is currently expanding the Emergency Power Facility Assessment Tool (EPFAT), which helps critical public facilities -- including water and wastewater utilities -- assess their generator requirements and provide connection data that will help USACE speed the installation of generators when an event occurs.⁵⁷ These assessments (and other

54 Morley, Kevin and Riordan, Ray, Utilities Helping Utilities: An Action Plan for Mutual Aid and Assistance Networks for Water and Wastewater Utilities, American Water Works Association, March 2006. <http://www.awwa.org/Portals/0/files/resources/water%20knowledge/rc%20emergency%20prep/rc%20warn%20resources%20pdf/WARNactionplan.pdf>

55 FEMA, Region V. <http://www.fema.gov/region-v-il-mi-mn-oh-wi>

56 FEMA, Emergency Support Function #3 – Public Works and Engineering Annex, <https://www.fema.gov/pdf/emergency/nrf/nrf-esf-03.pdf>

57 USACE, Emergency Power Facility Assessment Tool. <http://epfat.swf.usace.army.mil/>

initiatives underway by the 249th Engineering Battalion “Prime Power”) should be leveraged to help develop regional, cross-sector generator requirements and gap assessments using current and projected generator inventories.⁵⁸

c. Finding: Prioritizing Water Sector Support

It is vital that the NEPC team and other emergency managers understand the foundational importance of water and wastewater service (and hence their priority in allocating emergency generators) in Black Sky events, to avoid the threats to public health and safety likely to extend far beyond those experienced in Sandy.

Recommendation: Progress must continue on implementing the AWWA Report’s recommendations that in future events, the NEPC team and emergency management leaders at all levels “must grant high priority to water sector requests for emergency generators and/or fuel before it becomes an ‘immediate need.’”⁵⁹

c | External Support for Treatment Chemical Resupply: Findings and Recommendations

The situation with treatment chemical resupply is quite similar to that of emergency power. As the water sector works to define and implement rational, safe reductions in water treatment for Black Sky environments, it will likely reduce significantly the types and quantities of treatment chemicals they require.

Nevertheless, for long duration Black Sky Hazards, it is extremely unlikely that most utilities will be capable of maintaining sustained drinking water service without external, cross-sector support for treatment chemical resupply.

58 USACE, Emergency Power. <http://www.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/219/Article/475473/emergency-power.aspx>

59 AWWA Sandy report p. 6



Water and Wastewater Plants Require a Large Quantity of Treatment Chemicals

Finding: Treatment chemical resupply

In Black Sky events, utilities focusing on sustaining minimal drinking water service will need, in addition to support for sustained emergency power, external support to resupply treatment chemicals. While the types and quantities of such chemicals will likely fall to an irreducible minimum, as a result of the sector's assessment of internal requirements for Black Sky events, resupply will still be required for those minimum needs in the long duration power outages and disrupted environments characteristic of these events.

Recommendation: Establish a National Emergency Utility Consumables Council. In a fashion similar to the first steps already being taken toward establishing a National Emergency Power Council (NEPC), the extraordinary size and geographic distribution of the nation's water sector mandates a similar organizational approach. A National Emergency Utility Consumables Council (NEUCC) should be established, tasked with addressing resupply of consumables for lifeline infrastructures generally and, in the case of the water sector, with treatment chemical resupply.

To address this need in a disrupted Black Sky environment, NEUCC stakeholders should consider two taskforces, operating as part of the Council:

i. Treatment Chemical Production and Storage

Tasking:

- Assess, at top-level, treatment chemical requirements for extended duration, Black Sky events, as required for nationwide water utilities

serving high density populations. This should include estimated optimum regional distribution of these chemicals.

- Based on this needs assessment, evaluate the full supply chain for chemical supply, and develop a plan to provide adequate, cross-sector support to sustain production and storage of these chemicals, with attention given to regionally located sources. The plan should include provisions for storage, maintenance and logistics support.

ii. Treatment Chemical Distribution

Tasking:

- Preplan a range of options for real-time transportation and delivery of chemicals in Black Sky disrupted environments, to include logistics support, security, road clearing, and other requirements as appropriate.
- Maintain an updated, Black Sky-protected database of contact information of personnel at high population density-associated water utilities that may require NEUCC support during Black Sky events

APPENDICES

APPENDIX A

EVACUATION PLANNING (FOR EXTERNAL PARTNER SECTORS)

Developing multi-sector plans to support (minimized) mass evacuations and shelters

The need to pre-plan for targeted delivery of water and wastewater services to evacuees constitutes an additional resilience challenge. Under Emergency Support Function #6 (ESF-6), Mass Care, local, state and Federal emergency managers and NGO leaders should partner with the water sector to build regional, coordinated strategies to account for evacuation contingencies, including developing plans to prepare for regional shelters and to support sites along major evacuation routes, where water and wastewater service will be easiest to sustain in long duration, wide area blackouts. These locations should also become critical locations in electric sector planning for Black Sky events, for inclusion as critical load associated with Protected Enclave EMP-protected segments of Black Start cranking paths.

Co-development of requirements for controlled evacuation and sheltering in Black Sky scenarios will be essential, spanning government, NGO and lifeline utility sectors.

The EPRO ESC and Steering Committees provides a hosting platform for this process.

This example highlights the importance of very broad, rigorous cross-sector coordination in building plans and making resilience investments for Black Sky outages. Contingency plans for controlled, properly resourced evacuation and sheltering will be essential to save and sustain lives across a multi-region blackout. This requires thorough advance coordination and co-planning among the water, electricity, NGO, Federal government, and state government sectors. The EPRO Executive Steering Committee (ESC) and the corresponding EPRO State Sector Steering Committees for each of the above sectors provide an important hosting platform for co-development of the mission concepts and cross-sector interface requirements that will be needed.

APPENDIX B

OPPORTUNITIES TO REDUCE EMERGENCY POWER REQUIREMENTS

Energy Efficiency

The most efficient and cost-effective way to deal with emergency power requirements is to reduce the amount of electricity that a system needs to sustain operations. A growing number of water and wastewater facilities are investing in new technologies to make them more energy efficient, and cut the amount of electricity they require.¹ Those efforts can significantly reduce the number of generators required for emergency operations and the amount of fuel needed for them as an outage continues.

Energy Recycling

Large-scale wastewater facilities in Los Angeles, Washington DC, and other cities in the United States and abroad are also building gas generators fueled by methane captured during their treatment operations. Some of these projects produce so much power that the wastewater plants can rely largely on self-generated electricity. The “digester gas” generator at the Hyperion wastewater plant in Los Angeles, for example, is designed to provide 28 megawatts of electricity and meet all of the facility’s power needs.²

Black Sky Operating Protocols

In Black Sky environments, re-optimizing the operational configuration and operating procedures to meet minimal, well-defined and coordinated Black

1 US EPA, Energy Efficiency in Water and Wastewater Facilities: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs (2013), at <http://www3.epa.gov/statelocalclimate/documents/pdf/wastewater-guide.pdf>

2 In theory, these generators can not only reduce wastewater systems requirements for outside power, but also operate as a power “island,” and function as a self-contained micro grid in a regional power outage. In practice, as will be analyzed in Section V of this volume, many such systems lack the distribution infrastructure to do so.

Sky operating protocols in a number of areas can have a substantial impact on emergency power requirements, including total power consumption and fuel supplies.

- Geographic / zone prioritization
- Pressure Reduction
- Treatment focused solely on minimal safe purity levels

Other Approaches

Two additional approaches can downsize water sector requirements for emergency power. Both are useful in short duration, small-footprint blackouts, though they will be of much less value in Black Sky outages.

Dual Feeds

One frequently used measure to strengthen water and wastewater resilience against localized power outages is to have two independent grid-supplied sources of power, provided by relying on different substations or other measures to provide for redundant supplies. If dual feeds are genuinely independent and properly configured, they can enable utilities to sustain operations during localized outages where only one feed is compromised, even for utilities that lack backup generators.

Dual feeds provide no such redundancy when a blackout is large enough to affect both power feeds. Kevin Morley, Program Manager for Security and Preparedness for the American Water Works Association (AWWA), notes that dual feeds have been “useless” in mitigating the effects of regional blackouts such as those in Katrina, Ike, and the Derecho storms.³ They will be similarly ineffectual in Black Sky outages of wider scope and duration.

Prioritizing the Restoration of Grid Power to Water and Wastewater Systems: Essential but Not Sufficient

A more effective way to reduce the need for replacement generators and fuel resupply is to ensure that as electric utilities begin to re-energize the grid, they restore power to water and wastewater systems ahead of less critical customers.

3 Morely, A Lesson in Resilience from Derecho, p. 20.

Sandy has helped mobilize the water sector to seek such elevated status. The AWWA's Superstorm Sandy After Action Report recommends that when power distribution utilities prioritize the restoration of grid service to their customers, they should treat water sector assets as a "top priority."⁴

Many electric utilities already place water and wastewater systems in their top tier for restoring service. However, according to Peter Grevatt, Director of the EPA's Office of Ground Water and Drinking Water, a key goal for the Agency is to ensure that prioritized restoration for the water sector becomes a broadly accepted practice and focus of electric utility planning.⁵

Electric utilities face significant challenges in resolving competing claims for priority and determining which assets are most critical. Regional hospitals, major defense installations, transportation nodes, and other critical facilities and functions will also deserve consideration for the earliest possible restoration of grid service. Engineering and grid design factors can also constrain the order in which electric utilities can restore critical loads.

However, as with the electric sector itself, water and wastewater service is foundational: hospitals and many of the other critical facilities that merit early power restoration will be crippled, or become rapidly uninhabitable, without such service even if they can maintain emergency power until grid-provided electricity is restored.

Recommendation

Water and wastewater system owners should meet with their local electric utilities and other key stakeholders to agree on and provide for the prioritized restoration of service to those systems. As electric utilities identify the critical loads that should be served as soon as possible when black start power restoration operations begin, or as those utilities re-energize the grid by importing power from outside the affected area, critical water and wastewater system loads should be served as early as practical from an engineering perspective.⁶

As noted in Section III, water utilities vary by size. A useful starting point

4 AWWA Report, p. 6.

5 Presentation to E-PRO Summit, July 2015, Washington DC.

6 E-PRO Handbook, pp. 99-102.

would be to provide for the prioritized restoration of the largest of these systems (those serving 100,000 customers or more) and then work backwards to include smaller systems, especially those whose failure would nationally or create regionally significant cascading failures in critical infrastructure functions. Emergency management and homeland security officials can help support these criticality assessments by using the DHS's Regional Resilience Assessment Program (RRAP).

While critically important, however, providing for the prioritized restoration of power will also be inadequate for water sector resilience against Black Sky outage. "Waiting for the cavalry to arrive" in the form of a re-energized power grid is no panacea for such events. In a blackout lasting a month or more, emergency power will be essential for utilities to sustain water and wastewater service. To determine how much emergency generating capacity and fuel supplies these utilities need, the next steps are to decide what level of service they should be able to maintain in Black Sky outages, over what portions of their service area, and for how long.

APPENDIX C

MICROGRIDS

Microgrids and “secure power enclaves”

Instead of relying on multiple spot generators for backup emergency, water and wastewater utilities may also have the option of constructing larger scale generators and power distribution systems to serve multiple pumps and other critical loads in a blackout. Such utilities may be able to operate microgrids, and sustain emergency operations (especially at reduced service levels) without relying on grid-provided power. Over the longer term, opportunities will also emerge for the water sector to collaborate with electric utilities and other partners to establish secure power enclaves, protected against Black Sky hazards and scaled up to serve nearby hospitals, defense installations, and other facilities along with water and wastewater systems.

Finding: Major wastewater systems have especially promising opportunities to establish microgrids for Black Sky operations. In Washington DC, Los Angeles, and other metropolitan areas, wastewater systems are partnering with power companies to build combined heat and power (CHP) generation facilities, fueled by biogas that is captured from the waste treatment process. These multi-megawatt generators can provide much of the power required to sustain wastewater plant operations. However, unless such projects include the additional investments in power distribution systems and other requirements for islanded operation, wastewater systems will still depend on emergency power generators to function in blackouts. Washington’s Blue Plains facility, for example, is unable to operate as a microgrid and must rely on contractors to deliver and install emergency generators (required by large-scale fuel resupply operations) if grid-provided power goes out.

Recommendation: As wastewater utilities consider the development of CHP systems, utility leaders, elected officials, and other resilience stakeholders should carefully consider opportunities to provide for microgrid operations, and balance the incremental costs of doing so against the potential benefits for sustaining wastewater service in long duration blackouts.

Finding: Water utilities face significant (but resolvable) challenges in building larger-scale generators to help playbook implementation. For water utilities to strengthen the cost-effectiveness of investments in power generation capacity, including megawatt-level gas turbine units, one especially significant option is to build generators that can provide power to the grid during peak load periods, and be available to sustain emergency water system operations if a blackout occurs. Selling power to the grid can help defray the costs of constructing and maintaining such generators. Moreover, they can be sized for sufficiently large power outputs to serve multiple water system loads in an emergency, and (if the power distribution system is built out accordingly) can provide for microgrid operations in Black Sky events. However, air quality standards and other regulatory issues can impede efforts to construct/operate such generators. In addition, unless the flow of natural gas can be sustained in a power outage, generators that depend on that flow will be unable to help sustain emergency water operations in Black Sky events.

Recommendation: As with expanded fuel storage, water system owners should collaborate with regulators and other emergency management stakeholders to explicitly consider the tradeoffs between air quality standards and the benefits of improved water system resilience against long duration outages. Water systems located near military installations should also consider partnering to develop larger scale microgrids built around on-base peaking power plants (which are increasingly being developed by DOD as a way to serve critical loads in blackouts). Finally, as such generators are constructed, the natural gas system resilience initiatives proposed in Volume I of this Handbook will also be necessary to help ensure that fuel supplies are available for turbine units that water systems construct.

Finding: Over the longer term, secure power enclaves can provide a holistic means of strengthening water and cross-sector resilience. The E-PRO Handbook I examined ways that electric utilities can selectively protect grid components to develop secure power enclaves, capable of withstanding Electromagnetic Pulse attacks and other Black Sky hazards, and optimized to continue serving critical loads (including water and wastewater system) with

minimal interruption.¹ Such enclaves would maximize water sector resilience against Black Sky outages and be especially effective in helping communities in and near them avert mass migrations.

Recommendation: While electric utilities will need to make many of the investments necessary to create secure power enclaves, water and wastewater systems should help lead cross-sector discussion on their design to ensure that minimalist service goals can be sustained in Black Sky events.

1 E-PRO Handbook I, pp. 94-8.

