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Report to the Chairman, Committee on Environment and Public Works, U.S. Senate

March 2007

SECURING WASTEWATER FACILITIES

Costs of Vulnerability Assessments, Risk Management Plans, and Alternative Disinfection Methods Vary Widely

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Highlights

Highlights of GAO-07-480, a report to the Chairman, Committee on Environment and Public Works, U.S. Senate

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Why GAO Did This Study

Wastewater facilities provide the essential service of collecting and treating wastewater, and discharging treated effluent into receiving waters. Since September 11, 2001, the nation's water infrastructure has received greater attention, including the risk of terrorist attacks at wastewater facilities that store hazardous chlorine gas for disinfection.

In 2006, GAO reported that many large wastewater facilities have responded to this risk by voluntarily conducting vulnerability assessments and converting from chlorine gas to other disinfection methods. The Clean Air Act requires all wastewater facilities that use threshold quantities of chlorine gas to prepare and implement risk management plans to prevent accidental releases and reduce the severity of any releases.

In this study, GAO was asked to provide information on (1) the range of costs large wastewater treatment facilities incurred in preparing vulnerability assessments and risk management plans, and (2) the costs large wastewater treatment facilities incurred in converting from chlorine gas to alternative disinfection processes. To answer these questions, GAO conducted structured telephone interviews with a number of facilities surveyed for the 2006 report. The Environmental Protection Agency (EPA) agreed with the report and provided several technical changes and clarifications.

www.gao.gov/cgi-bin/getrpt?GAO-07-480.

To view the full product, including the scope and methodology, click on the link above. For more information, contact John Stephenson at (202) 512-3841 or stephensonj@gao.gov.

What GAO Found

Among the large wastewater facilities GAO examined, the costs reported to prepare vulnerability assessments ranged from $1,000 to $175,000, while costs to prepare risk management plans ranged from less than $1,000 to over $31,000. Whether the documents were prepared in-house or contracted to third parties such as engineering firms was a factor in cost differences. Despite higher costs, some facilities preferred to use contractors due to their expertise and independence. According to one wastewater security official, these attributes can give contractor findings and recommendations greater credibility with utility governing boards that determine spending priorities. One facility that used a contractor to complete a vulnerability assessment in 2002 did so because, at the time, vulnerability assessment software and training were not widely available. Since that time, EPA has increased funding for the development and dissemination of risk assessment software and related training. Overall, cost estimates for vulnerability assessments and risk management plans did not relate to facility size, as measured by millions of gallons of wastewater treated per day.

For the large wastewater facilities GAO examined, reports of actual and projected capital costs to convert from chlorine gas to alternative disinfection methods range from about $650,000 to just over $13 million. Most facilities converted, or planned to convert, to delivered sodium hypochlorite (essentially a concentrated form of household bleach shipped in bulk to the facility). Managers of these facilities told GAO they considered other options, but chose delivered sodium hypochlorite because its capital conversion costs were lower than those associated with other alternatives, such as generating sodium hypochlorite on-site or using ultraviolet light. Overall, the primary factors associated with facilities' conversion costs included the type of alternative disinfection method chosen and the size of the facility. Other cost factors facility managers cited included (1) whether existing buildings and related infrastructure could be used in the conversion, (2) labor and building supply costs, which varied considerably among locations, (3) the cost of sodium hypochlorite relative to chlorine gas, and (4) the extent to which training, labor, and regulatory compliance costs were reduced for utilities that no longer had to rely on chlorine gas.

Contents

Abbreviations

AWWARF	American Water Works Association Research Foundation
DHS	Department of Homeland Security
EPA	Environmental Protection Agency
NACWA	National Association of Clean Water Agencies
OSHA	Occupational Safety and Health Administration
POTW	publicly owned treatment works
RAM-W	Risk Assessment Methodology for Water Utilities
VSAT	Vulnerability Self Assessment Tool
WEF	Water Environment Federation

United States Government Accountability Office
Washington, DC 20548

March 30, 2007

The Honorable Barbara Boxer
Chairman
Committee on Environment and Public Works
United States Senate

Dear Madam Chairman:

Wastewater facilities in the United States provide essential services to residential, commercial, and industrial users by collecting and treating wastewater and discharging treated effluent into receiving waters. The Centers for Disease Control and Prevention cited sewage disposal and water treatment as important contributors to the control of infectious diseases, which it considers 1 of the 10 greatest achievements in public health of the 20th century. Wastewater disinfection, a key component of the wastewater treatment process, reduces the risk that disease will be transmitted through wastewater effluents. Historically, chlorination has been the most commonly used method of wastewater disinfection because it destroys a variety of pathogens and microorganisms.

Since the events of September 11, 2001, the security of the nation's water infrastructure against terrorist threats has received greater attention, including the potential for terrorist attacks at wastewater facilities that store large amounts of chlorine gas. If released, chlorine gas may threaten utility employees and the public near the affected facilities. The gas can be deadly if inhaled and, at lower doses, can burn the eyes and skin and inflame the lungs. In a 2004 report, the White House Homeland Security Council determined that a terrorist attack on an urban chemical facility that resulted in the rupture of a chlorine gas rail car could kill up to 17,500 individuals and hospitalize as many as 100,000.

While federal law does not require wastewater systems to take security measures to protect specifically against a terrorist attack, it does require certain wastewater facilities to take security precautions that could mitigate the consequences of such an attack. For example, the Clean Air Act[1] requires wastewater facilities that use threshold quantities of certain

[1]Pub. L. No. 101-549 (1990).

hazardous substances, such as chlorine gas, to prepare and implement a risk management plan designed to prevent accidental releases of regulated substances and reduce the severity of those releases that do occur.[2]

As we reported in March 2006,[3] many of the nation's large wastewater facilities have improved security since September 11, 2001. For instance, a substantial number of facilities reported improving security fences, increasing security lighting, and implementing improved employee and visitor identification systems, among other security enhancements. In addition, though not required, many large wastewater facilities reported that they conducted vulnerability assessments[4] to identify risks to key process components such as the use, storage, and handling of chlorine gas. Finally, many facilities reported that they recently stopped or plan to stop using chlorine gas in favor of alternate disinfection methods. Commonly used alternatives include sodium hypochlorite, essentially a concentrated form of household bleach, and ultraviolet light, which breaks down disease-causing microorganisms.

For wastewater facility managers, the costs of preparing vulnerability assessments and risk management plans and converting to alternate disinfection methods must compete for available resources with other infrastructure needs. For instance, in 2003, in its most recent Clean Water Needs Survey, the Environmental Protection Agency (EPA) estimated that, nationwide, wastewater systems faced $181.2 billion in costs to upgrade treatment systems and sewer lines, reduce the incidences of combined sewer overflows, which result in the discharge of untreated wastewater into receiving waters, and meet other pollution control requirements. Major U.S. cities, including Washington, D.C., and Cincinnati, Ohio, are facing costs between $1 billion and $2 billion to implement necessary capital improvements.

[2]EPA requires that any facility storing at least 2,500 pounds of chlorine gas submit a risk management plan.

[3]GAO, *Securing Wastewater Facilities: Utilities Have Made Important Upgrades but Further Improvements to Key System Components May Be Limited by Costs and Other Constraints*, GAO-06-390 (Washington, D.C.: Mar. 31, 2006).

[4]According to the Environmental Protection Agency (EPA), vulnerability assessments performed by water sector utilities address not only utility vulnerabilities, but also utility threats and consequences.

This report provides information on (1) the range of costs large wastewater treatment facilities incurred in preparing vulnerability assessments and risk management plans, and (2) the costs large wastewater treatment facilities incurred in converting from chlorine gas to alternative disinfection processes.

To identify the costs of preparing vulnerability assessments and risk management plans, we conducted structured telephone interviews with a select sample of large wastewater facilities identified as having completed these assessments in our March 2006 report.[5] Our March report identified 106 large facilities that prepared vulnerability assessments or had one underway and 85 facilities that were required to prepare risk management plans because they currently used chlorine gas as a disinfectant. From this universe, we chose a nonprobability sample of facilities based largely on geographic representation and size.[6]

To identify the costs incurred by wastewater treatment facilities in converting from gaseous chlorine to alternative disinfection processes, we conducted structured telephone interviews with most of the 38 large facilities identified in the March report as having converted recently from chlorine gas or indicating that they planned to do so. We also conducted site visits with some of the facilities. Where available, we gathered documentation, such as capital plans, from these facilities in order to document conversion costs. We supplemented the cost information we gathered at individual wastewater facilities with information obtained at EPA, the Department of Homeland Security (DHS), and nongovernmental organizations. Reported costs for preparing vulnerability assessments, risk management plans, and conversion from gaseous chlorine include both actual and estimated costs. For estimated costs, we asked facility managers to explain how they arrived at these estimates. Reported costs were not adjusted for inflation. We determined that reported cost data were sufficiently reliable to provide useful information about the costs for preparing vulnerability assessments, risk management plans, and conversion from gaseous chlorine and the factors that affect these costs. We conducted our work between August 2006 and March 2007 in

[5]We defined large wastewater facilities as those publicly owned treatment works (POTW) that serve residential populations of 100,000 or greater.

[6]Results from nonprobability samples cannot be used to make inferences about a population, because in a nonprobability sample some elements of the population being studied have no chance or an unknown chance of being selected as part of the sample.

accordance with generally accepted government auditing standards. A more detailed discussion of our scope and methodology is included in appendix I.

Results in Brief

The expenses large wastewater facilities reported to prepare vulnerability assessments and risk management plans varied widely among the facilities we interviewed, costing less than $1,000 in some cases to $175,000 in others. The cost differences were related to whether the documents were prepared in-house or contracted to third parties such as engineering firms. Despite higher costs, some facilities preferred to use contractors due to their expertise and independence. According to one wastewater security official, these attributes can give contractor findings and recommendations greater credibility with utility governing boards that determine spending priorities. Overall, cost estimates of the facilities we interviewed did not relate to facility size, as measured by millions of gallons of wastewater treated per day.

Large wastewater facilities that converted or plan to convert from chlorine gas disinfection to alternative disinfection processes also report widely varying costs, ranging from about $650,000 to just over $13 million. Key factors associated with these costs included the type of alternative disinfection method chosen and the size of the facility. The majority of the facilities we examined converted or plan to convert to sodium hypochlorite (either delivered in bulk to the facility or generated on-site), which has lower capital costs than converting to ultraviolet light. For example, managers of a treatment facility in Virginia told us they spent about $1.2 million in 2004 converting to bulk sodium hypochlorite disinfection, while managers of a comparably sized facility in Maryland told us they plan to spend an estimated $4 million converting to ultraviolet light disinfection by the end of this year. Managers of the Maryland facility indicated that one reason they chose the more expensive ultraviolet treatment option over bulk deliveries of sodium hypochlorite was to reduce risk to local traffic that could result from additional deliveries to the plant. In addition, using ultraviolet light eliminates the need for wastewater treatment plants to handle and store significant amounts of hazardous or corrosive chemicals. Other than the disinfection method and facility size, key cost factors wastewater facilities cited included
(1) whether existing buildings could be used in the conversion,
(2) building costs, which varied considerably from location to location,
(3) the higher cost of sodium hypochlorite relative to chlorine gas, and
(4) the extent to which training, labor, and regulatory compliance costs were lower at plants that no longer had to rely on chlorine gas.

Background

A majority of the nation's wastewater is treated by publicly owned treatment works that serve a variety of customers, including private homes, businesses, hospitals, and industry. These publicly owned treatment works are regulated by the Clean Water Act. Wastewater treatment includes a collection system (the underground network of sewers) and a treatment facility. Wastewater enters the treatment facility through the collection system, where it undergoes an initial stage called primary treatment, during which screens remove coarse solids, and grit chambers and sedimentation tanks allow solids to gradually sink. Next, wastewater enters secondary treatment, where bacteria consume most of the organic matter in the wastewater. After these processes, wastewater is disinfected to eliminate remaining pathogens and other harmful microorganisms.

Wastewater facilities typically use both chemical and physical disinfection methods, including the following:

- *Chlorine gas*. Injecting chlorine gas into a waste stream has been the traditional method of disinfecting wastewater. Chlorine gas is a powerful oxidizing agent, is relatively inexpensive, and can be stored for an extended period of time as a liquefied gas under high pressure. Also, the residual chlorine that remains in the wastewater effluent can prolong disinfection after initial treatment. However, chlorine gas is extremely volatile and hazardous, and it requires specific precautions for its safe transport, storage, and use. Because it is stored and transported as a liquefied gas under pressure, if accidentally released, chlorine gas can quickly turn into a potentially lethal gas. EPA requires, among other things, that any facility storing at least 2,500 pounds of chlorine gas prepare a risk management plan that lays out accident prevention and emergency response activities. At certain concentrations, the residual chlorine that remains in wastewater effluent is toxic to aquatic life, so wastewater facilities that use chlorine compounds may also need to dechlorinate the treatment stream before discharging it to receiving waters.[7] Chlorine can also oxidize certain types of organic matter in wastewater, creating hazardous chemical byproducts, such as trihalomethanes. Our March 2006 report found that many large wastewater facilities have discontinued, or are planning to discontinue using chlorine gas as a disinfectant in favor of alternative disinfection methods such as sodium

[7]Sulfur dioxide, often used for dechlorination by wastewater facilities, is also covered by risk management plan rules when used or stored in threshold amounts.

hypochlorite delivered in bulk to the facility. Of the 206 large wastewater facilities responding to our survey, only 85 facilities indicated they currently use chlorine gas, and 20 of these facilities plan to switch from the gas to another disinfectant.

- *Sodium hypochlorite.* Injecting sodium hypochlorite—essentially a concentrated form of household bleach—into a waste stream is another chlorination method of disinfecting wastewater. Sodium hypochlorite is safer than chlorine gas because, if spilled, it remains liquid and can be contained and recovered. For this reason, it is not subject to EPA's risk management planning requirements. However, sodium hypochlorite is more expensive than chlorine gas, and it degrades quickly if it is exposed to sunlight or is not kept at proper temperatures. For this reason, properly storing delivered sodium hypochlorite in the concentration necessary to disinfect wastewater may require an on-site building with environmental controls. Sodium hypochlorite can also be generated on-site at a wastewater facility using an "electrochlorination system" that produces sodium hypochlorite through an electrical reaction with high-purity salt and softened water. Facilities choosing this method of disinfection reduce chemical costs, but face increased electrical costs from the generation equipment. Because it is a chlorine compound, wastewater facilities using sodium hypochlorite must also be concerned with residual chlorine and hazardous chemical byproducts, such as trihalomethanes.

- *Ultraviolet light.* This disinfection method uses ultraviolet lamps to break down disease-causing microorganisms in wastewater. Wastewater passes through an open channel with lamps submerged below the water level. The lamps transfer electromagnetic energy to an organism's genetic material destroying the ability of its cells to reproduce. Because ultraviolet light is a physical process rather than a chemical disinfectant, it eliminates the need to generate, handle, transport, or store hazardous and corrosive chemicals. In addition, there are no harmful residual effects to humans or aquatic life. However, ultraviolet light disinfection may not be effective given the turbidity of some wastewater streams. Wastewater facilities using ultraviolet instead of chlorine gas or delivered sodium hypochlorite for disinfection will face additional costs to maintain lamps and increased electrical costs.

- *Ozone.* This disinfection method feeds ozone generated on-site from oxygen exposed to a high-voltage current into a contact chamber containing wastewater. According to EPA, ozone is very effective at destroying viruses and bacteria, but it is the least used disinfection method in the United States largely because of its high capital and maintenance costs compared to available alternatives.

According to EPA, vulnerability assessments help water systems evaluate susceptibility to potential threats such as vandalism or terrorism and identify corrective actions that can reduce or mitigate the risk of serious consequences. The Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (the Bioterrorism Act)[8] required drinking water utilities serving populations greater than 3,300 to complete vulnerability assessments by June 2004.[9] Wastewater facilities are not required by law to complete vulnerability assessments. Congress has considered bills that would have encouraged or required wastewater treatment plants to assess vulnerabilities, but no such requirement has become law.

In our March 2006 report on wastewater facility security efforts, we found that many large wastewater facilities have either completed a vulnerability assessment or had one underway. Of the 206 large wastewater facilities that responded to our survey, 106 facilities—or 51 percent—reported that they had completed a vulnerability assessment or were currently conducting one. Several other facilities indicated they had conducted or planned to conduct other types of security assessments. Facilities cited several reasons for completing a vulnerability assessment or some other type of security assessment, but most—roughly 77 percent—reported doing so on their own initiative. Many facilities indicated they were combined systems—facilities that manage both drinking water and wastewater treatment. As such, 37 percent of facilities reported that they did some type of security assessment in conjunction with the required assessment for their drinking water facility.

The Clean Air Act requires wastewater facilities that use or store more than 2,500 pounds of chlorine gas to submit to EPA a risk management plan that lays out accident prevention and emergency response activities.

[8]Pub. L. No. 107-188 (2002).

[9]The Bioterrorism Act required the assessments to include, but not be limited to, a review of six components: (1) pipes and constructed conveyances; (2) physical barriers; (3) water collection, pretreatment, treatment, storage, and distribution facilities; (4) electronic, computer, or other automated systems that are utilized by the water system; (5) the use, storage, or handling of various chemicals; and (6) the operation and maintenance of such systems. The act further required systems to prepare or revise an emergency response plan incorporating the results of the vulnerability assessment within 6 months after completing the assessment.

Under this act, EPA requires that about 15,000 facilities—including chemical, water, energy, and other sector facilities—that produce, use, or store more than threshold amounts of chemicals posing the greatest risk to human health and the environment take a number of steps to prevent and prepare for an accidental chemical release. EPA regulations implementing the Clean Air Act require that the owners and operators of chemical facilities include a facility hazard assessment, an accident prevention program, and an emergency response program as part of their risk management plans. The regulations required that a summary of each facility's risk management plan be submitted to EPA by June 21, 1999. The plans are to be revised and resubmitted to EPA at least every 5 years, and EPA is to review them and require revisions, if necessary.

Costs of Preparing Vulnerability Assessments and Risk Management Plans among Large Wastewater Facilities Vary Widely

Although accurate information on the costs of vulnerability assessments and risk management plans is limited, available estimates suggest that their costs vary considerably. A factor contributing to the cost differential was whether they were contracted to third parties (such as engineering consulting firms) or prepared in-house with existing staff. Despite higher costs, some facilities preferred using contractors because their expertise and independence lent credibility to their assessments, which may be useful in obtaining support for security-related upgrades. Costs generally did not relate to facility size, as measured by million of gallons of wastewater treated per day.[10]

Vulnerability Assessment Costs Depend Primarily on Whether a Contractor Is Used

The reported cost of preparing vulnerability assessments at the 20 large wastewater facilities where we interviewed officials ranged from $1,000 to $175,000. Whether the assessment was done in-house with existing staff or contracted to a third party was a factor contributing to the cost differences. Officials from several facilities told us they used contractors to complete vulnerability assessments in 2002. For example, staff at the Denver Metro Wastewater Reclamation District reported that a contractor completed a vulnerability assessment in November 2002 for its Central Treatment Plant, which treats 130 million gallons of wastewater per day, at

[10]In our structured interviews we asked facility managers to provide estimates of their treatment facility's "existing flow" in millions of gallons per day. "Existing flow" refers to the calculated average flow for a recent 12-month period, as defined by EPA in its Clean Water Needs Survey, and is a common measure of treatment facility size. When we note how many gallons per day a facility treats, we are referring to its reported "existing flow."

an estimated cost of $175,000. Of this cost, $100,000 was for the contractor, and $75,000 was estimated for in-house staff time.

Other large wastewater facilities that reported completing vulnerability assessments in 2002 were part of combined systems that provide both drinking water and wastewater services. These systemwide vulnerability assessments were done before the 2002 Bioterrorism Act required drinking water utilities serving populations greater than 3,300 to complete vulnerability assessments by June 2004. The combined systems that conducted systemwide vulnerability assessments include the following:

- *San Antonio Water System (San Antonio, Texas)*. According to system staff, a contractor completed a systemwide vulnerability assessment for all its drinking water, wastewater, and related infrastructure in August 2002 for $112,000. Staff did not provide an estimate of in-house costs related to the assessment, but prorated the wastewater treatment plants costs related to this contract at $37,000: $25,000 for its Dos Rios plant, which treats 70 million gallons per day; $5,000 each for its Leon Creek and Salado Creek plants, which treat 33 million gallons per day; and $2,000 for its Medio Creek plant, which treats 5 million gallons per day.

- *The Phoenix Water Services Department (Phoenix, Arizona)*. According to department staff, a contractor completed a systemwide vulnerability assessment for its five drinking water plants, three wastewater plants, and related infrastructure in November 2002 for $479,725. Staff did not provide an estimate of in-house cost related to the assessment, but estimated the contract costs related to its largest wastewater treatment plant, the 91st Avenue Sewage Treatment Plant, which treats 140 million gallons per day, to be $100,000.

- *Fort Worth Water Department (Fort Worth, Texas)*. According to department staff, a contractor completed a systemwide vulnerability assessment for its four drinking water plants and one wastewater treatment plant in December 2002 at a cost of $292,300. Staff did not provide an estimate of in-house cost related to the assessment, but estimated the contract costs related to its Village Creek Wastewater Treatment Plant, which treats 96 million gallons per day, at $73,075.

Wastewater facility managers cited several reasons for using contractors to complete vulnerability assessments. Staff with the Phoenix Water Services Department told us they used contractors for their vulnerability assessment because a citywide policy required that contract services be used whenever possible. Staff at other wastewater facilities told us that, despite the higher costs, they preferred to use contractors because of their expertise. According to a wastewater security official, contractor expertise and independence can give contractor findings and recommendations greater credibility with utility governing boards that determine spending priorities.

One manager told us that he used a contractor for a 2002 vulnerability assessment because risk management software and tools were not yet available. After the events of September 11, 2001, EPA provided funding to the Association of Metropolitan Sewerage Agencies[11] to develop software, called the Vulnerability Self Assessment Tool (VSAT), for water utilities to use to develop vulnerability assessments. According to a Water Environment Federation (WEF) official, VSAT became available in June 2002. This official also said that EPA provided funding to WEF to provide training workshops to wastewater utilities on how to use VSAT to conduct vulnerability assessments beginning October 2002.[12]

According to interviews with wastewater facility managers, large wastewater facilities that prepared vulnerability assessments in-house with existing staff reported lower costs for preparing the document. These include the following:

- *City of Ventura Public Works Department (Ventura, California).* According to facility staff, in-house staff completed a vulnerability assessment in March 2003 for the Ventura Water Reclamation Facility, which treats 9 million gallons per day, at a cost of roughly $1,000 in staff time. Facility staff participated in VSAT training sponsored by EPA and completed the assessment using this tool.

[11]Now the National Association of Clean Water Agencies (NACWA).

[12]Prior to September 11, 2001, EPA worked to develop and disseminate risk assessment methodologies for water utilities. In 2000, EPA funded an initiative with the American Water Works Association Research Foundation (AWWARF) and the Sandia National Laboratories to apply risk assessment methodologies developed by the laboratories to water utilities. The methodology, called the Risk Assessment Methodology for Water Utilities (RAM-W), was designed to assist large water utilities and security professionals in assessing the risks from malevolent threats. Through an interagency agreement with EPA, Sandia National Laboratories provided training to selected firms in the RAM-W methodology so that these firms could then provide training and technical assistance to water utilities.

- *City of Fort Wayne Utilities Division (Fort Wayne, Indiana)*. According to facility staff, in-house staff completed a vulnerability assessment in November 2005 for the Fort Wayne Water Pollution Control Plant, which treats 43 million gallons per day, at undetermined staff time. Facility staff participated in VSAT training and updated a previous risk assessment prepared for the facility by a contractor in 2000 at a contracted cost of $10,000.

- *City of Eugene Wastewater Division (Eugene, Oregon)*. According to facility staff, in-house staff completed a vulnerability assessment in October 2005 for the Eugene/Springfield Regional Water Pollution Control Facility, which treats 38 million gallons per day, for about $2,000 in staff time.

- *City of Cedar Rapids Department of Water Pollution Control (Cedar Rapids, Iowa)*. According to facility staff, in-house staff completed a vulnerability assessment in January 2007 for the Cedar Rapids Wastewater Treatment Plant, which treats 35 million gallons per day, for about $5,000 in staff time.

- *Detroit Water and Sewerage Department (Detroit, Michigan)*. According to department staff, in-house staff completed a vulnerability assessment in January 2005 for the Detroit Wastewater Treatment Plant, which treats 700 million gallons per day, for about $20,000 in staff time.

Risk Management Plan Costs Also Influenced by Use of Contractors

Costs to prepare risk management plans ranged from less than $1,000 for facilities that completed the plan in-house to over $31,000 for facilities that used contractors. Costs to update risk management plans were generally less, ranging from less than $1,000 to $20,000 depending upon whether facilities used in-house staff or contractors.

Costs were generally higher at facilities that used contractors. These include the following:

- *The Phoenix Water Services Department (Phoenix, Arizona)*. According to department staff, a contractor completed risk management plans for all the system's drinking and wastewater facilities in 1999 for $230,086. Costs for the 91st Avenue Sewage Treatment Plant were prorated at $28,761. Department staff said a contractor updated the 91st Avenue plant's risk management plan in 2004 for $20,000.

- *Fort Worth Water Department (Fort Worth, Texas)*. According to department staff, a contractor completed risk management plans for all of the department's drinking water and wastewater facilities in 1999 for $124,718. Costs related to the Village Creek Wastewater Treatment Plant's risk management plan were prorated at $31,100. Department staff reported that the contractor later updated these risk management plans for $18,040 in 2004, $4,510 of which was for the Village Creek plant.

- *City of Fort Wayne Utilities Division (Fort Wayne, Indiana)*. According to facility staff, a contractor completed a risk management plan in 2001 for the Fort Wayne Water Pollution Control Plant for $16,000. Facility staff reported a contractor updated the plan in 2005 for $6,000.

- *South Central Regional Wastewater Treatment and Disposal Board (Delray Beach, Florida)*. According to facility staff, a contractor completed a risk management plan in 1999 for the South Central Regional Wastewater Treatment and Disposal Plant, which treats 18 million gallons per day, for $10,000. Facility staff reported a contractor updated it in 2006 for $2,000.

- *City of Portland Bureau of Environmental Services (Portland, Oregon)*. According to bureau staff, a contractor completed a risk management plan in 1999 for its Columbia Boulevard Wastewater Treatment Plant, which treats 143 million gallons per day, for $30,000. Bureau staff reported they updated the plan using in-house staff in 2004 for $10,000 in staff time.

Other large wastewater facilities that prepared risk management plans in-house with existing staff reported lower costs for preparing the documents. These include the following:

- *San Antonio Water System (San Antonio, Texas)*. According to system staff, in-house staff completed a risk management plan in 1999 for the Dos Rios Wastewater Treatment Plant for between $5,000 and $10,000 in staff time. In-house staff updated the plan in 2004 for less than $1,000 in staff time.

- *City of Cedar Rapids Department of Water Pollution Control (Cedar Rapids, Iowa)*. According to facility staff, in-house staff completed a risk management plan in January 2000 for the Cedar Rapids Wastewater Treatment Plant for $5,000 in staff time. In-house staff updated the plan in 2004 for about $250 in staff time.

- *Denver Metro Wastewater Reclamation District (Denver, Colorado).* According to district staff, in-house staff completed a risk management plan in 1999 for $10,000 in staff time. In-house staff updated the plan in 2006 for about $1,000 in staff time.

- *City of Savannah Water and Sewer Bureau (Savannah, Georgia).* According to facility staff, in-house staff completed a risk management plan in 1999 for the President Street Water Pollution Control Plant, which treats 17 million gallons per day, at a cost of only $150 in staff time. In-house staff updated the plan in 2006 for about $130 in staff time.

Costs of Converting to Alternative Disinfection Methods at Large Wastewater Facilities Depend on the Method Used and Other Factors

Large wastewater facilities that convert from chlorine gas disinfection to alternative disinfection processes incur widely varying capital costs, which generally depend on the alternative treatment chosen and facility size. Other factors that affect capital costs include the characteristics of individual facilities, such as whether existing structures can be used, and local factors, such as building costs. Alternative disinfection processes may also pose higher annual operating costs than chlorine gas. However, these costs may be offset, at least somewhat, by savings in training and labor costs, and regulatory burdens associated with the handling of chlorine gas. Some facilities even reported or projected net annual cost savings related to wastewater disinfection.

Disinfection Method Chosen, Facility Size and Characteristics, and Other Factors Determine Capital Conversion Costs

The 23 large wastewater facilities that we interviewed reported capital costs for chlorine conversion ranging from $646,922 to just over $13 million. Table 1 identifies the 23 large wastewater facilities that recently converted or plan to convert from chlorine gas to another disinfection method and their reported and planned capital conversion cost.

Table 1: Reported and Planned Disinfection Conversion Costs for Large Wastewater Treatment Facilities

Facility name	Facility location	Conversion year	Facility size (in millions of gallons treated per day)[a]	Disinfection method	Reported or planned conversion cost[b] (in dollars)
Facilities that have completed conversion from chlorine gas					
Chambers Creek	University Place, Wash.	2002	19	Ultraviolet light	$3,900,608
Blue Plains	Washington, D.C.	2003	307	Sodium hypochlorite	12,980,726
Northeast	Philadelphia, Pa.	2003	190	Sodium hypochlorite	2,600,000
Back River	Baltimore, Md.	2004	150	Sodium hypochlorite	3,300,000
Essex and Union	Elizabeth, N.J.	2004	65	Sodium hypochlorite	775,000
Chesapeake-Elizabeth	Virginia Beach, Va.	2004	21	Sodium hypochlorite	1,225,000
Nansemond	Suffolk, Va.	2004	17	Sodium hypochlorite	1,650,740
Columbia Boulevard	Portland, Ore.	2005	143	Sodium hypochlorite	4,660,490
Valley Creek	Bessemer, Ala.	2005	46	Ultraviolet light	3,561,272
Dry Creek	Fort Wright, Ky.	2005	36	Sodium hypochlorite	646,922
Southern Regional	Boynton Beach, Fla.	2005	22	Sodium hypochlorite[c]	2,592,800
Burbank	Burbank, Calif.	2005	9	Sodium hypochlorite	2,500,000
Southeast	Philadelphia, Pa.	2006	90	Sodium hypochlorite	1,920,000
Papillon	Omaha, Neb.	2006	62	Sodium hypochlorite	3,000,000
Facilities that plan to convert from chlorine gas					
Metro Central	Denver, Colo.	2007	130	Sodium hypochlorite	13,135,000
Fort Wayne	Fort Wayne, Ind.	2007	43	Sodium hypochlorite	1,791,417
Everett	Everett, Wash.	2007	18	Sodium hypochlorite	2,562,460
South Central	Delray Beach, Fla.	2007	18	Sodium hypochlorite[c]	2,454,700
Mill Creek	Cincinnati, Ohio	2008	120	Sodium hypochlorite	3,085,000
Western Branch	Laurel, Md.	2008	20	Ultraviolet light	4,000,000
South Treatment Plant	Renton, Wash.	2009	75	Sodium hypochlorite	2,575,000
Hartford	Hartford, Conn.	2009	51	Ultraviolet light	10,892,000
Eugene-Springfield	Eugene, Ore.	2009	38	Sodium hypochlorite	4,498,000

Source: GAO.

[a]Plant size figures are figures for existing flow (a measure of average daily flow) reported by wastewater facilities in our survey.

[b]Conversion costs were not adjusted for inflation. Figures do not reflect changes in annual costs, but are reported costs for construction, labor, and materials related to the disinfection conversion. Reported conversion costs include actual costs and estimates from facility managers. As such, these cost figures do not represent the present value of the life-cycle cost of conversion. Conversion costs include reported temporary and permanent conversion costs.

[c]These facilities will generate sodium hypochlorite on-site. All other facilities listed as converted or planning to convert to sodium hypochlorite are having the chemical delivered in bulk to the facility.

As shown in the table, 17 of the 23 facilities converted or plan to convert to sodium hypochlorite delivered in bulk to the facility. Officials with several of these facilities told us they considered ultraviolet disinfection, but chose delivered sodium hypochlorite because of its lower capital conversion costs. The remainder converted or plan to convert to sodium hypochlorite generated on-site or ultraviolet light. None of the facilities we contacted adopted ozone.

Interview responses indicate that several factors affect the cost of conversion; among these are disinfection method chosen, facility size, key facility characteristics such as available buildings, and whether the conversion was permanent or temporary, as follows.

Disinfection Method

Generally, conversion to delivered sodium hypochlorite has the lowest capital costs, followed by sodium hypochlorite generated on-site, and followed again by ultraviolet light.[13] This observation is supported by cost estimates in the Chlorine Gas Decision Tool, a software program released by DHS in March 2006. The decision tool was designed to provide water and wastewater utilities with the means to conduct assessments of alternatives to chlorine gas disinfection. DHS cautions that the final costs of the disinfection systems will depend on project design details, actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, continuity of personnel and engineering, and other variable factors.[14] With these caveats, the decision tool estimates that for a wastewater facility with an average disinfection flow of 10 million gallons per day and a peak disinfection flow of 20 million gallons per day, capital costs for conversion to delivered sodium hypochlorite would amount to $533,000, on-site generation of sodium hypochlorite would total $1,238,000, and ultraviolet disinfection would reach $1,526,000.[15]

[13]Conversion to disinfection methods such as ozone and ultrafiltration can have higher capital costs than ultraviolet light.

[14]The decision tool provides cost estimates for disinfection conversion alternatives where there is limited site-specific engineering data. DHS notes that cost estimates were based on cost curves that were developed from a combination of the actual construction costs of different-sized disinfection systems and cost estimates based on conceptual designs.

[15]DHS notes that it is normally expected that an estimate of this type would be accurate within +50 percent to -30 percent.

Our interviews with wastewater facilities provide specific examples of conversion costs. For example, managers of the Chesapeake-Elizabeth Treatment Plant, which treats 21 million gallons per day and serves customers in Virginia Beach, Virginia, reported spending an estimated $1,225,000 in 2004 converting to bulk sodium hypochlorite disinfection. Managers of the comparably sized Western Branch Wastewater Treatment Plant, which treats 20 million gallons per day and serves customers in Laurel, Maryland, estimated that they will spend $4 million converting to ultraviolet light disinfection by January 1, 2008. Managers of the Western Branch plant indicated that one reason they chose the more expensive ultraviolet treatment option over bulk deliveries of sodium hypochlorite was to avoid the risk to local traffic that could result from additional deliveries to the plant. Plant managers indicated that because sodium hypochlorite degrades more quickly than chlorine gas, truck deliveries would increase under a disinfection system using sodium hypochlorite. They also noted that ultraviolet light disinfection would eliminate the need for the facility to handle and store significant amounts of hazardous and corrosive chemicals.

Facility Size

In addition to disinfection method chosen, facility size can also influence capital conversion costs. In general, larger facilities spend more converting to alternative disinfection methods. For example, because larger facilities process a greater flow of wastewater, converting to delivered sodium hypochlorite would require a larger sodium hypochlorite storage building or buildings relative to a smaller facility. It may also require additional pumps, instrumentation, and piping to deliver treatment chemicals to a greater number of contact tanks. Importantly, the largest facilities also tend to serve high-cost urban areas, and their conversion costs reflect the higher costs for construction materials and contract labor in these markets.

For example, the Blue Plains Wastewater Treatment Plant, which treats 307 million gallons per day and serves over 2 million customers in the Washington, D.C., metropolitan area, converted from chlorine gas to delivered sodium hypochlorite in 2003 at a cost of almost $13 million. According to facility managers, the facility temporarily converted from chlorine gas to delivered sodium hypochlorite in April 2002 at a cost of $500,000, primarily for storage tanks, pumps, piping, and related instrumentation. It completed the permanent conversion in October 2003 at an added cost of about $12.5 million, which included the purchase of additional storage tanks, related pumps, piping and instrumentation, and the construction of storage facilities for sodium hypochlorite and sodium bisulfate (used for dechlorination).

Other Key Facility Characteristics

In addition to facility size, other physical characteristics related to individual facilities also play a large role in conversion costs. For instance, the availability of usable buildings on facility grounds will determine whether a facility needs to construct, expand, or update a building to properly house sodium hypochlorite and its associated metering equipment. In addition, the distance between the storage building and treatment tanks will determine the amount of piping needed to deliver stored sodium hypochlorite to the treatment tanks. An example comes from the Hampton Roads Sanitation District which provides wastewater treatment to approximately 1.6 million people in 17 cities and counties in southeast Virginia, including the cities of Newport News, Norfolk, Suffolk, Virginia Beach, and Williamsburg. In 2004, the sanitation district converted from chlorine gas to bulk sodium hypochlorite disinfection at two of its plants—the Nansemond Treatment Plant, which treats 17 million gallons per day for the city of Suffolk, and the previously mentioned Chesapeake-Elizabeth plant, which treats 21 million gallons per day. The Nansemond plant conversion cost an estimated $1.65 million, while the slightly larger Chesapeake-Elizabeth plant conversion cost about $1.2 million. Costs were higher at the Nansemond plant because a building needed to be constructed for sodium hypochlorite storage, while the Chesapeake-Elizabeth plant had an existing building that only needed to be upgraded to properly store the chemical.

Federal discharge permit requirements related to individual treatment facilities can also influence conversion costs. Certain wastewater facilities may be allowed higher chlorine residuals in treated effluent because they discharge into less sensitive waters. Often, these facilities do not have to dechlorinate wastewater, saving the facility the cost of dechlorination chemicals, equipment, and storage. For example, the Philadelphia-area Southeast and Northeast Wastewater Treatment Plants, which treat 90 and 190 million gallons per day, respectively, need only to chlorinate water prior to discharging into the Delaware River. Both plants were converted to delivered sodium hypochlorite—the Southeast plant in 2006 at an estimated cost of $1.9 million and the Northeast plant in 2003 at an estimated cost of $2.6 million. In contrast, the Baltimore-area Back River Wastewater Treatment Plant, which treats 150 million gallons per day and discharges into the ecologically sensitive Chesapeake Bay, must chlorinate and dechlorinate its wastewater before discharge. This facility converted to delivered sodium hypochlorite in 2004 at a reported cost of $3.3 million.

Temporary Conversions

Finally, some facilities have reduced conversion costs in the short term through temporary conversions. For example, the Metropolitan Sewer District of Greater Cincinnati decided to convert its Mill Creek Wastewater

Treatment Plant, which treats 120 million gallons per day, from chlorine gas to sodium hypochlorite disinfection soon after September 11, 2001. According to the plant manager, by mid-October 2001, the facility had begun disinfecting with sodium hypochlorite by hooking up a rented sodium hypochlorite trailer to its disinfection system at a cost of $25,000. By May 2002, the facility had completed an interim conversion to sodium hypochlorite by purchasing and installing two 8,000 gallon outdoor storage tanks for sodium hypochlorite at a cost of $60,000. According to the plant manager, this interim disinfection system is still in use today, though the plant intends to permanently convert to delivered sodium hypochlorite in 2008 or 2009 at an estimated cost of $3 million. The plant manager said the permanent conversion would include an unloading station for sodium hypochlorite deliveries and a new storage building for the chemical and related instrumentation. The plant manager said the new storage building was needed to reduce the decay of stored sodium hypochlorite. The plant manager added that the storage building and additional piping would improve plant safety because it would allow for central storage and delivery of sodium hypochlorite. Currently, sodium hypochlorite deliveries are made at several plant locations for odor control which, according to the plant manager, increase the odds the chemical may be mishandled and accidentally mixed with other reactant chemicals used at the plant, such as ammonia.

Similarly, the Eastern Water Reclamation Facility, which treats 16 million gallons per day and provides service to Orange County, Florida, converted from chlorine gas to sodium hypochlorite disinfection at a cost of $60,000 in November 2001 through the addition of outdoor storage tanks and related pumps. According to the plant manager, the facility may consider additional changes in the future, such as permanent sodium hypochlorite storage or on-site generation.

Changes in Annual Costs Vary Widely, with Some Facilities Reporting Savings

Changes in annual costs related to disinfection treatment conversions were hard to measure due to lack of data. Many facilities we interviewed were unable to provide complete information on annual costs related to disinfection before and after converting from chlorine gas. Available data show that annual chemical costs related to disinfection increased for facilities that converted to delivered sodium hypochlorite, because sodium hypochlorite costs more than chlorine gas.[16] Available data also show that electrical costs related to disinfection increased for facilities that converted to on-site generation of sodium hypochlorite or ultraviolet light treatment, however these facilities also saw large reductions in chemical costs. Available data also show that increases in annual costs related to disinfection were offset somewhat by savings in training and regulatory requirements, as several facilities that converted reported a reduced need for staff time devoted to complying with the EPA risk management planning that was required when the plant used chlorine gas.

A few facilities were even able to report or project annual savings due to the disinfection conversion. For example, the wastewater treatment manager of the Columbia Boulevard Treatment Plant, which treats 143 million gallons per day and provides wastewater service to Portland, Oregon, estimated that annual costs related to disinfection fell by over $100,000 after the plant completed a 2005 conversion from chlorine gas to delivered sodium hypochlorite disinfection.[17] According to the wastewater treatment manager, increases in disinfection chemical costs for the plant were more than offset by reductions in electrical, labor, and training costs. Electrical power costs fell because the plant no longer had to power chlorine gas evaporators, which heat and help convert the pressurized liquid into gas before it is injected into the waste stream. In contrast, sodium hypochlorite is fed into the waste stream via less energy-intensive pumps. Labor and training costs also fell because the plant no longer had to meet the Occupational Safety and Health Administration's (OSHA) Process Safety Management of Highly Hazardous Chemicals standard,[18] and risk management and emergency response planning costs associated with the use of chlorine gas were eliminated.

[16]In addition, sodium bisulfate, the dechlorination chemical often used with sodium hypochlorite, costs more than sulfur dioxide, the dechlorination chemical often used with chlorine gas.

[17]According to the wastewater treatment manager, annual costs related to disinfection fell from $411,531 for the operating year covering July 1, 2004, to June 30, 2005, to $302,998 for the operating year covering July 1, 2005, to June 30, 2006. The wastewater treatment manager reported the plant's annual operations and maintenance budget at $12.4 million for the most recently completed operating year.

[18]OSHA's Process Safety Management of Highly Hazardous Chemicals standard (29 CFR 1910.119) contains requirements for the management of hazards associated with processes using highly hazardous chemicals.

In another example, the South Central Regional Wastewater Treatment and Disposal Plant, which treats 18 million gallons per day for customers in the cities of Delray Beach and Boynton Beach, Florida, predicts that it too will achieve annual savings once it converts from chlorine gas to sodium hypochlorite generated on-site, which it anticipates completing in September 2007. According to the Executive Director of the South Central Regional Wastewater Treatment and Disposal Board, potential disruptions of sodium hypochlorite delivery during hurricane seasons motivated them to begin generating their disinfection chemicals on-site. The plant's most recent fiscal year operating and maintenance budget for disinfection is estimated to be roughly $307,000 for chlorine gas and associated costs including equipment and maintenance, labor, and risk management planning. Postconversion annual operating and maintenance costs for disinfection are estimated to fall to $205,000 in the 2008 calendar year, primarily due to the suspension of chlorine gas purchases.

Agency Comments and Our Evaluation

We provided a draft of this report to EPA for review and comment. In its letter, reproduced in appendix II, EPA concurred with the results of the report. EPA's Water Security Division in the Office of Ground Water and Drinking Water provided technical comments and clarifications that were incorporated, as appropriate.

As agreed with your office, unless you publicly release the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies of this report to the appropriate congressional committees; interested Members of Congress; the Administrator, EPA; and other interested parties. We will also make copies available to others on request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

Should you or your staff need further information, please contact me at (202) 512-3841 or stephensonj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.

Sincerely yours,

John B. Stephenson
Director, Natural Resources
and Environment

Appendix I: Scope and Methodology

To identify the costs of preparing vulnerability assessments and risk management plans, we conducted structured telephone interviews with a select sample of large wastewater facilities identified as having completed these documents in our March 2006 report.[1] Our March report identified 106 large facilities that reported they had prepared vulnerability assessments or had one underway, and 85 facilities that were required to prepare risk management plans because they currently used chlorine gas as a disinfectant. From these two groups, we identified 47 facilities that reported that they had prepared vulnerability assessments and currently use chlorine. Of this universe, we chose a nonprobability sample of 25 facilities to assure geographic dispersion and adequate variation in size, since these factors were likely to influence their costs.[2] We completed structured interviews with 20 of the remaining 25 facilities. We sent an interview schedule in advance of each of the interviews. We completed the structured interviews between November 2006 and February 2007. Reported costs included both actual and estimated costs. For estimated costs, we asked facility managers to explain how they arrived at these estimates. Reported costs were not adjusted for inflation.

To identify the costs incurred by wastewater facilities in converting from gaseous chlorine to an alternative disinfection process, we conducted structured telephone interviews with a nonprobability sample of 26 of the 38 large facilities identified in the March report as having recently converted or planning to convert from chlorine gas to an alternative disinfection process. We sent an interview schedule in advance of each of the interviews. We completed the structured interviews between October 2006 and February 2007. Reported costs included both actual and estimated costs. For estimated costs, we asked facility managers to explain how they arrived at these estimates. Reported costs were not adjusted for inflation. We also conducted site visits with some of the facilities. Where available, we gathered documentation, such as capital plans, from these facilities in order to document conversion costs. We supplemented the cost information we gathered at individual wastewater

[1]GAO, *Securing Wastewater Facilities: Utilities Have Made Important Upgrades but Further Improvements to Key System Components May Be Limited by Costs and Other Constraints*, GAO-06-390 (Washington, D.C.: Mar. 31, 2006). We defined large wastewater facilities as those publicly owned treatment works (POTW) that serve residential populations of 100,000 or greater.

[2]Results from nonprobability samples cannot be used to make inferences about a population, because in a nonprobability sample some elements of the population being studied have no chance or an unknown chance of being selected as part of the sample.

facilities with information obtained at the Environmental Protection Agency, the Department of Homeland Security, nongovernmental organizations, and industry representatives. We determined that reported cost data were sufficiently reliable to provide useful information about the costs for preparing vulnerability assessments, risk management plans, and conversions from gaseous chlorine and the factors that affect these costs.

We conducted our work between August 2006 and March 2007 in accordance with generally accepted government auditing standards.

Appendix II: Comments from the Environmental Protection Agency

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 20 2007

OFFICE OF WATER

Mr. John B. Stephenson
Director, Natural Resources and the Environment
Government Accountability Office
Washington, DC 20548

Dear Mr. Stephenson:

Thank you for the opportunity to review the draft Government Accountability Office (GAO) Report *Securing Wastewater Facilities: Costs of Vulnerability Assessments, Risk Management Plans, and Alternative Disinfection Methods Vary Widely*. We appreciate the information in the report. This draft report is useful, well thought out, and demonstrates a well conceived and executed project. Our review did not identify any issues of concern for the Agency and my staff has provided GAO with technical comments on the draft under a separate cover.

We all rely on clean, safe, and secure water. Therefore, from a public health and economic perspective, it is critical that we protect our nation's wastewater infrastructure. Although there are no federal statutory requirements for wastewater utilities to conduct risk assessments, the Environmental Protection Agency (EPA) continues to develop tools and provide training to assist those water sector utilities that choose to perform these assessments on a voluntary basis. As your report notes, many wastewater utilities have elected to conduct these assessments or are planning to do so in the future.

The Agency is also interested in working with the water sector to identify disinfectants that are appropriate for their needs to meet water quality standards and to protect human health and the environment. Although the conversion from gaseous chlorine to an alternate disinfectant would eliminate the impacts of a hazardous gaseous chemical release, it is important to recognize that water sector utility owners and operators need to make the choice of disinfectant that is best for their utility. Therefore, many water sector utilities may continue to use chlorine gas as a disinfectant.

I appreciated the opportunity to coordinate with your staff on this project. Should you need additional information or have further questions, please contact me or Cynthia C. Dougherty, Director of the Office of Ground Water and Drinking Water at (202) 564-3750.

Sincerely,

Benjamin H. Grumbles
Assistant Administrator

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

John B. Stephenson, (202) 512-3841 or stephensonj@gao.gov

Acknowledgments

In addition to the contact named above, Jenny Chanley, Steve Elstein, Nicole Harris, Greg Marchand, Tim Minelli, Alison O'Neill, Daniel Semick, and Monica Wolford made key contributions to this report.

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