The History of Philadelphia’s Water Supply and Sanitation System

Lessons in Sustainability for Developing Urban Water Systems

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June 2007
Acknowledgements

The authors would like to thank Ed Grusheski of the Philadelphia Water Department for his availability for discussions, provision of research materials, and constant commitment to education about Philadelphia and its water supply history. We would also like to thank Adam Levine for research suggestions and valuable materials, as well as for the extraordinary website he compiles on the history of Philadelphia’s watersheds and sewers, at www.phillyh2o.org. Elizabeth Bernick provided valuable editing. Finally, we would like to extend our appreciation to Stanley Laskowski, who mentored this project from its inception.

This report was researched & written as a project of the Philadelphia Global Water Initiative for the United Nations Development Programme.

The Philadelphia Global Water Initiative is a group of interested organizations and individuals committed to helping to meet the UN Millennium Development Goals for water/sanitation throughout the world. It includes the University of Pennsylvania, Philadelphia Water Department, Water for People, Aqua America, Pennoni Associates, US Environmental Protection Agency, Uhl, Baron, Rana and Associates, the United Nations Association - Greater Philadelphia Chapter, and Meta Quality of Life Improvement Foundation.

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Executive Summary

Today, over 1.5 million Philadelphians enjoy abundant clean water, modern sanitation, and freedom from the deadly plagues of waterborne diseases that frequented the city in past centuries. Though this is now true in many cities, Philadelphia pioneered pivotal technologies and institutional changes that fueled the revolution of water and sanitation services in the United States. Developing cities today have access to far superior technologies than in Philadelphia 200 years ago, but water managers can learn from Philadelphia’s unique experiences in water and sanitation systems.

This study explores Philadelphia’s water history and summarizes the lessons learned to inform water managers and policy makers aiming to meet the United Nations’ Millennium Development Goals for clean water and sanitation in developing urban areas. Of particular interest are four universal challenges that water managers face:

- the public health-water-sanitation link;
- shortages of clean water obstructing economic development;
- politics and institutional delays; and
- ineffective political leadership.

Key findings of this research are:

1. Public advocacy and civil action can mobilize water utilities to engage stakeholders and be more accountable. This was powerfully demonstrated in Philadelphia, when public pressure forced the construction of the first centralized, city-wide water distribution system, which was run as a public utility. By lowering barriers to public involvement and by increasing public accountability, governments and water mangers can leverage the public’s power, drive substantial improvements, and respond to emerging problems.

2. Strategic planning for water and sanitation improvements must consider population and economic growth. Philadelphia paid dearly for myopia; rather than following recommendations for a sustainable system, on several occasions it continued with stop-gap measures. Consequently, Philadelphia was forced to make several costly upgrades to secure water for a growing population and burgeoning industrial base.

3. Urban water management should be based on an integrated water resources approach, with a single apolitical entity responsible for both water supply and wastewater treatment. Philadelphia’s history shows that uni-dimensional approaches, such as preventing pollution by simply purchasing land for source water protection, are ineffective and unsustainable. Philadelphia’s history also vividly illustrates how strife among political parties stagnates progress in developing water systems.
Introduction

Human development and social prosperity are linked to clean and adequate water resources. Individuals need water for drinking, cooking, and bathing; communities need water for agriculture and industry. In many parts of the world, water is a major source of energy and means of transportation. Beyond these obvious uses, there is also a complex relationship between water and sanitation and their role in alleviating poverty, safeguarding human health, advancing educational opportunities, and reducing gender inequity [1, 2].

For these reasons, the United Nations’ Millennium Development Goals set two specific global water targets: by 2015, to halve the proportion of people without safe drinking water, and to halve the proportion of people lacking adequate sanitation.

The world faces an immense challenge in meeting these goals: more than 1 billion people lack clean water, 2.6 billion people lack adequate sanitation, and 1.8 million children die annually from waterborne diseases [1]. Substandard water systems also undermine economic growth and public health; women and children who are forced to collect water from distant, inaccessible locations are less likely to receive an education or earn income, and become trapped in a cycle of poverty and inequity.

The lack of water supply and sanitation systems are an obvious part of the problem, but the United Nation’s 2006 Human Development Report attributes a more subtle cause to flawed governance that exacerbates, rather than alleviates, water scarcity [1].

This study investigates how Philadelphia wrestled with water governance from the 18th to 20th century. Philadelphia’s rich and eventful water history is lauded for many distinguished achievements that aided public health and economic growth. Today, it remains at the forefront of water and wastewater management and is heralded for using progressive ways to integrate watershed management, educate the public, and protect its water supply.

But the path to prominence was rocky. Problems such as outdated technology, industrial pollution, corruption, inadequate finances and political machinations challenged Philadelphia’s water managers. This study explores the lessons learned - the successes and blunders - to inform water managers and policy makers in developing urban areas who are leading the way to the United Nations’ Millennium Development Goals for clean water and sanitation.
Unable to cope: Privies - such as these in North Philadelphia, in 1919, were used before sewer lines were installed throughout the city; they regularly overflowed. Philadelphia City Archives.

Water Challenges in Developing Urban Areas

The developing world faces immense challenges to bringing clean water and sanitation to its people. While the details may differ in geographic and cultural context, Philadelphia struggled with identical problems during its 200 year water history. Developing cities today can choose from far superior water and sanitation technologies; but timeless lessons can be distilled from Philadelphia’s experience. This paper focuses on four themes that parallel water management in Philadelphia and developing urban areas:

1) the link among public health, water and sanitation;
2) clean water as the fuel to economic growth;
3) institutional inefficiency that derails technical advances; and
4) leadership as the base for success.

1. Public Health, Water, and Sanitation are Inextricably Linked

Just a few generations ago, cities like Philadelphia faced grave health threats - such as typhoid and yellow fever - from unclean water and poor sanitation [1]. As water managers now know, accessible water supplies sever disease transmission routes. The simple change of being able to wash hands with soap and water sharply lowers child mortality rates. This was the case in Burkina Faso in West Africa: in the mid-1990s, the country’s second largest city started a hand-washing program whose main objective was to reduce the risks of water-borne diseases to children caused by poor hygiene. After three years, the cost-effective program averted 9,000 diarrhea episodes, 800 outpatient visits, 300 hospital referrals, and 100 deaths, at a cost of only $0.30 per inhabitant [1]. However, education alone is not sufficient; the more grave challenge is the lack of access to clean water. A study in villages of Kyrgyzstan found that hand-washing rates were three times higher in households with piped water and washstands [1].

While clean water and proper hygiene may improve a community’s health, benefits are offset if human waste is not removed and treated. Sanitation often lags behind water because clean water clearly is vital for life while the more subtle benefits of sanitation are overlooked. When sanitation is seen as a private amenity instead of a public responsibility, the financial burden for sanitation systems falls on households that cannot afford it rather than becoming part of a government infrastructure investment.

Some communities have tackled sanitation challenges and vividly revealed sanitation’s role improving public health. Orangi, a large slum in Karachi, Pakistan, implemented a pilot project in 1980 to improve appalling sanitation conditions [1]. Neighborhoods designed and constructed sewer channels that collected waste from individual households, and Orangi financed a trunk sewer to collect and dispose waste from the entire community. This modest sanitary improvement reduced infant mortality rates in the slum by over 60 percent. Similar links are found in other cities: favelas in Salvador, Brazil witnessed dramatic drops in disease after the community built sanitation systems [1].
2. Clean Water Fuels Development

Growing cities and economies need large, reliable sources of clean water and often face competing demands for limited supplies. Such is the case in northern China, where acute pressures on the water system are at odds with continued economic development [1]. Water resources are stressed by pollution from high-growth textile, chemical, and pharmaceutical industries, whose water needs reduce flows in rivers and overdraw groundwater aquifers. Declining groundwater tables impede irrigation and reduce agricultural yields - a severe economic problem because these areas are the breadbasket of the country. Without adequate clean water, these regions will have difficulty supporting more industry and their projected population.

China is not alone; the challenge of managing intensified water demands from rapid economic growth is a catalyst for cities worldwide to develop better water governance policies.

3. Institutional Inefficiency Can Derail Technological Advances

Nearly every aspect of contemporary urban water management involves capital-intensive projects. The high cost of treating drinking water and sewage creates two major risks: projects will be held hostage to political machinations, or struggling governments will shift responsibility to private entities that may not be able to construct and operate extensive systems, or that may not place public interests over private financial gain.

However, institutional delays may be overcome, and do not always result in privatization. For example, Porto Alegre, a city of 1.4 million people, charges the lowest prices for water in Brazil and provides all residents with access to the water supply. Its efforts markedly lowered its previously high rate of infant mortality. Porto Alegre was successful by creating an autonomous municipal unit, responsible for its own financing and budget, but subject to public scrutiny and regulatory oversight [1].

![Laborers constructing the massive Mill Creek Sewer in 1883, demonstrating the challenge of building an urban water and sanitation infrastructure. This large sewer, built over a 25-year period, ran for 5 miles. Philadelphia Water Department.](image)

**Introduction**
4. Sustainable Water Systems Need Committed Political Leadership

Water and sanitation projects are often sidelined by more pressing political priorities such as economic development, trade, and defense [1]. Consequently, the strong leadership needed for expensive water and sanitation projects is lacking. Additionally, without political consensus on water and sanitation needs, internal conflict and corruption can freeze needed plans and funds.

In Uganda, for example, water reforms were achieved with substantial political commitment. The country’s national poverty reduction strategy in the mid-1990s named water as a high priority, and developed an investment plan aiming at 100 percent water coverage by 2015 [1]. Interim targets were established and leaders focused programs on schools and government and water user association partnerships [1]. Political commitment enabled leaders to increase water budgets 5-fold; enabling 5.3 million more people to have access to water [1].
Water Challenges in Philadelphia’s History

Today, over 1.5 million Philadelphians enjoy abundant clean water, modern sanitation, and freedom from the deadly plagues of waterborne diseases that frequented the city over its 200-year water supply history. Though this is now true in many other cities, Philadelphia was not only the first city to provide water as a public utility, but also pioneered new technologies - such as distributing its water supply through a centralized system, using hydropower for pumps, and installing disinfection systems - that fueled the revolution of water and sanitation services in the United States.

Philadelphia also faced challenges in creating effective institutions to manage water resources. Public demand for better health was often at odds with city leaders’ short term goals. But Philadelphia made notable institutional achievements through its foresight in planning and merging water and sanitation systems.

Philadelphia’s geography (Figure 1) is like many other older big cities: it sits at the confluence of two rivers, the Schuylkill and Delaware, whose waters are the source for drinking water and the destination for wastewater. Today, Philadelphia’s water system is impressively large by any standard: Three drinking water treatment plants send over 310 million gallons of clean water each day across a network of pipes covering a 130 square mile area. Three wastewater treatment plants collect sewage from an underground web of 3,100 miles of sewer pipe and send over 370 million gallons of treated sewage back into the Schuylkill and Delaware Rivers each day.

Figure 1: Left: Satellite image of North America. Right: Part of Philadelphia, the fifth largest city in the United States, whose urban reach extends 130 square miles. The city is bounded by the Schuylkill River and Delaware River, which are the primary sources of drinking water for its 1.5 million residents. Google Earth images.
### Timeline of Major Events in Philadelphia’s Water History

**1790s-1800s:** Yellow fever epidemics cause widespread panic; residents believe contaminated water supply is the cause. Watering Committee formed in 1799 to provide clean water.

**1801-1820s:** Centre Square distribution system transports water pumped from the Schuylkill River. New pumping station and reservoir built at “Faire Mount”, the highest point of the city.

**1820-1850s:** Fairmount Dam and millhouse harness the hydropower of the Schuylkill River. Efficient hydraulic turbines replace traditional breast water wheels.

**1855:** City purchases land along the Schuylkill River to protect the water supply. Land purchases continue through the 1890s, creating several thousand acres of buffer known as Fairmount Park, the world’s largest urban park.

**1860s:** The Civil War spurs massive industrial development and the coal industry thrives. City water managers’ ability to provide reliable water supply system plays a pivotal role in Philadelphia becoming the first major industrialized U.S. city. Use of the river for waste disposal leads to crisis: Typhoid.

**1880s:** Annual typhoid outbreaks drive up death counts; medical reports point to contaminated drinking water as the source of the epidemics.

**1890s:** Citizens push for city government to build filtration plants to treat water supplies and stop annual typhoid outbreaks. The city weighs piping clean water to the city from distant locations, but all plans are rejected. Privatization is proposed and rejected.

**1902-1912:** After many political and financial delays, the city builds 5 filtration plants to treat drinking water and stop epidemics. Industrial and domestic wastes continue to flow into the river, degrading water quality further.

**1913:** The city treats its water supply with chlorine and disease rates plummet. River water quality continues to deteriorate from increasing amounts of waste.

**1914:** The city’s master plan for sewer and sewage treatment system receives wide acclaim from water managers, but is not put into place.

**1950-1966:** Over 30 years after conception, the city constructs three sewage treatment plants and associated sewers.

**1970s-Present:** Increasingly stringent government regulations drive engineering advances in water and wastewater treatment. Stormwater management becomes a priority.

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**Introduction**
Centralized Water Supply

In the late 1700s and into the early 1800s, yellow fever swept through the city, killing thousands. We know now that yellow fever is transmitted by mosquitoes, but panic-stricken people blamed the disease on polluted drinking water and filth in the streets [3]. Privies and cesspools located near wells fouled water supplies and residents pressured the city to provide clean water for drinking, firefighting, and street washing. In 1799, several hundred citizens of the young city signed a petition to ask “the city Councils to seek a new source of water” [4]. In response, Philadelphia convened a “Watering Committee” and became the first major city in the world to shoulder the responsibility of supplying public water to its residents [3].

Secure Water Supplies Drive Industrial Growth

As the city’s population swelled and new industries flourished in the 19th century, there was acute competition for water. The Centre Square distribution system became too small for the growing need. Just as troubling were the water shortages that occurred when the overloaded steam engine failed, because reservoir tanks at Centre Square held a meager 25-minute water supply for the entire city [3]. Water security – both quantity and reliability – was critical if the city wanted to keep growing.

In a bold move, Philadelphia built a new pumping station and reservoir on the Schuylkill River at the highest point near the city, “Faire Mount.” Designed by Frederick Graff, the superintendent of the first Waterworks at Centre Square, the new Fairmount Water Works facility made Philadelphia world famous for its impressive combination of classical architecture and state-of-the-art technology.

Initially, the Fairmount pump house held two steam engines; a back-up engine would continue to feed water to the city if the first engine failed. Water security was further enhanced by a large reservoir capable of holding 3 million gallons per day. Water flowed through five wooden distribution mains to the existing Center Square distribution chest, and then through the original distribution network to all of Philadelphia (Figure 2).

Technological Progress

This section examines how Philadelphia improved facilities and its system during three segments in Philadelphia’s municipal water system history: the development of a central water supply, the introduction of water treatment, and the construction of wastewater sewers.
Still more improvements were made to the distribution system to increase the quantity and reliability of the city’s water supply. In a major construction project lasting almost 30 years and ending in 1848, city engineers laid a network of cast-iron pipes throughout the city with curved connectors to maintain high water pressure around the city’s sharp street corners [5, 3]. These engineering innovations were the direct result of the city’s desire to reduce the risks of water shortages. Philadelphia recognized that industrial and economic development depended on the availability of resilient and adequate water supplies made possible by strategic investments in water storage and back-up systems.

Pumping Power Evolves with Rising Energy Costs

The third important driving force behind technological change in Philadelphia’s water and sanitation system was the immense operating cost. Graff estimated the annual expense of operating the rapidly expanding centralized distribution network at $30,858. A large part of the cost was for the fuel (coal and wood) that fed the steam engines; these high energy costs were not being covered by revenues and discouraged the city from operating both steam engines simultaneously [3]. The Watering Committee embarked upon a revolutionary plan to keep water system operating: harness the hydropower of the Schuylkill River.

The Fairmount Dam was built across the Schuylkill River, along with a canal and locks to maintain high water levels. Water flowing over the dam and rushing into buckets turned massive wooden breast water wheels (Figure 3). The rotating wheel shafts activated connecting rods that moved pistons in the pump cylinders, drawing water. The mill house began operating in 1821 and additional waterwheels and reservoirs were later added to the Fairmount Water Works system to keep up with population and industrial development. By 1843, there were eight water wheels in the mill house [3].

The hydropower project was a resounding success: first, it provided a steady and inexpensive source of energy for water distribution; second, damming the river created a water supply reservoir and; third, the reservoir

Figure 2. Water makes the city grow: This section of a map from 1840 shows the Water Works on the Schuylkill River and the major distribution pipes throughout the city - which allowed for widespread settlement and development.

and beautiful gardens around the Fairmount Water Works became a popular area for public recreation.

Philadelphia’s Fairmount was the prototype of urban water supply in the U.S. and abroad, greatly admired for its engineering ingenuity and cost-effectiveness. The city treasury, in fact, enjoyed unprecedented surplus revenues from increased water payments and lower operating costs [3].

The evolution of pumping power did not stop at water wheels. Philadelphia continued to embrace new, more efficient technologies to decrease power costs and meet the skyrocketing water demands of an expanding populace. In 1851, the city installed the first hydraulic turbine in the United States, the Jonval turbine introduced by the French engineer Emile Geyelin [3]. A new mill house was constructed in place of the old to convert the entire Fairmount system to six Jonval turbines (Figure 4) that could operate more powerful pumps. The hydraulic turbines faithfully served Philadelphia’s water supply system until the Fairmount Water Works was decommissioned in the early 20th century.

Figure 3. The water wheel provides a continuous water supply for a thirsty, growing community: Frederick Graff’s drawing of a traditional wooden water wheel. The Franklin Institute Science Museum.

Figure 4. Another technological advance: Philadelphia installs the first hydraulic turbines in the U.S., as seen in this drawing of the Jonval’s Turbine installed in 1851. The Hagley Museum and Library (Gibson, 1988).
After the facilities and systems were in place to provide adequate, reliable, and inexpensive water supplies, Philadelphia’s urbanization and industrial development soared in the second half of the 19th century. But there was a serious side effect: pollution.

Disregarding European cities’ experiences, textile and dyeing houses, paper mills, coal mines and oil refineries emptied waste directly into the Schuylkill River. There was no treatment of sewage from residences and businesses. It all ran into the river - the water supply for the city.

Outbreaks of typhoid - which had been an unfortunate annual occurrence since the 1860s - dramatically worsened; the water-borne disease caused at least 600 deaths a year in the 1880s. Though several hundred typhoid deaths were expected in warm weather months, as unprecedented amounts of waste tainted the drinking water supplies, the death rate climbed. By the 1890s, citizen groups desperately petitioned the city to clean the drinking water supply [3]. Not until 1902, nearly two decades after drinking water treatment was proposed, did filtration begin, followed a decade later by chlorination. The long and costly impasse was, retrospectively, a valuable lesson in public controversy and stakeholder engagement.

At the time, filtering drinking water to remove typhoid bacteria was enormously expensive. The science of bacteriology was still somewhat of a novelty and engineers were unfamiliar with filtration technologies. Even though the public health consequences were clear, policymakers favored the more familiar but less effective treatment method of sedimentation [3].

Monumental sums were at stake: An adequate filtration system for Philadelphia required 400 acres of land and $8 million to construct. In contrast, the city believed that a modest investment of $200,000 was enough to repair leaking reservoirs and improve sedimentation [6]. In 1896, the city government defeated a bill to install filtration treatment in favor of enlarging the sedimentation reservoirs.

As a response to the annual typhoid death count, which continued to climb, the city built larger reservoirs which allowed the pollution in the water a longer time to settle [7]. Additionally, the city stopped drawing water from areas of the river that were visibly dirty. But without a system to overhaul to repair failing pipes, plug leaking sewers, or add treatment equipment, the city could not stop the outbreaks.

After the death toll nearly doubled in 1899, opposition finally gave way and construction of a filtration system began in 1902; it was completed in 1912. The city began chlorinating its water supply shortly after, in 1913. The effect of water treatment on typhoid deaths was dramatic and illustrates the powerful connection between human health and sanitation (Figure 5).

The struggle to filter Philadelphia’s drinking water highlights the extent to which water systems hinge on public and political support. Water managers need to provide citizens with easily understandable information about new technologies and involve both private and public interest groups in the decision process. The drop in typhoid deaths after treatment started demonstrates the public health overwhelming benefits of technology and is a startling reminder of the overwhelming cost of delay.
Figure 5. Typhoid deaths in Philadelphia drastically drop with city-wide water filtration (1912) and chlorination (1913).

Data from the Philadelphia Water Department Collection.
Sewers and a Sewage Treatment System

Philadelphia’s underground sewers, built in the 18th century, conveyed stormwater to the Delaware River and kept the city from flooding during heavy rains. By the early 1860s, massive amounts of human and industrial wastes flowed into the storm sewers as the city attempted to abate the “extremes of filth and misery,” resulting from “horrid heaps of manure from hog and cow pens; putrefying garbage and refuse of every kind; carcasses in disgusting decomposition; filthy rooms and damp, dirty, and moldy cellars, full and foul privies in close and ill-ventilated locations gave off their noxious gases” [8].

Philadelphia’s reliable water supply, which promoted hygiene and public health by enabling people to install bathtubs and water closets, also created a new need: a way to remove dirty water. The simplest solution for the overcrowded city was to use the street sewers as waste conduits. Rather than solving the problem, this merely moved the public health hazard to a new location, since the sewers emptied into nearby streams.

In response, the city encapsulated the streams carrying sewage in huge pipes. But the sewage - now carried by pipe - was still dumped into the Schuylkill and Delaware Rivers, the city’s water supply. The rivers’ health worsened until the mid-twentieth century, when the city built a system of interceptor sewers and treatment plants to treat sewage before it was discharged to the rivers, and when newly-formed national agencies made sure treatments followed environmental and health regulations.

Clean Water Investments are Delayed Without Steady Revenues

In 1914, the city published its master plan for its sewer and sewage treatment system, *Report on the Collection and Treatment of the Sewage of the City of Philadelphia* (Figure 6). Despite its thorough and pragmatic findings, over 50 years passed before Philadelphia followed the plan’s recommendations to create an adequate wastewater treatment system. The delay was caused by a variety of factors, but lack of funds was the primary impediment.

Surplus finances to spend on this new system, the most expensive public works project ever proposed, simply did not exist. World events, such as the Great Depression and two World Wars, greatly reduced tax revenues [9] and Philadelphia’s poor financial health kept it from borrowing funds to support the projects. Sewer taxes were hugely unpopular.

Because of these financial difficulties, only one of the three planned sewage treatment plants was constructed. Not surprisingly, the lone plant couldn’t treat all the city’s sewage. Only when federal loans became available and the city adopted sewer taxes in 1944 did the project move forward more rapidly. All three plants were completed in the 1950s, though the interceptor system was not finished until 1966.

This immense inertia in carrying out the plan was deplorable, though not unique to Philadelphia; financing water and sanitation infrastructure is challenging in developing cities with tight budgets and a long list of other priorities. Philadelphia’s sewer story highlights an enduring lesson: water managers need to plan for and establish ways to obtain a steady revenue stream to finance projects. Without a formal financing mechanism, projects will be significantly delayed.

Technological Progress
Regulations Stimulate Change from Above

The creation of the U.S. Environmental Protection Agency (EPA) in 1970 dramatically changed water and sanitation technologies. The Federal Water Pollution Control Act (or Clean Water Act), which passed in 1972, regulated pollution in streams and rivers; it was followed by the Safe Drinking Water Act in 1974, which set the first of many standards for drinking water. National regulations, updated in the 1980s, required utilities to release annual reports that described water quality [10, 11].

The Philadelphia Water Department upgraded the city’s sewage and drinking treatment plants several times to install modern technologies to meet these regulations. Extensive and sophisticated treatment processes for drinking water and wastewater are now the norm (Figures 7 and 8, next page).

The success of the “top-down” approach, where national governments set command-and-control regulations, highlights the way centralized government can drive water and sanitation improvements after certain minimum standards are attained. The disadvantage is that public health becomes decoupled from water quality and grassroots efforts are displaced. Instead, government must assume the responsibility of proactively managing water and sanitation systems.
Figure 7. Federal regulations drove the city to adopt advanced technologies for its current water supply system. *Philadelphia Water Department*

Figure 8. Wastewater treatment processes have evolved from the basic filtration system used in 1910. Not shown in the diagram is a recently-added process of oxygenation following disinfection, immediately before the treated wastewater is discharged. *Philadelphia Water Department*
The Forces Driving Technological Change Evolve

Public pressure and grass-roots advocacy catalyze technological change when people can see the link between public health, water supply, and sanitation conditions. In contrast, government-issued, centralized regulations catalyze continued technological advances after water supply systems meet basic standards and public health problems lose visibility. Regardless of the origin of drivers for progress, water managers need to be responsive to these catalysts.

Selecting Sustainable Technologies Requires Strategic Planning

Water managers should choose sustainable, secure, reliable and affordable water supplies that provide flexible, long-term solutions. Philadelphia’s experience shows that it is more economical to invest in energy-efficient systems that can adapt to population and development pressures rather than upgrade systems multiple times in reaction to circumstances.

A Responsive Approach to Public Demands Can Move Projects Forward

Philadelphia’s long and costly impasse in selecting an appropriate water treatment method demonstrates that stakeholders need to be engaged in a transparent decision-making process to share scientific information about new technologies and the expected benefits of capital intensive projects. In addition, open and democratic public consultation can increase trust in the project’s viability, produce technologies that residents are willing to pay for, and justify large public expenditures.

Summary - Technological Lessons Learned

| Addressing problems: Repairing the Schuylkill dam in 1904. Philadelphia Water Department | }

Technological Progress
Almost two decades after Philadelphia identified the source of its typhoid epidemics, the city began using filtration, an accepted and proven method to remove bacterial contamination in drinking water. The decision to use filtration and the reasons for the delay demonstrate important aspects of institutional and societal deliberations in Philadelphia’s water history. The lessons learned from its delays along with some far-sighted decisions made to protect water supplies and integrate water management can be applied to problems faced by developing cities.

In 1883, a report from the water works’ chief engineer named contaminated drinking water as the source of Philadelphia’s ongoing typhoid problem. As typhoid annually spread through the city, Philadelphia residents read of cholera epidemics in Europe and feared for the worst. Bowing to public pressure, the city government “approved an ordinance to build an experimental filtration station on the Schuylkill” [7]. But when the typhoid threat passed with the onset of cold winter weather, the bill was forgotten and no funds were allocated.

Outbreaks occurred during the warm months of the next two decades; with every spike in typhoid incidence, public pressure grew. Not limited to outbursts from angry masses, the public organized a multi-sector public engagement campaign. During the 1889 epidemic, residents in hardest-hit areas held public meetings and implored local physicians and chemists to publicly discuss the city’s options. Leaders from distinguished universities and civic groups formally organized the meetings into a city-wide lecture series [7].

Filtration proposals received vast public support, particularly since experimental plants in Massachusetts and Kentucky were successful and because, in the late 1890s, Philadelphia’s typhoid rate jumped ten-fold [7]. To coordinate efforts, the citizen groups created a Filtration Committee. A century before, the city created the Watering Committee to study options for supplying water; in contrast, the Filtration Committee was a grassroots citizen committee working outside of the established system. Members wrote letters to city officials, demanded to speak at meetings, and made questions about the water supply one of the most important campaign issues in the local elections. The Filtration Committee drew members from a diverse group of stakeholders, ranging from residents of afflicted areas, professionals from the Engineers Club and the County Medical Society, editors and owners of local newspapers, and influential university presidents [7].

This elaborate public organization was needed to counter not only the bureaucratic delays inherent in most large cities at the time, but also Philadelphia’s notorious political maneuverings.
Politics Create an Impasse

Attempts to improve drinking water and build a sewage system became victims of politics: any proposal from the mayor met with immediate opposition from the other party. Because city-wide water supply was expensive, government officials found that debate on any potential changes was a highly effective way to get public attention.

When filtration was initially proposed in 1896, the opposition party stopped the city government from voting on the measure, despite overwhelming public support [7]. In later years, when it became impossible to block adoption, opposition parties heaped on additional, insurmountable hurdles around measures to approve funding for the filtration system.

Some of this political maneuvering was not without good reason: many members of city government felt that water treatment plants in one part of the city would not help their constituents living elsewhere. Others were legitimately skeptical of the enormous expense of a then-fledgling technology. Additionally, several city officials felt it was unfair and impractical for the city to be responsible for cleaning drinking water from the river if local industries continued to put wastes in [12].

Nevertheless, most of the government’s opposition – including that of the notorious Typhoid Thirteen of 1899, who blocked funding for an approved ordinance for filtration – was no more than “a personal vendetta” against the mayor [7]. Debate continued, bills were reintroduced and blocked, public tensions rose. As the Philadelphia Inquirer exclaimed in 1899: “When the reason for the terrible discrepancy is so well known, where there is such an absolute agreement as to the remedy necessary to be applied, is it not monstrous that our councilmen continue to talk, talk, talk and do nothing!” [7].

To break the impasse, the mayor commissioned a third-party expert report; though this meant more delay, it proved valuable. Calling on engineers from other cities, the mayor asked them how to improve the water system and meet the needs of a growing population. Their answer was no surprise: filtration was necessary for disease prevention [7]. The city accepted the report; in 1899 and 1900 it approved funds for a filtration system and so “water reform, controversial for so long, quietly became a reality” [7].

Right: Workers in 1905 cleaning the slow sand filters in the massive Belmont facility. Philadelphia City Archives.
Another obstacle to drinking water filtration was the existence of other options: using additional reservoirs as stop-gap measures, abandoning the Schuylkill River for remote water sources, or turning water supply responsibilities over to a private company. Philadelphia wisely decided to keep both physical and institutional control of its water supply.

**Water Supply Stays Within City Limits**

Philadelphia was not alone facing disease epidemics. Many cities at the time with water quality problems chose to use aqueducts or ‘upcountry’ water, as was the case in New York City, Washington, D.C, and Paris [7]. An aqueduct was a practical possibility for Philadelphia, given the large number of rivers whose waters could flow into the city by gravity through aqueducts.

Water piped from distant sources was attractive but risky. New bacteriological discoveries made seemingly pristine waters suspect; the Water Department opposed using upstream water sources since, “Although to the eye the water of the upper Delaware is usually quite clear and transparent, it is perhaps not much purer than other proposed sources near home” [7].

The city also feared losing control over its source of water, particularly since water was essential for economic growth as well as a myriad of public services such as firefighting. But one particular incident made it difficult for officials to ignore upstream options: one week in 1889, Philadelphia had over 300 cases of typhoid and 38 typhoid deaths. In the same week, New York City, which drew water from a distant source, had only 14 cases and six deaths [7]. When a local businessman proposed pumping water from his undeveloped lands in the nearby New Jersey Pine Barrens, it met with immediate interest; only after careful deliberation did the city decide that, because the source was in another state, the risk to water autonomy was too great [7].

Despite the precedent set by other cities’ distant or seemingly pristine sources, Philadelphia continued to use the Schuylkill and Delaware Rivers as sources of drinking water. During times of peak pollution and contamination, this decision appeared unwise, yet the city realized several things: no remote water source could be assured to be cleaner than local water, and, if pollution worsened, the city would have been forced to find increasingly distant sources of water. Cleaning and maintaining its own local surface water was a more sustainable investment than constantly seeking distant sources.
Attempts at Privatization

The ideals of Philadelphia’s Watering Committee - to provide water as a public utility - persisted despite two serious attempts in the nineteenth century to bring the water supply under private administration.

Faced with building an expensive filtration treatment system at the end of the nineteenth century, selling the public water department to a private company seemed a legitimate way to improve drinking water treatment. In the early 1890s, the Upper Schuylkill Water Company offered to shoulder the responsibility for Philadelphia’s water supply in return for all water fee revenues spanning a 50-year contract term. At first glance this was not a farfetched proposal: Philadelphia had a successful private gas supply [7]. However, gas and water were very different utilities: gas required many workers but relatively few technological improvements; in contrast, water systems required constant upkeep and improvements but relatively few workers, leading to very different financial and operating pressures.

The company’s proposed price was steep: $75 million over 50 years. The sale would pay for the construction of filtration plants (estimated at $10 million), but the public and city officials believed $75 million was too much - particularly since the city would be losing all its revenues from existing water fees. Though the water fees for each household were modest, the steady stream of revenue stoked the city’s coffers. The city was also skeptical of any private company’s claim that it could build the dams and reservoirs needed to meet the its growing water demand [7].

Despite public skepticism about price and capabilities, the Upper Schuylkill Water Company’s proposal continued to appear before the city government through adept political maneuvering by several city officials who opposed the mayor [7]. Cronyism played a large part, as several officials had financial and personal stakes in the company. More deceit followed; over the next year, a major scandal erupted as city officials were bribed to vote for the private water company scheme. The proposal culminated in a dramatic public revelation, when one city official revealed that he had been offered – and refused – a bribe, that he knew others had taken it, and that the company owners had even tried to bribe leaders of citizen groups [7].

Privatization resurfaced at the height of the 1899 typhoid epidemic. A bill passed one government chamber to have a private company operate the city’s water supply. The proposed company would be run by, interestingly, the same individuals involved with the failed Upper Schuylkill Water Company [7]. When the bill reached the second government chamber, the disgusted members rejected the return of corrupt privatization and passed an ordinance demanding public water filtration plants. Yet when this bill returned to the first chamber, city officials rejected it and water progress was gridlocked [7].

Though these proposals for water privatization were laced with corruption and politics, the reason for their defeat seems more closely linked to the city’s inherent skepticism of any private company’s ability to build the massive water system infrastructure and maintain the city government’s sincere interest in preserving public health. Today, in an era of strongly enforced water regulations, many towns near Philadelphia have successfully privatized water supplies. Though it required a large outlay of public funds, the city’s decision to keep responsibility for water supply and treatment proved to be a sensible and far-sighted way to preserve public health at a time before water quality standards or regulation.

Opposite Page: Essential for the City: Philadelphia’s rivers were heavily used, as seen in this 1840 engraving, leading to suggestions to use distant rivers for drinking water - which, ultimately, were rejected. Above: Repairing the Fairmount Reservoir in 1896. Philadelphians doubted that a private company could manage the massive infrastructure facilities necessary for the growing city’s water supply, but privatization proposals - with more than a hint of political corruption - kept returning to the city council. Both: Philadelphia City Archives.

Fairmount Park Protects the Source

Over the course of a century, Philadelphia bought large tracts of riverfront property from estates along the Schuylkill River, creating the “most elaborate park system in the city” and preserving “the purity of Schuylkill water from the possible pollution which might result if buildings were constructed adjacent to the Fairmount Water Works” [5].

As the city grew, Fairmount Park expanded (Figure 9); when Philadelphia absorbed nearby counties, city limits were shifted to several miles above the water works. The new city government quickly took advantage of this development and over the next three decades acquired several thousand acres of land on both banks of the river. Not only did this create the largest urban park in the world, it also successfully prevented any development on either side, from the Water Works up to the edge of the city limits. The city’s objectives in creating Fairmount Park were realized: the Schuylkill River remained relatively unpolluted and provided an essential foundation for the city’s enviable water supply system.

Yet as the city’s population increased, and as industrialization took hold, even the large undeveloped stretch of river was unable to absorb the enormous amount of untreated sewage and industrial waste dumped from facilities upstream. The Park prevented discharges into the river immediately above the Water Works, by the late 1860s numerous factories, slaughterhouses, textile mills, and workers’ residences had been built on the river banks just upstream of the park. Providing coal and equipment for the U.S. Civil War was more a priority than maintaining the river’s health, and water quality quickly worsened.

The city struggled to protect its water supply. Residents, physicians, and government officials saw how upstream users were harming water quality but because the pollution originated outside city limits, Philadelphia could not enforce its restrictions on dumping human waste, industrial effluent, or dead animals into the river [7]. Runoff and sewage from within the city also made its way to the river; because runoff came from a multitude of users, rather than a single source, Philadelphia could not enforce a clean-up. The Schuylkill River, Philadelphia’s main source of drinking water, became a sewer of untreated waste.

The financial, legal, and engineering obstacles to preventing pollution shifted public and governmental attention to treating the water after it was removed from the river, rather than relying on the river as a natural filter. Yet rivers’ health was still equated with public health: in 1905, the Pennsylvania Public Health Department was created, with the sole purpose of cleaning up rivers. There was a pragmatic purpose for this, since mechanisms for treating drinking water, such as slow sand filtration and chlorination, could not offset the immense pollution load in urban rivers [13].

Attempts to control pollution on the Schuylkill and Delaware Rivers “met with little success before 1952. Conditions indeed were worsening as raw sewage continued to be dumped in the Delaware and its tributaries by many upstream municipalities” [13]. Clearly, Philadelphia could not continue to provide safe water if attention was focused merely on drinking water treatment; the quality of the sewage effluent entering the river also had to be addressed.
Rivers - and water quality - suffered as industry developed. Though the larger Delaware River - seen in this 1940 photograph - experienced more industrial pollution than the smaller Schuylkill, both were severely polluted by the mid-20th century - and both still served as sources of drinking water.

Philadelphia City Archives.

Right: **Figure 9.** Protecting the River: Philadelphia set up a buffer to development along the Schuylkill River upstream of its water works, as shown in this 1868 Map of the Fairmount Park System. *Philadelphia Water Department.*

Opposite Page: Functional & Recreational: The river-side land purchased to protect the river became an enormous urban park; boathouses (seen in this photo from 1910) were the only development permitted. *Philadelphia City Archives.*
Wastewater and Drinking Water Responsibilities Merge

Even after Philadelphia began filtering and disinfecting its drinking water, the quality remained poor. Disease in the city was lower (Figure 5) but political cartoons correctly characterized Philadelphia’s rivers’ water as dirty and dangerous during most of the 20th century (Figure 10). This was no surprise, since unchecked dumping of industrial waste and city sewage created “rivers so polluted that their water took the paint off the hulls of the warships at the Navy Yard and on the hot, humid days of summer filled the air over center city with what the eighteenth century would have called ‘noxious vapors’” [14].

The city faced the daunting challenge of renovating the sewer system to deal with enormous amounts of increasingly deadly waste.

A seemingly small but highly significant institutional change made by Philadelphia had dramatic impact: the city gave the Water Department responsibility for all water and sewage treatment (which previously had been under the City Surveys Department) and addressing all water issues – from the quality of the source of intake to the ultimate destination of the effluent – in a comprehensive framework within the Water Department. By merging responsibility for the popular and successful water treatment system with the under-funded and unappealing wastewater treatment facilities, Philadelphia provided an institutional and symbolic basis for integrated water resource management.

Figure 10.
The Philadelphia public perceived drinking water as dirty and dangerous, using the term “Schuylkill punch” to describe the drinking water “cocktail” resulting from polluted river water and chlorination treatment.

Philadelphia Record, 1937, original document in the Philadelphia Water Department archives.
The Stormwater Challenge

One hundred and eighty years ago, Philadelphia knew that protecting its water supply source was crucial. The Fairmount Park buffer zone created a spectacular urban recreation area and, for a time, protected the city’s water supply; Philadelphia had taken the first steps to integrated water resource management. But the pressures of industrialization and the difficulties of undertaking expensive and controversial municipal projects during times of war and economic depression made it hard for the city to make a deeper commitment to water treatment and sanitation.

Today, Philadelphia has regained its focus on the essential link between the health of the rivers and the health of its citizens. Though drinking water and wastewater are treated to high standards, these treatment facilities would be less effective and more expensive if the city were to stop enforcing regulations to prevent pollution from entering the rivers. The park system still filters polluted runoff and prevents development on many parts of the riverbanks, protecting the city’s drinking supply and the local environment.

The present challenge to water quality is polluted runoff from city streets, rural farms and upstream mines. Wastewater is treated before it enters the rivers and their tributaries, but rainwater running over rooftops and across yards, farmed fields and roads picks up pollution and flows unchecked into the rivers and streams. As the amount of paved and hard surfaces increases, so does the amount of runoff. Reducing pollution from stormwater runoff is a top priority for city and non-governmental organizations such as the Schuylkill Action Network (www.schuylkillactionnetwork.org), whose innovative ways of involving stakeholders have resulted in a more holistic watershed approach.

Other challenges persist because of the antiquated combined sewer system which collects a mix of sanitary waste and stormwater. During heavy storms, the system overflows and dilute but untreated wastes are forced back up the pipes in some areas, into residences and businesses. This system was put into place in the eighteenth century, before the advent of wastewater treatment, to prevent the streets from flooding. Today, however, the untreated wastewater backup is a serious unforeseen consequence with which Philadelphia must grapple, demonstrating that water and sanitation decisions have far-reaching consequences.
Realities of Fees and Financing

One of the most revolutionary aspects of Philadelphia’s water system was its unprecedented conception as a public utility, provided by the city for the good of the people. Users had to pay to have pipes installed, but water was free [15].

Beyond this, however, Philadelphia did not pioneer any innovative practices or theories in water system finance. Instead, it became entangled in several of the same challenges facing developing urban areas today. Technological innovations allowed the city to operate its extensive water supply system with remarkable profits. But as the population increased, water quality deteriorated and treatment facilities became necessary; supplying water became less profitable. Every upgrade required enormous capital investments.

One step that could have been taken to reduce the demand for water - and reduce the size and cost of new treatment plants - was installing meters to record the amount of water used in private homes. For more than two decades, while public debates raged over treatment options, the Water Department’s chief executive gave few comments other than to speak out in favor of water meters. He estimated that “over 60 percent of the city’s water was going down the drain unused” and that by using meters to measure and reduce consumption, the cost of the debated filtration plants could be reduced by two-thirds [7].

Instead of using meters, Philadelphia’s water fees were based on the number of appliances (sink, bath, water closet, etc) in a residence, and users were charged a flat rate for each type of appliance. These flat-rate fees were too low to pay for upgrades to the water and sanitation systems.

But even funds raised from metered water would not have been enough, so the city issued municipal bonds to finance the large constructions. It was a tedious and long process. Layers of public, legislative, and judicial approvals were required and offerings often fell victim to political maneuverings, but the city had no other financing options.

In some cases, even municipal bonds were not enough. Federal funds were infused to complete the wastewater treatment system, the most expensive capital works project Philadelphia ever undertook.

Several important lessons can be taken away from these seemingly unremarkable financial exertions:

- First, even modest fees, if applied appropriately, can bring in revenue and, more importantly, keep operating costs low by reducing waste.
- Second, water supply and sanitation systems are expensive, and in many cases construction is impossible without securing significant external financing or taking on debt.
- Third, and perhaps most important, is that these enormous expenditures are painful but essential for sustainable systems.

By constructing adequately sized, high quality drinking water and wastewater treatment facilities, water managers can avoid constant costly repairs, system interruptions due to failures, and expensive incremental upgrades.

Investing in water and sanitation systems is also cost effective. Philadelphia should have learned this lesson earlier than it did; in the midst of a typhoid epidemic, when filtration plants were rejected as too expensive, one contemporary calculation found that if the epidemic continued, Philadelphia would lose more than $1,390,000 as a result of deaths, productive days lost to illness, and funeral expenses. The author of this report noted that “public works which could eliminate a great fraction of this great ‘typhoid tax’ would certainly pay for themselves in the course of a few years, even though they were originally expensive” [16].

Today, of course, the costs both of dealing with illness and of water treatment facilities are much higher. But unsafe water is still a serious hazard, and the same financial principles can be applied: “There is no system of filtration, or other efficient method for purifying a polluted water, so expensive but that a community cannot well afford to introduce it rather than to drink a dangerous water in its raw state, and this, too, from purely economic considerations, and leaving out of sight all ethical questions whatsoever” [16].
Summary - Institutional Lessons Learned

Water Plus Politics Equals Delay
As a highly visible capital investment, water and sanitation projects risk the whims of politics as people delay, attack, or malign legitimate improvements merely out of political considerations. Effective water and sanitation systems should be recognized as essential to public health and to urban functions. Additionally, by seeking credible and apolitical experts to study controversial expansion or repairs options, cities can maintain public confidence and keep project goals focused on system improvements.

Engaging Stakeholders Keeps Projects Moving Forward
Water and sanitation systems must be responsive to public needs and accountable to public scrutiny. For most of Philadelphia’s history - before water quality and wastewater regulations - only a public water supplier could be trusted to prioritize public health and welfare, and only a large municipality had the capacity for large infrastructure projects. Today, circumstances have changed, yet every water and sanitation system still needs public accountability and a system for enforcing regulations and stakeholder priorities.

Additionally, direct control over the quality of source waters is an important part of water security. Water sources within city boundaries should be protected and maintained, since a water source’s beneficiaries are more likely to take a strong and sustainable interest in its quality and management.

Integrated Water Resource Management
Using a polluted water source makes drinking water treatment more expensive and less effective. However, Philadelphia’s experience demonstrates that a water management system based only on source water protection is inadequate to ensure safe drinking water. Integrated water resource management with a regional approach best maintains sustainable sources of clean drinking water for large populations. An integrated approach requires managers to consider environmental factors (such as watershed protection for an entire basin), infrastructure (maintenance and upgrades), conservation (to prevent deterioration of the natural systems and engineered facilities), and proper drainage (to remove waste and prevent contamination). Water is always a transboundary issue, and water managers must determine ways to protect their sources of water from upstream contamination while ensuring that their wastes do not adversely affect those downstream.

Combined Management of Water and Wastewater is More Effective
Wastewater treatment systems are not glamorous and they are expensive; they receive scant public interest and little funding or support even in times of sanitation crises. To address the sewage needs of urban areas, these services should be administered by the same entity providing drinking water. Not only does this highlight the ways in which wastewater impacts drinking water quality, it also provides a way to finance and manage an essential element of urban infrastructure whose importance for public health is belied by the lack of attention it receives.
Philadelphia’s outstanding engineering feats and institutional achievements were not fully envisioned or planned at their inception. Rather, technological change evolved over the centuries in response to public pressure, exigencies of the moment, and scientific advances; institutional change was driven by similar factors.

Some of the key findings of this research are:

- Public pressure and bottom-up civil advocacy can overcome inertia and catalyze reforms in the water sector, especially when lack of clean water and adequate sanitation directly threatens public health.
- Government-issued central regulations catalyze continued technological advances after water supply systems meet basic standards and public health problems lose visibility.
- Choices of supply and treatment technologies, water supply, and financing methods should be evaluated with sustainability and long-term use as top priorities. Convenient “quick fixes” almost always translate to water systems unable to withstand population and development changes. Additionally, decisions lacking foresight not only can diminish public trust in water utilities, but also result in larger overall system costs.
- Sustainability requires public engagement and consultation. Water supply and sanitation systems should be accountable to the public as well as proactive in engaging stakeholders through education, consultation, and feedback in order to share information, garner support for projects, and improve trust in water management.
- An apolitical institutional framework for water utilities should be structured to ensure that political agendas do not divert attention from core public health priorities. Political support should be principled and focused on public good.
- A single organization or agency should be responsible for water supply and wastewater management to streamline operations and to allocate resources appropriately between these two facets of water systems management.
- To ensure that water and sanitation systems prioritize public health and their city’s interests, mechanisms for accountability, transparency, and/or external regulations should be created and enforced.
- Utilities should incorporate fair pricing programs and public education for demand-side conservation as an integral part of their business functions.
- Integrated water resource management provides an effective, long-term, sustainable approach to water and sanitation systems construction and operation. Water managers, members of the public, and other stakeholders must consider environmental factors, infrastructure maintenance and upgrades, conservation, and proper drainage to ensure clean, reliable, and sustainable water supply and sanitation systems for growing urban areas.
Philly’s water supply history is remarkable not only because the city was the first to provide water as a public utility and to pioneer many technological innovations, but also because its experience mirrors the typical challenges of modern developing cities. Philadelphia faced the same threats as those of Nairobi, Rio de Janeiro and New Delhi today, such as polluted water, disease outbreaks, and inadequate funds for capital investments.

In the 21st century, far more sophisticated technologies exist than those that were available for most of Philadelphia’s history, but more than technology is required for effective water supply and sanitation. Adequate human capacity, transparency, and stakeholder involvement are necessary to ensure universal coverage and financing. The largest barrier to these goals is the lack of good governance, political will, and effective management for sustainability. In this spirit, it is appropriate to examine Philadelphia as a case study of both exemplary and poor policy choices, to illuminate lessons learned from history that should either be replicated or avoided.

Two recommendations for water managers are proposed based on the conclusions of this report:

1. **Secure Political Commitment for Water and Wastewater Programs.** Having a secure political commitment ensures that water and sanitation development will have consistent budget allocations and specific, enforceable regulations for drinking water and wastewater quality. Water and sanitation should be explicitly integrated with economic development and public health goals in local and national policy documents in order to secure long-term commitment from government leaders. The link between water security and economic growth, industrialization, and urbanization can be especially useful in elevating water projects in political agendas.

2. **Make Sustainable Decisions about Water and Sanitation.** Strategic investments in water infrastructure, though expensive, are worthwhile in the long-term; though integrated water resource management provides the best approach for sustainable management and planning, specific recommendations for each area vary. Developing cities should fully leverage the benefit of sharing experiences and best practices of developed countries, which have the “hindsight” that can assist in making sustainable decisions. Independent studies through international development agencies can aid the dissemination of information. In addition, water utilities should actively consult and share information.
References


Most images in this report have been cropped for space and clarity. Full images can be found at Philly H20: The History of Philadelphia's Watersheds and Sewers, compiled by Adam Levine, at www.phillyh20.org.

Additional images can be found at phillyhistory.org, a photo and map collection from the Philadelphia City Archives.

Water Distribution Main, near completion in 1946. Philadelphia Water Department.
This report was researched & written by Lydia Loh and Niva Kramek at the University of Pennsylvania as a project of the Philadelphia Global Water Initiative for the United Nations Development Programme.

The Philadelphia Global Water Initiative is a group of interested organizations and individuals committed to helping to meet the UN Millennium Development Goals for water/sanitation throughout the world. It includes the University of Pennsylvania, Philadelphia Water Department, Water for People, Aqua America, Pennoni Associates, US Environmental Protection Agency, Uhl, Baron, Rana and Associates, the United Nations Association - Greater Philadelphia Chapter, and Meta Quality of Life Improvement Foundation.