Water Quality Impacts of Extreme Weather-Related Events [Project #4324]

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OBJECTIVES

The objective of this research was to identify and characterize water quality impacts, ranging through all levels of conveyance and treatment from source to tap, of extreme weather-related events. This project was specifically intended to support the Water Research Foundation's Climate Change Strategic Initiative objective to provide water utilities with a set of tools to identify and assess their vulnerabilities, and develop effective adaptation strategies. By identifying the characteristics of extreme weather-related events, better characterizing the impacts of these events on water quality, and documenting the "lessons learned" from such events, we can help utilities obtain a better understanding of the potential impacts of extreme weather events on water quality so that they can prepare and respond to such events quickly and effectively.

BACKGROUND

In light of recent weather-related disasters and our increased awareness of the vulnerability of water supply infrastructure, many water utilities and industry support entities are struggling with the issue of how best to prepare for the broad range of possible climate change impacts, and are searching for new approaches to respond to an uncertain future. Extreme weather-related events are of primary concern to drinking water utilities, since they could affect the supply availability and quality, treatability, and infrastructure integrity/function that may in-turn affect water service reliability and complexity, drinking water quality, regulatory compliance, consumer perception, and overall costs. Water utility infrastructure and operations procedures are generally designed to enable utilities to reduce the risks from typical, region-specific, weather events to an acceptable level, but a thorough understanding of the potential risks from atypical, extreme weather, combinations of extreme weather events, and unexpected trends in weather patterns is necessary for proper planning for the future. Therefore this study was designed to gain a deeper understanding of the implications of recurrent extreme events on water supply systems so that proper planning and management of available resources can be accomplished to limit current and future vulnerabilities. Due to the sensitivity of much of the material collected throughout this project, care was required to ensure proper anonymity of sources where required.

APPROACH

The project approach consisted of a phased two-year process to engage and involve project partners in developing case studies that describe the impacts of extreme weather-related events on water quality, treatment processes, infrastructure, personnel, and customers. In addition to case studies collected throughout the project, published sources of data were used to compliment and support the information gathered from the case studies. Both qualitative and quantitative impacts were collected and evaluated, in addition to "lessons learned," from the case studies of previous events. Several working definitions were used throughout the project including:

Water Quality Impact

Any substantial change in source quality/availability, treatment needs, or distribution/finished water storage conditions affecting, or potentially affecting, drinking water quality. In the context of this project, discussion regarding water quality impacts may also include damage or other impacts to the treatment plant itself (physical infrastructure) in addition to impacts on staffing requirements during and after extreme weather-related events. Infrastructure and staff impacts are included here, as both are viewed as an integral part of ensuring optimum water quality and public health protection.

Extreme Weather-Related Event

Any substantial change in weather type, severity, frequency, duration, or combination of events. Events may be relatively brief but severe, such as a tropical (wind, rain, electrical) storm, flood, forest or bushfire, or a longer term change such as seasonal or average temperature changes, drought, seawater or wastewater influence. An 'event' may be a single extreme event occurrence, or it may be an unusual combination of less-intense events that lead to negative and/or unexpected impacts on water quality.

WaterQIEWE

This acronym was used as the name for the Excel tool, based on an abbreviation of "Water Quality Impacts from Extreme Weather-related Events." The Tool is available on the WRF Website on the 4324 project page under Project Resources/Web Tools.

The research conducted during this study included the following strategies:

1) Utilization of a broad-reaching, technology-based collaborative approach incorporating virtual meetings, webinars, and workshops to collect and organize data and experiences from the United States and Australia regarding water quality impacts from extreme weather-related events;

2) Inventory, categorization, and assessment of the occurrence of extreme weather-related events affecting participating utilities;
3) Identification and characterization of the impacts of extreme weather-related events on source water quality, treatment and distribution processes, and finished water quality;
4) Development of a broadly-applicable Excel-based tool (WaterQIEWE) to assist large and small utilities with identifying system vulnerabilities, planning for extreme weather-related events, monitoring and documenting such events, and minimizing costs associated with such events; and
5) Development of broad-based findings, summaries, and recommendations for use by utilities and support entities to understand and adapt to extreme and changing weather, specifically to minimize negative water quality impacts.

RESULTS/CONCLUSIONS

Climate change predictions indicate potential long-term changes in the hydrologic cycle resulting in increasing intensity and frequency of events that challenge water utilities to maintain operational and water quality objectives. Changes to source water quality, such as weather-related increases in loading of chemical or microbial contaminants, generally necessitate treatment/operational changes, which in turn may result in higher operation and maintenance costs; variations to chemical application rates (disinfectant, oxidant, coagulant, or pH/alkalinity adjustment); alterations in filtration schemes (more frequent granular media backwashing, GAC regeneration, membrane fouling, etc.); and increased residuals and waste-stream volumes that may overwhelm facilities). If present treatment technologies cannot be adapted to source quality changes, alternate sources or new treatment technologies may be needed. Because extreme events can theoretically happen at any time, and may occur with greater intensity and frequency in the future, utilities without appropriate contingency plans and future infrastructure planning will be less able to quickly recover from, adapt to, and plan for future weather-related impacts. Such preparation for future events may include the planning, upgrade, and building of facilities that are more resilient to extreme weather-related events.

During some events, utilities may not be able to maintain the same level of quality that regulations require or consumers expect. This could result in severe consequences, such as having to announce boil notices for tap water, or other concerns such as aesthetic impacts (e.g., taste and odor). Consumer responses to water quality changes vary depending on the circumstance, and will need to be understood if they are to be effectively addressed. If quality changes are aesthetically discernible (taste, odor, color, turbidity) but present no safety hazard, customer education will be needed to prevent unwarranted alarm, and targeted flushing may be needed. If consumer advisories are required in the case of treatment failures or distribution system breaches, these advisories need to be properly targeted and delivered according to regulations and best practices to maximize public health protection and maintain regulatory compliance. Where consumers are impacted by weather or climate change-related increases in cost of service and/or mandatory water conservation measures, an attentive ear to customers and customer advocates will also be required. Thus, it will be critical for utilities to understand the potential for such events beforehand, so that proper protocols can be developed for responding to incidents in a timely manner. A rapid, organized response by the utility can help minimize negative public perception.

The costs associated with responding to extreme weather events varied widely and were dependent upon the size of the utility and the type of response required (e.g., building a desalination plant for a major urban area vs. adding powdered activated carbon for a small utility). For some utilities much of the response cost was covered in normal operating budgets, or was simply not reported in the case studies. However, over half of the case studies did include itemized costs for at least some of their preparedness, responses, and future adaptive measures. Table ES-1 (also in Chapter 5, **Error! Reference source not found.**) summarizes these immediate response costs and future adaptation costs in millions of USD or AUD. It should be noted that the costs were not normalized on a per MGD or per connection basis due to the complexity and variety of utilities (e.g., wholesalers, urban, rural, groundwater, surface water) and the manner in which they reported data (population served, number of service connections, treatment capacity, number of treatment plants, etc.).

Table ES-1: Extreme Weather-Related Event Response, Adaptation Costs*

	Immediate	Future	Per year
Number of Responses	23	18	5
Median	$353,000	$10,000,000	$61,000
Average	$58,900,000	$181,000,000	$295,000
Minimum	$1,000	$52,000	$10,000
Maximum	$1,200,000,000	$3,000,000,000	$1,000,000

* Costs of US Dollar and the Australian Dollar were approximately equal at the time of writing

APPLICATIONS/RECOMMENDATIONS

A recurring theme throughout the case studies and this report is that combinations of extreme events are much more challenging from an operations and response perspective than stand-alone extreme events. During times of crisis, all systems are tested to their maximum capacity, flexibility, and capability and often that leads to startling discoveries of weaknesses, failures, and limitations that were not previously anticipated or understood. Having a well-trained staff that knows the most recent response plans and can respond to them, regularly inspecting and testing equipment, such as valves, gates, and pumps, having redundant, inter-connected systems, and having worst-case scenarios included in training, long-term planning, and decision-making procedures all help utilities respond efficiently and effectively to extreme weather-related events. Another important take-home message is the importance of staff being ready to document new real-time responses and new lessons learned when extreme weather events occur. Thus, it is critical that future planning efforts consider the impact of combinations of events, and the various permutations of water quality impacts from those events, to create a water utility infrastructure and staff that can manage and respond to extreme events.

Some of the most pertinent recommendations that came from the case studies and that are relevant to all utilities, regardless of the type of extreme weather event or water quality impact, are summarized below.

- Join the Water/Wastewater Utilities Agency Response Network (WARN) in the United States or the Water Services Infrastructure Assurance Advisory Group in Australia

- Deploy online water quality monitors in the reservoir(s) and watershed/catchment to help identify water quality excursions prior to water reaching the treatment plant and to help guide decision-making on where to obtain the highest quality water
- Consider supply redundancy options (water reuse, desalination, groundwater, multiple reservoirs) to improve the ability of a utility to manage extreme weather (and water quality) events
- Plan for an increased volume of residuals and have a means of removing or disposing of those residuals during extreme events
- Train multiple staff members to perform jar testing, as it is a critical skill needed at most drinking water treatment facilities
- Ensure operators understand the entire water supply system to better shape and inform decision-making during extreme events
- Wholesalers should ensure they are able to provide information to retailers quickly and efficiently during events
- Budget for additional testing and additional chemicals and fuel that are needed during extreme events
- Link SCADA systems to field response personnel to help inform decision-making and response efforts
    - Backup data systems/data centers should be located at physically distinct locations to avoid having both systems fail form a single event
- Delineate a crisis management time for response during the event and a recovery team for response after the event
- Be prepared to issue boil water advisories or other public information when needed and do so quickly
- Conduct a "hot debrief" with staff during, or at the end of, the event to capture as much knowledge as possible; debriefs that occur weeks or months after the event are less valuable
- Regularly conduct training refresher exercises to ensure staff will be prepared to respond

MULTIMEDIA

The Microsoft Excel®-based Water Quality Impacts of Extreme Weather Events (WaterQIEWE) Tool is available on the 4324 project page under Project Resources/Web tools. It was designed to provide a means of quickly sorting and accessing case studies that may be relevant to a particular utility. Case studies can be sorted based on various criteria including geographic location, weather, water quality, year of event, and water source. The Case Studies are also available packaged into a single PDF document, bookmarked by Case Study Number. These are available on the 4324 project page under Project Resources/Case Studies.

RESEARCH PARTNERS

Project funding was provided by the following agencies:
Water Research Foundation
Water Services Association of Australia
Water Environment Research Foundation

PARTICIPANTS

The key to the success of this study was the involvement of utility and agency partners from across the United States and Australia. The following utilities or agencies participated in one or more project phases, including response to the introductory questionnaire, workshop participation, case study development, project materials review, and/or worked with the team to develop and provide a case study for this study.

Utility or Agency Name	Country	State
ACTEW Corporation	Australia	ACT
Coliban Water	Australia	VIC
Hunter Water Corporation	Australia	NSW
Melbourne Water	Australia	VIC
Mid-Coast Water	Australia	NSW
SA Water	Australia	SA
Seqwater	Australia	QLD
Sydney Catchment Authority	Australia	NSW
Sydney Water	Australia	NSW
Alaskan Native Tribal Health Consortium	USA	AK
Aqua America	USA	TX
Broward County	USA	FL
Central Arkansas Water	USA	AR
Central Lake County Joint Action Water Agency	USA	IL
City of Boulder	USA	CO
City of Fort Lauderdale	USA	FL
City of Houston	USA	TX
City of Raleigh	USA	NC
City of Santa Cruz	USA	CA
City of St Louis	USA	MO
City of Tulsa	USA	OK
Clayton County Water Authority	USA	GA
DC Water	USA	DC
Fairfax Water	USA	VA
Greater Cincinnati Water Works	USA	OH
Jordan Valley Water Conservancy District	USA	UT

Utility or Agency Name	Country	State
Lake Havasu City	USA	AZ
Lansing Board of Water and Light	USA	MI
Manchester Water Works	USA	NH
Mohawk Valley Water Authority	USA	NY
Monroe County Water Authority	USA	NY
Nashville Metro Water Services	USA	TN
New York City Department of Environmental Protection (NYC DEP)	USA	NY
Newport News Waterworks	USA	VA
Northern Kentucky Water District	USA	KY
Ohio River Valley Water Sanitation Commission (ORSANCO)	USA	IN, WV, OH, NY, IL, KY, PA, TN
Orange Water and Sewer Authority (OWASA)	USA	NC
Pinellas County Utilities	USA	FL
Southern Nevada Water Authority	USA	NV
United Water	USA	PA
West Virginia American Water	USA	WV
Wichita Water Utilities	USA	KS