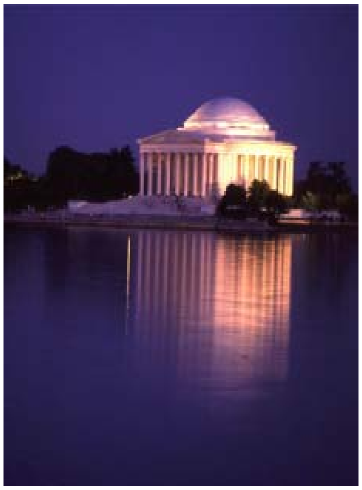
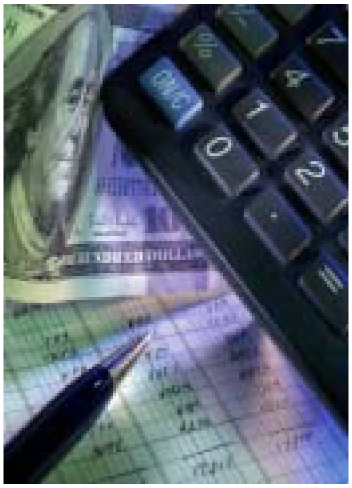
United States Environmental Protection Agency

The Clean Water and Drinking Water Infrastructure Gap Analysis





Message from EPA's Assistant Administrator for Water

As our economy and population grow, we must periodically take a good look at the challenges ahead and reassess our nation's needs for infrastructure to ensure clean and safe water. By "infrastructure" we mean the pipes, treatment plants and other critical components that deliver safe drinking water to our taps and remove waste water from our homes and other buildings. Recognizing the importance of having a common understanding of the challenges ahead, the U.S. Environmental Protection Agency (EPA) undertook a "Gap Analysis" to review the historical patterns of infrastructure investment, compare it to projections of future needs, and provide a transparent assessment of the gap between needs and spending. The result of our effort is this report on the *Clean Water and Drinking Water Infrastructure Gap Analysis*.

In keeping with our commitment to subject our analysis to external scrutiny, EPA submitted the methods and data used in the Gap Analysis to a diverse panel of peer reviewers drawn from academia, think tanks, consulting firms, and industry. Overall, the reviewers commended the report as a reasonable effort to quantify the gap. As a result of the peer review process, we revised the preliminary projections and approaches to incorporate the comments and views of these expert external reviewers.

This report makes clear that there is no single correct number to describe the gap. Any gap study must be built using methodologies and definitions of need, which in turn rest on assumptions about the present conditions of infrastructure nationwide, and desirable or appropriate policies to follow in the future. While much of the projected gap is the product of deferred maintenance, inadequate capital replacement, and a generally aging infrastructure, it is in part a consequence of future trends we can anticipate today, such as continuing population growth and development pressures. Yet, funding gaps need not be inevitable. They will occur only if capital and operations and maintenance (O&M) spending and practices remain unchanged from present levels. The analysis suggests that a large gap will result if the challenge posed by an aging infrastructure network—a significant portion of which is beginning to reach the end of its useful life—is ignored.

EPA has encouraged a national dialogue on the appropriate roles for addressing infrastructure needs and continues to work in partnership with Congress and other stakeholders in helping to define effective approaches to meeting these emerging challenges. This report on the *Clean Water and Drinking Water Infrastructure Gap Analysis* is one of EPA's contributions toward an ongoing dialogue. Our objective is to ensure clean and safe water for generations to come. Water infrastructure is key to that future.

G. Tracy Mehan, III

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Executive Summary

To gain a better understanding of the future challenges facing the clean water and drinking water industries, the U.S. Environmental Protection Agency (EPA) has conducted a study to identify whether there is a quantifiable gap between projected clean water and drinking water investment needs over the twenty-year period from 2000 to 2019 and current levels of spending. The analysis found that a significant funding gap could develop if the nation's clean water and drinking water systems maintain current spending and operations practices.

However, this gap largely disappears if municipalities increase clean water and drinking water spending at a real rate of growth of three percent per year. This real rate of growth represents a three percent per year increase over and above the rate of inflation and is consistent with the long-term growth estimates of the economy.

The scope of this report is limited to a discussion of methods for calculating the capital and operations and maintenance (O&M) gaps for clean water and drinking water. Although the findings will inform policy discussion, this report confines itself to estimating the gap, and it does not attempt to discuss the array of policy considerations stemming from the results.

In calculating capital investment needs over the twenty-year period, both the clean water analysis and the drinking water analysis used their respective Needs Surveys as a starting point. Adjustments were made to account for under-reporting of needs, especially with regard to needs associated with capital replacement. Estimates of capital needs for clean water from 2000 to 2019 range from $331 billion to $450 billion with a point estimate of $388 billion. Estimates of capital needs for drinking water over the twenty-year period range from $154 billion to $446 billion with a point estimate of $274 billion.

The methods used several alternative assumptions that generated hundreds of different permutations for estimating the capital and O&M gaps. The range represents the uppermost and lowermost extremes of these estimates. Providing a range explicitly acknowledges the uncertainty of the analysis, which stems from the limited quality of the available data and the potential for variance in key factors affecting costs. The point estimates were calculated by taking an average of each possible combination of assumptions.

The analysis also compared projected operations and maintenance (O&M) needs to current spending. O&M needs for both clean water and drinking water were assumed to be a function of capital stock. To estimate current O&M spending, both analyses used historical O&M spending data from the Congressional Budget Office and the Census Bureau and held this level constant over the 20-year period.

The resulting O&M gap for clean water over the next twenty years is between $72 billion and $229 billion with a point estimate of $148 billion for the no revenue growth scenario, and the gap is between $0 billion and $80 billion with a point estimate of $10 billion[1] for the revenue growth scenario. The drinking water O&M gap is between $0 billion and $495 billion with a point estimate of $161 billion[2] for the no revenue growth scenario, and this gap is between $0 billion and $276 billion with a point

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[1] The actual range is $-55 to $80 billion with a point estimate of $10 billion. Under the assumptions used for certain scenarios, the models predict a surplus of infrastructure funds, or rather, a negative gap. In these scenarios, total spending and/or revenues will exceed the total need over the next 20 years. The report excludes these negative values in the text, because systems generally would not collect revenues in excess of their current estimated infrastructure needs. However, it should be noted that doing so would free infrastructure funds for situations where gaps remain.

[2] The actual range is $-67 to $495 billion with a point estimate of $161 billion. See Footnote 1 for further explanation.

estimate of $0 billion[3] for the revenue growth scenario.

Whereas municipalities pay O&M costs from current revenues, they often use debt instruments to finance some of their clean water and drinking water infrastructure investments. However, the portion of clean water infrastructure that is financed is significantly greater than the portion of drinking water infrastructure that is financed. The analysis assumes that clean water and drinking water systems will finance a significant portion of projected capital needs over the estimation period. Estimates of payments for clean water capital needs range from $321 billion to $454 billion, while estimates of payments for drinking water capital needs range from $178 billion to $475 billion.

Capital spending (payments) estimates for the twenty-year period were made using historical data from the Congressional Budget Office and the U.S. Census Bureau. Current capital spending for clean water is estimated at $13 billion per year. For drinking water, current capital spending is estimated at $10.4 billion per year.

The capital payments gap is equal to the capital payment needs less the current spending on capital. For clean water, estimates of the capital gap range from $73 billion to $177 billion with a point estimate of $122 billion for the no revenue growth scenario, and the estimates range from $0 billion to $94 billion with a point estimate of $21 billion[4] for the revenue growth scenario. For drinking water, estimates of the capital gap range from $0 billion to $267 billion with a point estimate of $102 billion[5] for the no revenue growth scenario, and the estimates range from $0 billion to $205 billion with a point estimate of $45 billion[6] for the revenue growth scenario.

It is also important to note that the range of needs and gaps are provided to explicitly acknowledge variations within the estimates, but are not intended to support comparative analysis between the clean water and drinking water industries. The drinking water analysis was able to use data sets that were not available to clean water, e.g., data sets of pipe inventory and age of assets. These data allowed drinking water to use four different methods to estimate capital needs and vary assumptions within each method, whereas the clean water analysis used a single method and varied assumptions within that method. The broader array of methods available to the drinking water analysis generated a broader range of needs and gaps. As such, the resulting ranges provide insight into the impact of varying assumptions within each industry, but the data and methods cannot be used to conduct a valid comparison of the funding gaps facing the clean water and drinking water industries.

EPA submitted the methods and data used in this analysis to a panel of peer reviewers drawn from academia, think tanks, consulting firms, and industry. In general, the reviewers found that the analysis represented a commendable and credible effort to quantify the infrastructure gap. EPA refined the analysis to address comments made by the reviewers, although implementation of some of the recommendations would require data that are as yet unavailable. The results, therefore, should be viewed with the understanding that the present body of data constrains our ability to estimate the gap with a high degree of certainty. This caveat aside, the report offers estimates to ensure that policy discussions of a pressing infrastructure challenge will not be forestalled while we await improvements in data quality—rather, any refinements to the estimates should inform ongoing deliberations. The major issues and concerns raised by the peer review panel are summarized in Appendix B.

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[3] The actual range is $-286 to $276 billion with a point estimate of $-58 billion. See Footnote 1 for further explanation.

[4] The actual range is $-39 to $94 billion with a point estimate of $21 billion. See Footnote 1 for further explanation.

[5] The actual range is $-17 to $267 billion with a point estimate of $102 billion. See Footnote 1 for further explanation.

[6] The actual range is $-94 to $205 billion with a point estimate of $45 billion. See Footnote 1 for further explanation.

Introduction

1.0 Purpose

The objective of this report is to determine whether a potential funding gap could emerge between projected needs and current spending with respect to clean water and drinking water infrastructure. The analysis presents in detail the methods for quantifying the gap for the purpose of providing transparency as to how the estimates were derived. The results are expressed as a range; each range also has a point estimate that is the average of the different combinations of assumptions that could be used in calculating the gap. By presenting the findings as a range, the report acknowledges the uncertainty. The report confines itself to quantifying the funding shortfall for capital and operations and maintenance (O&M) investments that will be needed to ensure that clean water and drinking water systems can continue to protect the environment and public health. The policy implications of the funding gap are beyond the scope of the present analysis. The remainder of this chapter provides the historical and technical context for understanding the infrastructure issues confronting the clean water and drinking water industries.

1.1 Background

Water is life. Clean and safe water is critical for human health and ecosystem health. As early as 5000 years ago, centralized systems supplied drinking water to communities in parts of the Middle East. Twenty-five hundred years ago, Athens, Greece rebuilt its city with sewers that transported sanitary waste to rural areas for disposal onto orchards and agricultural fields. In the centuries since, these two services—supply of drinking water and disposal of wastewater—have become intrinsic responsibilities of communities worldwide.

As recently as the mid-nineteenth century, however, drinking water supply and wastewater disposal were largely matters of transportation—of bringing drinking water to citizens and removing wastewater. In the United States, health concerns and technological advances brought changes to drinking water infrastructure around the turn of the twentieth century. In 1872, Poughkeepsie, NY introduced slow sand filtration to reduce turbidity in drinking water. This treatment via filtration removed microbial contaminants that had caused typhoid, dysentery, and cholera epidemics. In 1908, Jersey City, NJ introduced drinking water disinfection treatment, and chlorination further reduced drinking water disease outbreaks.

If a community's wastewater received any treatment prior to 1900, this treatment consisted of physically separating solids and floating debris from wastewater before discharge into a nearby waterbody. In 1907, Gloversville, NY built the nation's first wastewater filtration facility, and in 1916, Chicago, IL constructed an activated sludge treatment plant. These advances, called secondary treatment, helped to alleviate epidemics of typhoid, cholera, and other waterborne diseases. This treatment also improved ecosystem health—highlighted by resurging fish and shellfish populations.

In the last century, treatment of drinking water and wastewater has become more advanced, and it has spread to almost all systems in the country. The 1972 Clean Water Act mandated that all publicly owned treatment works (POTWs) provide secondary treatment of wastewater. By 1996, fewer than 200 systems—out of 16,204 nationwide—had not met this standard. The 1974 Safe Drinking Water Act established a system of nationwide standards for drinking water contamination. Today, the Environmental Protection Agency regulates more than 80 drinking water contaminants and the vast majority of people receive drinking water from systems that have no reported violations of health-based standards.

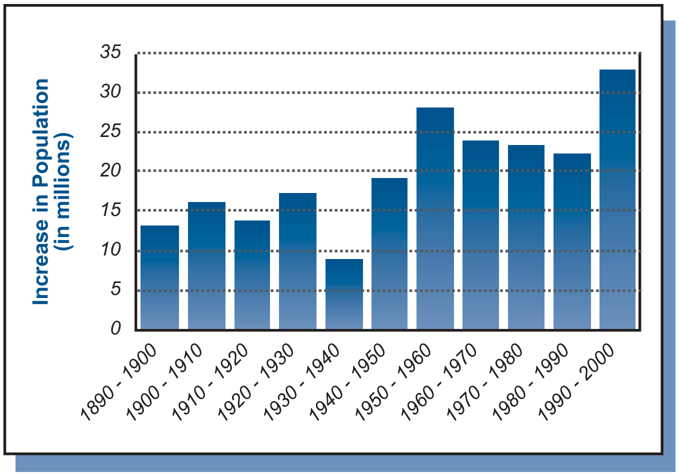

Figure 1–1: Increase in U.S. Population by Decade

The advancement and expansion of clean water and drinking water systems has been worthwhile but costly. In the last twenty years, communities have spent $1 trillion in 2001 dollars on drinking water treatment and supply and wastewater treatment and disposal.[7] This spending is impressive, but it may not be sufficient to keep pace with infrastructure needs of the future. Several issues provide cause for concern.

- *Our systems are aging.* Generally, installation of clean water and drinking water infrastructure has followed overall patterns of population growth in cities across the country (Figure 1–1). Treatment plants typically have an expected useful life of 20–50 years before they require expansion or rehabilitation. Pipes have life cycles that can range from 15 to well over 100 years—with actual pipe life varying considerably depending on soil conditions, pipe material, climate, and capacity requirements. In some eastern cities, systems have some pipes in use that are almost 200 years old.

- *Populations are increasing and shifting geographically.* The 2000 Census identified a population of 281 million in the country, an increase of more than 32 million from the 1990 Census. This change was the largest census to census increase in United States history. The Census Bureau projects a population of more than 325 million by the year 2020. Systems will need to increase capacity to meet the demands posed by this growth. To complicate the issue, population is shifting geographically, requiring rapid increases in system capacity in some parts of the country and requiring maintenance of aging systems in other parts of the country with diminishing populations (and a diminishing rate base).

- *Current treatment may not be sufficient.* In 1998, states, tribes, and interstate commissions assessed water quality in 32 percent of the nation's estuaries and found 44 percent of the assessed areas to be impaired. Wastewater treatment facilities and combined (wastewater and stormwater) sewer overflows were two of the leading causes of impairment. Wastewater treatment efficiencies may be leveling off, which, when combined with population and economic growth, could have the effect of reversing hard-won water quality gains. By 2016 pollution levels could be similar to levels observed in the mid-1970s (Figure 1–2).

- *Investment in research and development has declined.* Innovation, research, and development are essential elements in promoting the use of more effective, efficient, and affordable technologies in water and wastewater treatment. A recent EPA report on R&D expenditures (public and private) associated with water pollution abatement showed that expenditures decreased by half from the early 1970s to the late 1990s (Figure 1–3).

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[7] Based on annual outlays reported in the Bureau of the Census Government Finances Data Series for local government expenditure for sewerage and the Engineering News-Record's Construction Cost Index (www.enr.com/cost/costcci.asp).

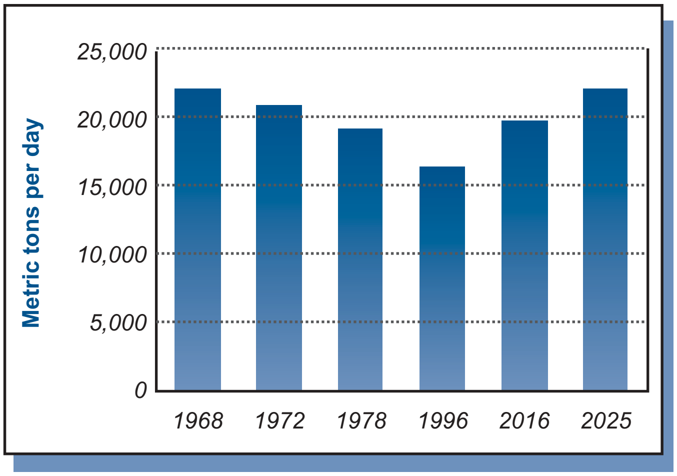

Figure 1–2: Projection of Increase in Biological Chemical Oxygen Demand (BOD)[8]

- *Services are non-centralized.* Twenty-five percent of all households in the U.S. have on-site wastewater treatment systems and 15 percent of all households receive drinking water from private wells. Generally, states and communities have not established adequate management programs to assure proper functioning of onsite systems for wastewater treatment and private drinking water wells. This under-investment in support results in poor location and design decisions, inferior materials, faulty installation, and a general lack of maintenance. Adequate investment is critical to ensuring that these systems operate properly. At the local, state, and national level, more attention will have to be paid in the future, not only to replace and repair existing infrastructure, but also to establish and support management programs.

- *Some communities will have a difficult time meeting funding challenges.* Some communities, particularly small communities which lack the economies of scale associated with a large customer base, are challenged in meeting the cost of installing and maintaining infrastructure. The financial impact of the need to address aging infrastructure will be greater for these communities. There are also communities in the country that are unserved or underserved by clean water and drinking water systems (Indian Tribes, *Colonias*, Alaska Native Villages).

To gain a better understanding of the challenges the clean water and drinking water industries will face in the future, EPA has conducted a study to identify whether there is a quantifiable gap between the estimated investment needs for clean water and drinking water systems and current spending by these systems over the next 20 years. In order to frame the discussion, Chapter 2 of this report describes the characteristics of the clean water and drinking water industries. Chapters 3 and 4 lay out the Agency's identification of the needs and spending associated with clean water and drinking water infrastructure, respectively, in an effort to identify whether there is a gap. Chapter 5 summarizes the findings and suggests areas for further research.

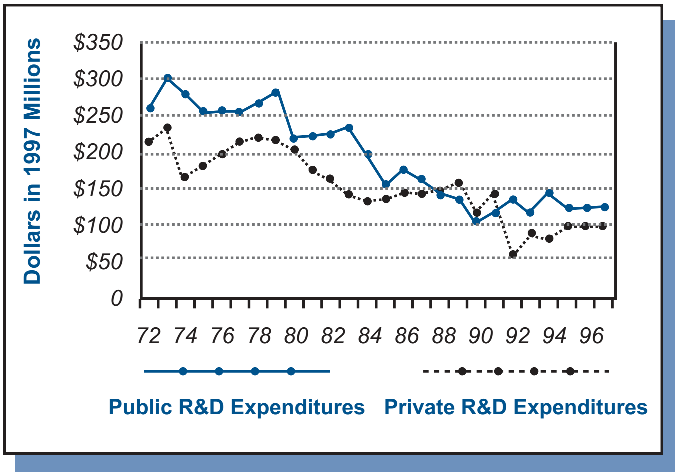

Figure 1–3: Declining Trend in R&D Water Pollution Abatement Expenditures[9]

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[8] U.S. EPA, *Progress in Water Quality: An Evaluation of the National Investment in Municipal Wastewater Treatment*, June 2000.

[9] U.S. EPA, *A Retrospective Assessment of the Costs of the Clean Water Act: 1972 to 1997*, October 2000.

Characteristics of the Clean Water and Drinking Water Industries

2.0 Purpose

A discussion of the characteristics of the clean water and drinking water industries provides a useful context for understanding the results of the gap analysis. For example, the differences between the industries necessitated the use of different methods in estimating needs, costs, and payments gaps.

2.1 Characteristics of the Clean Water Industry

In the United States, there are 16,024 publicly owned treatment works for treating municipal wastewater. Although there are also some privately owned wastewater treatment works, most of the industry (98 percent) is in fact municipally owned. These POTWs provide service to 190 million people, representing 73 percent of the total population (at the time of the 1996 Clean Water Needs Survey Report to Congress). Seventy-one percent of the facilities serve populations of less than 10,000 people. Furthermore, approximately 25 percent of households in the nation are not connected to centralized treatment, instead using on-site systems (e.g., septic tanks). Although many of these systems are aging or improperly functioning, this analysis is restricted to centralized collection and treatment systems.

2.2 Characteristics of the Drinking Water Industry

The drinking water industry has over ten times the number of systems as the clean water industry. Of the almost 170,000 public water systems, 54,000 systems are community water systems, that collectively serve more than 264 million people. A community water system serves more than 25 people a day all year round. The remaining 114,000 water systems are transient noncommunity water systems (e.g., camp grounds) or non-transient noncommunity water systems (e.g., schools). The scope of the gap analysis is largely confined to community water systems,[10] as these systems serve most of the population. Small systems serving fewer than 10,000 people comprise 93 percent of all community water systems in the nation. However, most of the population (81 percent) receives drinking water from larger systems (Figure 2–1).

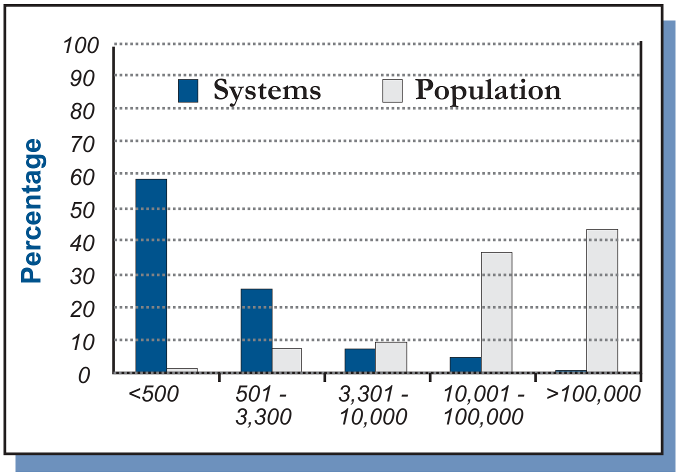

Figure 2–1: Percentage of Drinking Water Systems and Population Served by Size Class

In contrast to the clean water industry, only about 43 percent of community water systems are publicly owned. Most of these systems are under the authority of local governments (Figure 2–2). Ownership type varies by system size—with almost 90 percent of systems serving more than 10,000 people under public ownership.

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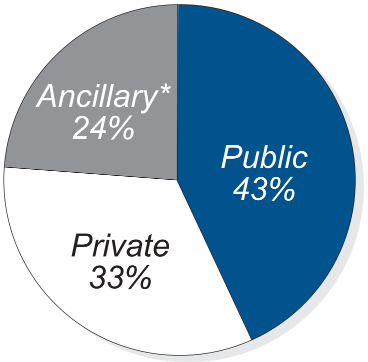
[10] The Needs Survey data also includes $3.1 billion in needs for 21,400 not-for-profit noncommunity systems. Therefore this analysis includes those systems as well. It also includes needs for Alaskan Native Villages and American Indian systems.



** Ancillary: Water supply is not primary purpose of business (e.g., mobile home park)*

Figure 2–2: Percentage of Drinking Water Systems by Type of Ownership

2.3 General Characteristics of Capital Stock and Impact on Operations and Maintenance

The different components of capital stock that make up our nation's clean water and drinking water systems vary in complexity, materials, and the degree to which they are subjected to wear and tear. The expenditures that utilities must make to address the maintenance of systems are largely driven by the condition and age of the components of infrastructure.

2.3.1 Useful Life

The life of an asset can be estimated based on the material, but many other factors related to environment and maintenance can affect the useful life of a component of infrastructure. On a national level, it is not feasible to conduct a condition assessment of all clean water and drinking water infrastructure systems. However, approximation tools can be used to estimate the useful life of these infrastructure systems.

One such approximation tool is a useful life matrix, which can serve as a tool for developing initial cost estimates and for long-range planning and evaluating programmatic scenarios. An example of a matrix developed as an industry guide in Australia is shown in Table 2–1.[11] Although the useful life of a component will vary according to the materials, environment, and maintenance, matrices such as that shown in Table 2–1 can be used at the local level as a starting point for repair and replacement, strategic planning, and cost projections. The U.S. as well as other industrialized countries have engineering and design manuals that instruct professional designers as to the accepted standards of practice for design life considerations. The U.S. Army Corps of Engineers, the American Society for Testing Materials, the Water Environment Federation, the American Society of Civil Engineers, and several associations maintain data that provides guidance on design and construction of conduits, culverts, and pipes and related design procedures.

Table 2-1 - Useful Life Matrix

Years	Component
	Clean Water
80 - 100	Collections
50	Treatment Plants - Concrete Structures
15 - 25	Treatment Plants - Mechanical & Electrical
25	Force Mains
50	Pumping Stations - Concrete Structures
15	Pumping Stations - Mechanical & Electrical
90 - 100	Interceptors
	Drinking Water
50 - 80	Reservoirs & Dams
60 - 70	Treatment Plants - Concrete Structures
15 -25	Treatment Plants - Mechanical & Electrical
65 - 95	Trunk Mains
60 - 70	Pumping Stations - Concrete Structures
25	Pumping Stations - Mechanical & Electrical
65 - 95	Distribution

The useful life of pipe, which comprises most of the assets of both clean water and drinking water systems, varies considerably based on a number of factors. Some of these factors include the material of which the pipe is made, the conditions of the soil in which it is buried, and the character of the water or wastewater flowing through it. In addition, pipes

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[11] *The International Infrastructure Management Manual*, Version 1.0. Australia / New Zealand Edition, April 2000

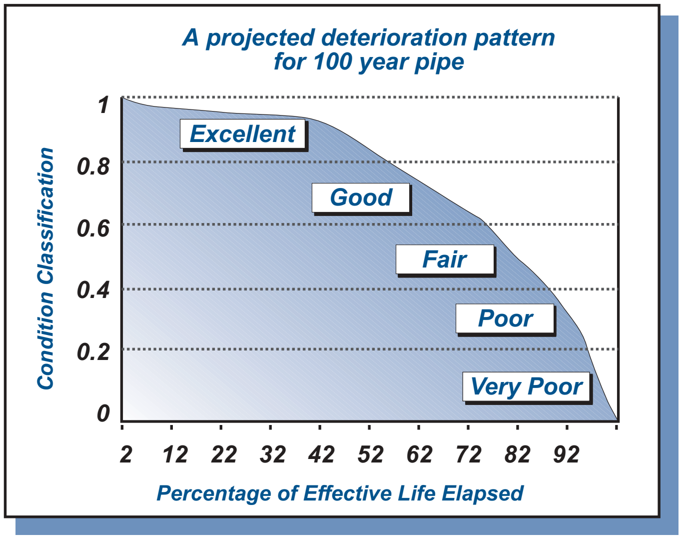

Figure 2–3: Example of Life Cycle Deterioration Curve

do not deteriorate at a constant rate. During the initial period following installation, the deterioration rate is likely to be slow, and repair and upkeep expenses low. For pipe, this initial period may last several decades. Later in the life cycle, pipe will deteriorate more rapidly. Figure 2–3 is an example of a deterioration classification scheme.

The best way to determine remaining useful life of a system is to conduct periodic condition assessments. The new financial reporting requirements (GASB 34) of the Government Accounting Standards Board recognize the role condition assessments play in advancing its 'preservation report' framework. At the local level, service providers can conduct condition assessments of their collection systems to ascertain their condition for maintenance and replacement purposes. It is essential for local service providers to complete periodic condition assessments in order to make the best life-cycle decisions regarding maintenance and replacement.

2.3.2 Operating and Maintaining Capital Stock

As shown in Figure 2–4, spending in constant dollars on operations and maintenance (O&M) for clean water and drinking water has grown significantly since 1970. In 1994, for example, 63 percent of the total spending for clean water was for O&M, and 70 percent of the total spending for drinking water was for O&M.[12]

Likely explanations for the increase in clean water and drinking water O&M costs include the following:

- Expansion and improvement of services, which translated into an increase in capital stock and a related increase in operations and maintenance costs.

- Aging infrastructure, which requires increasing repairs and increasing maintenance costs.

Also, increases in clean water operations and maintenance have been driven, in large part, by a large number of solids handling facilities coming on-line. The installation of these facilities has increased O&M costs beginning in the mid-1980s.

Over the next 20 years, O&M expenses are likely to increase in response to the aging of the capital stock: that is, as infrastructure begins to

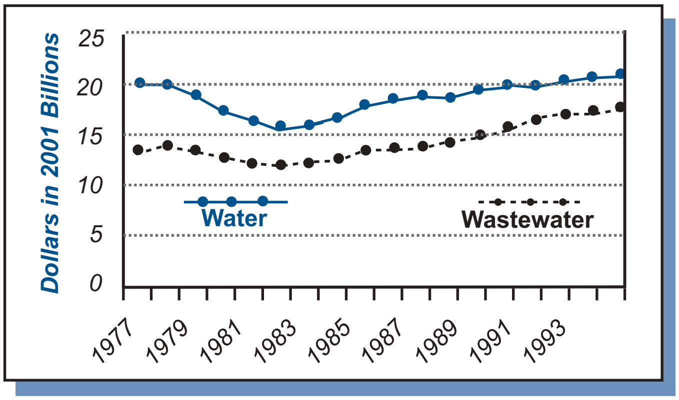

Figure 2–4: Operations and Maintenance Spending from State and Local Sources (1978–1994)

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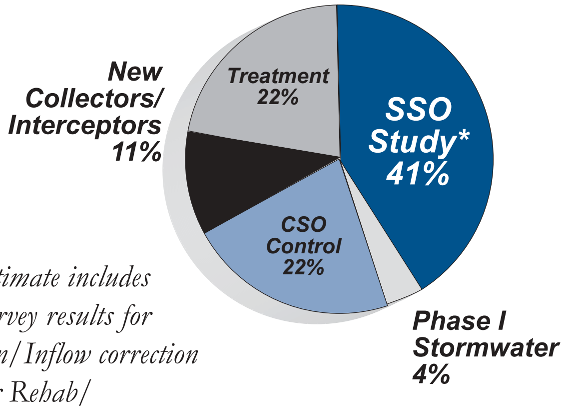
[12] Congressional Budget Office, *Trends in Public Infrastructure*, May 1999.

deteriorate the costs of maintaining and operating the equipment will increase. An American Water Works Association (AWWA) study found that projected expenditures for deteriorating infrastructure would increase steadily over the next 30 years.[13] The projected increase in O&M costs finds support in the historical spending data, which indicate an upward trend for O&M (Figure 2–4).



** SSO estimate includes Needs Survey results for Infiltration/Inflow correction and Sewer Rehab/ Replacement*

Figure 2–5: 1996 Clean Water Needs by Category (adjusted for the SSO study)–$225 Billion in 2001 Dollars

Increasing O&M needs will present a significant challenge to the financial resources of clean water and drinking water systems. As the nation's water infrastructure ages, systems should expect to spend more on O&M. Some systems might even postpone capital investments to meet the rising costs of O&M—assuming that their total level of spending remains constant. The majority of systems likely would increase spending to ensure that both capital and O&M needs are fulfilled, and thus total spending would increase significantly. Many systems would recognize that delaying new capital investments would only increase expenditures on O&M, as old and deteriorated infrastructure would need to be maintained at increasingly higher costs.

2.4 Clean Water Capital Stock

The basic components of clean water infrastructure are collection systems and treatment works. Systems vary across the clean water industry as a function of the demographic and topographic characteristics of the service area, the unique characteristics of the particular waste stream, and the operating requirements dictated in the permit conditions. The type of treatment is largely controlled by discharge limitations and performance specified through state or federal permits.

The Clean Water Needs Survey collects needs documentation from publicly owned treatment works. Although the results likely underestimate true needs, particularly when considering replacement of pipes (discussed further in Chapter 3), they can serve as an example of the components of a system. Figure 2–5 shows the percent of need associated with the major needs categories in the 1996 Clean Water Needs Survey, adjusted based on results of the Agency's recent cost analysis conducted to estimate costs associated with correcting sanitary sewer overflows (SSOs).

Pipe networks represent the primary component of a clean water system. During the last century, as population grew and spread out from urban centers, the amount of pipe increased as homes were connected to centralized treatment. Although there is not an actual inventory of the total amount of sewer pipe associated with wastewater collection systems in the U.S., the American Society of Civil Engineers (ASCE)[14] has developed an estimate based on feet of sewer per capita—with the average length estimated at 21 feet of sewer per capita. The range varied from 18 feet to 23 feet per capita. The resulting estimate is about 600,000 miles of publicly owned pipe.

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[13] American Water Works Association, *Dawn of the Replacement Era: Reinvesting in Drinking Water Infrastructure*, May 2001.

[14] American Society of Civil Engineers, *Optimization of Collection System Maintenance Frequencies and System Performance*, February 1999.

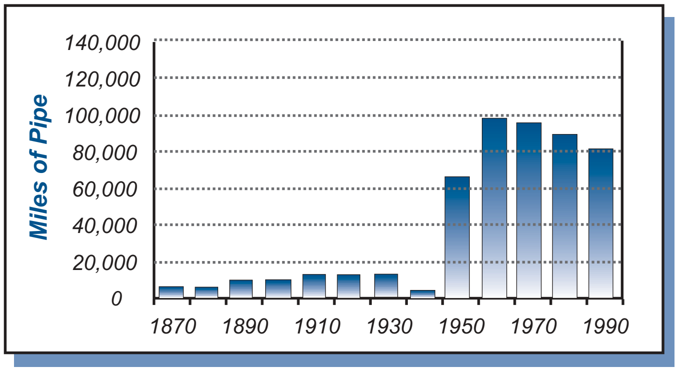

Figure 2–6: Histogram of Miles of Sanitary Sewer Pipe Installed per Decade

Because there is no nationwide inventory of wastewater collection systems, the actual age of sewer pipe is not known. However, it is safe to say that installation of pipe has followed demographic increases in population and growth in metropolitan areas associated with suburbanization. Figure 2-6 represents an estimate of the amount of sewer pipe installed per decade, using population, urban density, and public sewerage system data from the U.S. Census Bureau.

The vast majority of the nation's pipe network was installed after the Second World War, and the first part of this wave of pipe installation is now reaching the end of its useful life. For this reason, even if the pipe system is extended to serve growth and the country invests in the replacement of all pipe as it comes to the end of its useful life, the average age of pipe in the system will still increase until at least 2050 (Figure 2-7.)

Although there will be differences based on pipe material and condition, the need to replace pipe will generally echo the original installation wave. Figure 2-8 applies a deterioration curve to the pipe network as it ages from 1980 to 2020. Based on the deterioration projections over the next twenty years, if the pipe system is extended to serve growth but there is no renewal or replacement of the existing systems, the amount of pipe classified as either "poor," "very poor," or "life elapsed" will increase from 10 percent of the total network to 44 percent of the total network.

Many of the wastewater treatment plants in the U.S. were completely renovated with major plant expansion and upgrade work beginning in the 1970s, responding to new treatment requirements of the 1972 Clean Water Act and financed to a great extent by EPA's Construction Grants program. Although plants have shorter useful lives than sewer pipe, plant replacement needs are not projected to be a major part of the renewal and replacement requirements until after 2020. In the near term, 22 percent of the needs identified in the 1996 Clean Water Needs Survey were related to treatment.

Of course, some of the components in the treatment plants (e.g., mechanical and electrical components) will need to be replaced within the next 20 years, but relative to the collection systems, they are much less significant. Furthermore, there tends to be greater awareness of the condition of the plant structures since they are easier to observe (i.e., not buried underground) and are subject to more frequent inspection. However, there are implications to the costs associated with the plants. As the treatment plants continue to age, their operation and maintenance costs will increase at a more rapid rate, having a major impact on future operating budgets.

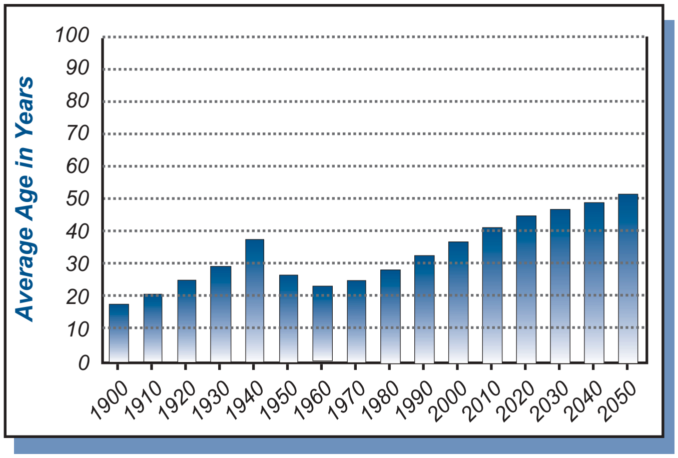

Figure 2-7: Average Age of Wastewater Pipe Network

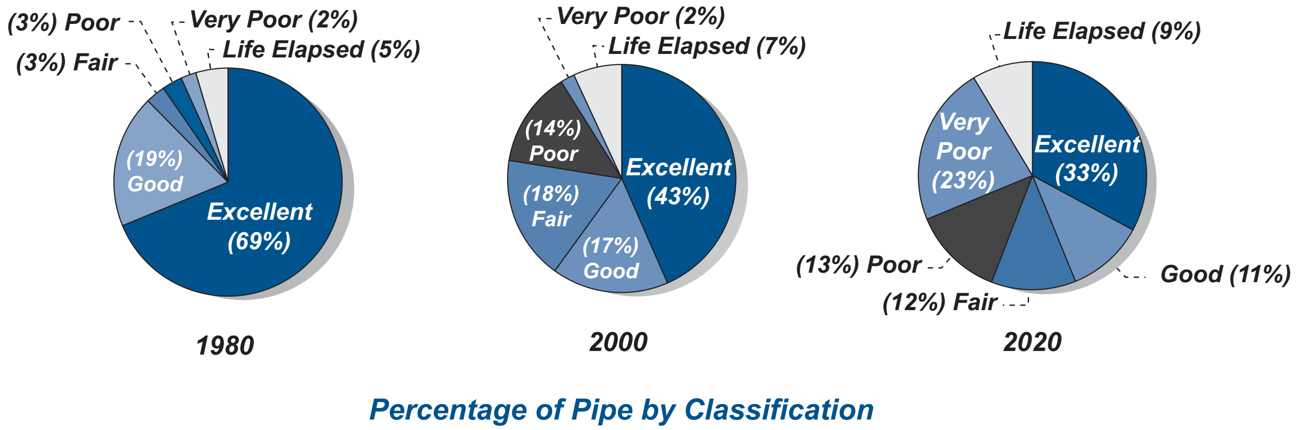

Figure 2–8: Shift in the Likely Condition Associated with the Aging Miles of Pipe in the Network (percentage of pipe by classification)

Furthermore, because so many treatment plants were constructed near the same point in time (i.e., beginning in the 1970s), replacement needs will hit at relatively the same time. The initial treatment plant replacement needs will occur at the same time that many pipes installed post-WWII will begin requiring replacement. Deferral of timely renewal and replacement associated with the oldest pipe over the next twenty years will likely put a system in a difficult financial condition. The typical system could experience a very significant bump in expenditures over a very short period of time to accommodate replacement of old pipes, new pipes, and plant structures in the same time frame.

2.5 Drinking Water Capital Stock

The analysis in Chapter 4 discusses the needs and spending associated with maintaining the capital stock of public drinking water systems. The capital stock of an individual drinking water system can be broken down into four principal components: source, treatment, storage, and transmission and distribution mains. Each of these components fulfills an important function in delivering safe drinking water to the public.

While there is no study available that directly addresses the capital make-up of our nation's drinking water systems, a general picture can be obtained from the 1999 EPA Drinking Water Infrastructure Needs Survey (Figure 2–9). Although it is the least visible component of a public water system, the buried pipes of a transmission and distribution network generally comprise most of a system's capital value. Transmission and distribution needs accounted for 55 percent of the total need reported in the 1999 survey. Treatment facilities that are needed to address contaminants with acute and chronic health effects represented the second largest category—with 25 percent of the total need. Storage projects needed to construct or rehabilitate finished water storage tanks represented 12 percent of the total need. Projects needed to address sources of water accounted for six percent. The source category included needs for constructing or rehabilitating surface water intakes, raw water pumping facilities, drilled wells, and spring collectors. Neither the storage nor source categories considered needs associated with the construction or rehabilitation of raw water reservoirs or dams.

The need to replace aging transmission and distribution components is a critical part of any drinking water system's capital improvement plan. A recent AWWA report, *Dawn of the Replacement Era,*[15] surveyed the inventory of pipe and the year in which

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[15] American Water Works Association, *Dawn of the Replacement Era: Reinvesting in Drinking Water Infrastructure*, May 2001.

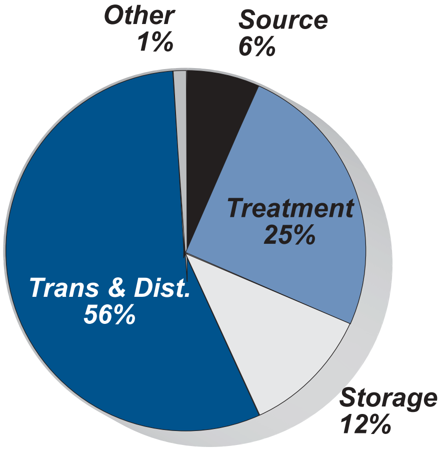


Figure 2–9: Percent Needs by Drinking Water Infrastructure Category (total needs $150.9 billion)

the pipe was installed for 20 cities in an effort to predict when the replacement of the pipe would be needed. While the 20 cities in the sample were not selected at random, the cities likely represent a broad range of systems of various ages and sizes from across the country. More importantly, the study provides the only available data on the age of pipe from a reasonably large number of systems. Figure 2–10 shows the distribution of the age of pipe currently in the inventory of these 20 cities.

While Figure 2–10 presents the distribution of the age of pipe for the 20 cities, the data do not indicate when the pipe would need to be replaced. Age is one factor that affects the life expectancy of pipe. A simple aging model, therefore, was developed to predict when pipes for these 20 cities would need to be replaced. It was assumed that pipes installed before 1910 last an average of 120 years. Pipe installed from 1911 to 1945 is assumed to last an average of 100 years. Pipe installed after 1945 is assumed to last an average of 75 years. In estimating when the current inventory of pipe will be replaced, the model assumes that the actual life span of the pipe will be distributed normally around its expected average life; that is, pipe expected to last 75 years will last 50 to 100 years, pipe expected to last 100 years will last from 66 to 133 years, and pipe expected to last 120 years will last 80 to 160 years.

This assumption greatly simplifies reality, as the deterioration rates of pipe will vary considerably as a function not only of age, but also of climatic conditions, pipe material, and soil properties. Pipe of the same material, for example, can last from 15 years to over 200 years depending on the soil characteristics alone. In the absence of data that would allow for the development of a model to estimate pipe life (i.e., accounting for local variability of pipe deterioration), the application of a normal distribution to an average life expectancy may provide a reasonable approximation of replacement

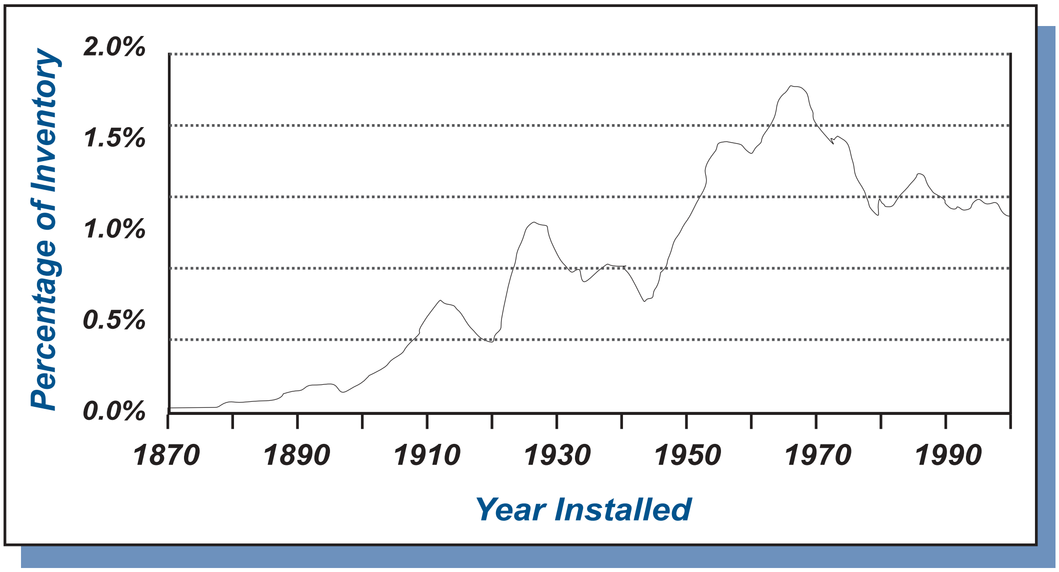


Figure 2–10: Age Distribution of Current Inventory of Pipe for 20 Cities

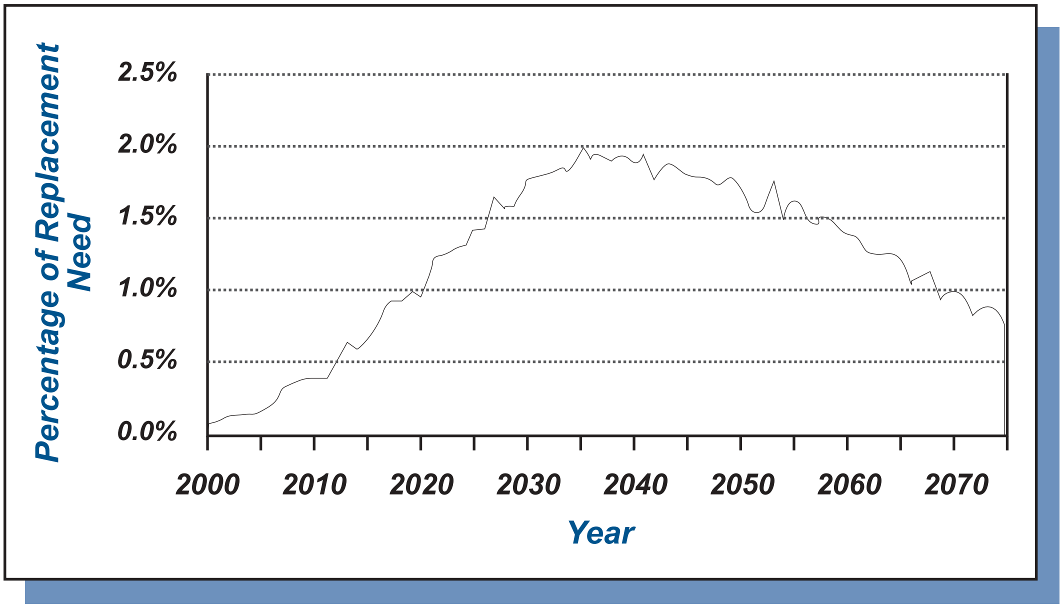


Figure 2–11: Projected Annual Replacement Needs for Transmission Lines and Distribution Mains, 2000–2075

rates. This model also does not account for other factors, most notably inadequate capacity, that may have equal or greater importance than deterioration in determining pipe replacement rates.

Applying this simple aging model to the historical inventory of pipe for the 20 cities reveals that most of the projected replacement needs for those cities will occur beyond the 20-year period of the analysis–with peak annual replacement occurring in 2040 (Figure 2–11). This conclusion makes sense considering that most of the nation's drinking water lines were installed after the 1940s.

2.6 Costs of Providing Service

Although many water and wastewater providers obtain funds from the federal government to finance the costs of capital improvements, most of the funds that systems use for both capital and operations and maintenance come from revenues derived from user fees. As utilities look to address

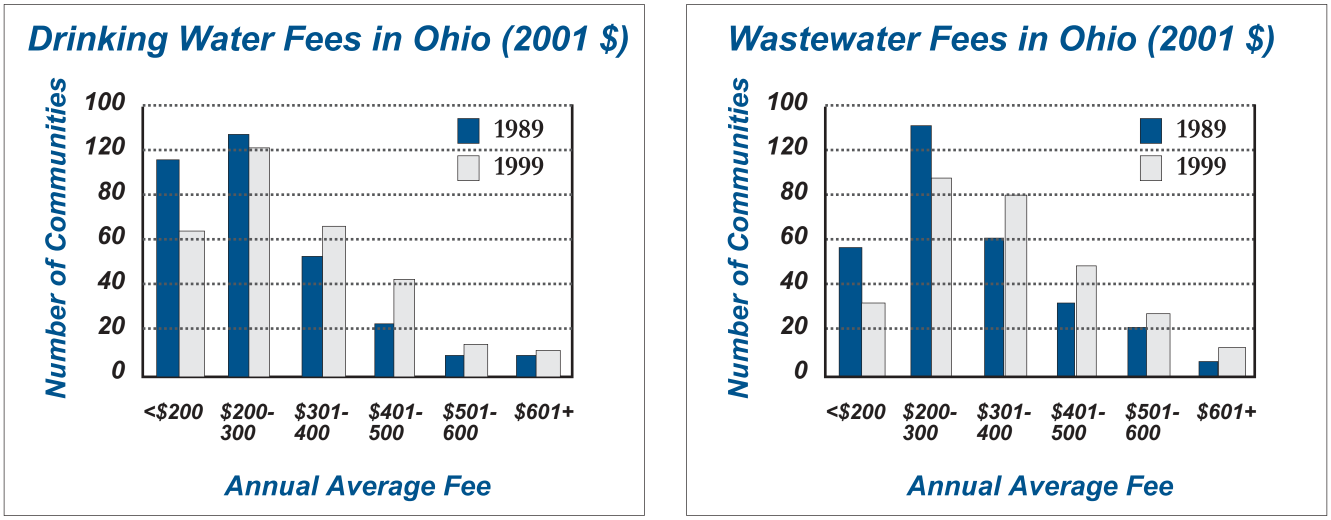
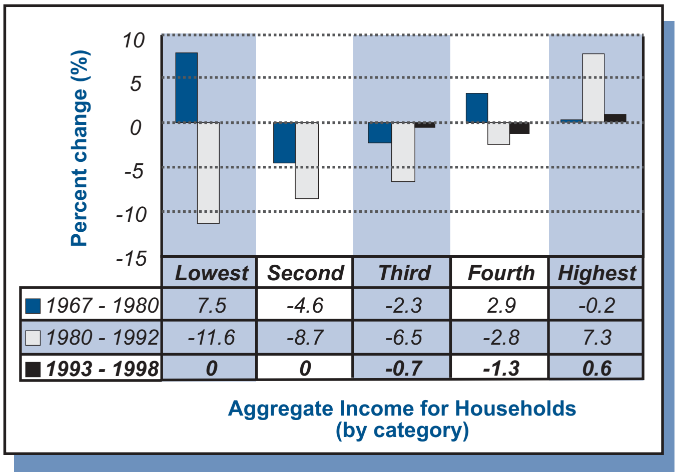


Figure 2–12: Change in Distribution of User Fees for Communities in Ohio between 1989 and 1999



	Lowest	Second	Third	Fourth	Highest
🟦 1967 - 1980	7.5	-4.6	-2.3	2.9	-0.2
□ 1980 - 1992	-11.6	-8.7	-6.5	-2.8	7.3
■ 1993 - 1998	**0**	**0**	**-0.7**	**-1.3**	**0.6**

Figure 2–13: Percentage Point Change in Share of Aggregate Income for Households (measured from initial year in range)

future capital needs and increasing O&M costs, they may need to increase fees to obtain the funding needed for these activities.

While there is no complete source of national data on how rates have changed through time, the State of Ohio has information that can serve as an example for the purposes of a simple discussion. For more than 15 years, the State has conducted an annual survey of water and sewer rates for communities in the state. Data from communities that reported rates for both 1989 and 1999 reveal that there has been an upward shift in the number of communities paying higher annual fees with time (Figure 2–12).

User rates that are needed to meet the cost of providing service have the potential to negatively impact those segments of the population with low incomes. Data from the Census Bureau[16] show that between 1980 and 1998, incomes at the lower range (as a percentage share of aggregate income for households) declined or stagnated (Figure 2–13). If rates increase to fund increasing needs, utilities may be challenged to develop rate structures that will minimize impacts on the less affluent segments of society.

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[16] U.S. Census Bureau, *The Changing Shape of the Nation's Income Distribution*, U.S. Census P60-204, Current Population Reports Series, June 2000.

Methods for Estimating Needs and Spending for Clean Water

3.0 Purpose

The purpose of this analysis is to quantify the relationship between the estimated infrastructure needs of clean water systems over the next 20 years and current levels of spending. The limitations of the data necessitate reporting the results of the analysis as a range. A range explicitly acknowledges the uncertainty of the analysis, specifically, the different underlying assumptions that can be used (with no clear distinction of validity) to estimate the capital and O&M needs. Within each range, however, the analysis provides a point estimate, which represents the average of the hundreds of different scenarios that can be generated for each combination of assumptions.

3.1 General Steps

The method for estimating the difference between needs and current spending involves five primary steps, each of which is described in the following sections.

1. Estimate the total capital investment needs for the next 20 years using data from the 1996 Clean Water Needs Survey, add a modeled estimate of Sanitary Sewer Overflow needs, and then adjust the analysis for underreported replacement needs.

2. Calculate the impact of financing the capital investment needs to determine the total capital cost and the total capital payments from 2000–2019.

3. Estimate the total O&M needs for the next 20 years using data from the Bureau of the Census Government Finances Data Series for local government expenditure for sewerage.

4. Considering historical spending, develop base levels of current annual capital spending and current annual O&M spending. Historical data on local government expenditures for sewerage are taken from the Bureau of the Census Government Finance Data Series.

5. Compare the projected annual needs to current annual spending estimates, considering both capital needs and O&M needs, and project the annual payment gap in clean water spending.

3.2 The Clean Water Capital Need

3.2.1 Clean Water Capital Investment Needs

The 1996 Clean Water Needs Survey (CWNS) provides data to estimate the total capital investment need over 20 years. The CWNS identifies a total capital investment need of $156.9 billion.[17] Table 3–1 summarizes the results of the needs survey.

A few factors may lead the CWNS to underreport needs at wastewater facilities over the next twenty years.[18] First, the CWNS mainly identifies capital investment needs related to compliance, not needs related to service levels. Second, the CWNS includes only needs that can be justified by project-specific documentation that describes the nature of the problem, recommended solutions, and the basis of the cost estimate. Survey information is collected through a buildup of state and local estimates, which are subjected to quality control review techniques to assure consistent

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[17] All figures in Chapter 3 are adjusted to 2001 dollars using the Engineering News-Record's *Construction Cost Index* (www.enr.com/cost/costcci.asp).

[18] An updated needs survey, the 2000 Clean Water Needs Survey, will be submitted to Congress in August 2002.

Capital Needs Identified in the 1996 Clean Water Needs Survey (in Billions of 1996 Dollars Adjusted to Billions of 2001 Dollars)			
Needs Category		1996	2001
I.	Secondary Treatment	$26.5	$29.8
II.	Advanced Wastewater Treatment	$17.5	$19.7
III.	Sewer Infiltration/Inflow Correction & Replacement/Rehabilitation	$10.3	$11.6
IV.	New Collector/Interceptor Sewers	$21.6	$24.3
V.	Combined Sewer Overflows (modeled estimate)	$44.7	$50.3
VI.	Stormwater (modeled estimate)	$7.4	$8.3
Wastewater/Infrastructure Related Subtotal		$128.0	$144.0
VII.	Various nonpoint source controls (modeled estimate)	$11.5	$12.9
Total		$139.5	$156.9

Table 3–1: Summary of 1996 Clean Water Needs Survey

treatment of data. The documentation requirement provides assurance that the needs and costs derived from different sources can be aggregated since they are developed using similar criteria and applying a common standard. Where little documentation exists across a need category, such as costs for controlling combined sewer overflows, sanitary sewer overflows, and storm water, EPA develops estimates using cost models.

Third, the need is only defined as a need if it exists on January 1 of the needs survey year (e.g., 1/1/96 for the 1996 survey). In other words, to have a future need recognized, it must be tied to a current need. The fourth factor is the planning period used to estimate needs. Historically, clean water infrastructure needs were planned and implemented based on a 20-year planning period. More recently, communities have been using a shorter planning period (e.g., 5 to 10 years), so the estimates they report for the Clean Water Needs Survey likely do not include the full cost needs associated with the 20-year period. This analysis assumes that modeling Sanitary Sewer Overflow needs and developing an underreported replacement estimate will capture many, if not most, of the underreported needs relating to existing infrastructure.

The clean water capital investment need is estimated in the following manner.

1. The CWNS identifies a total capital investment need of $156.9 billion for 20 years.

2. CWNS-identified needs for activities related to nonpoint source (e.g., agriculture, silviculture, urban runoff, estuaries, wetlands, and groundwater) (Category VII—$12.9 billion) are eliminated from the analysis.

3. The CWNS also identifies infrastructure needs for infiltration/inflow correction and sewer replacement/rehabilitation (Category III). These needs ($11.6 billion) are replaced in this analysis by modeled estimates ($92.1 billion) developed by EPA to better estimate the costs associated with correcting existing SSO problems in existing wastewater collection systems and bringing them into compliance with existing regulations. EPA based the SSO needs estimate on data from the 1996 Clean Water Needs Survey database and case studies from 65 municipalities. The methodology to estimate capital costs associated with reducing SSOs included a hydrologic model. The model simulates the effects of wet weather on each separate sanitary sewer system; a set of cost functions associated with infiltration/inflow reduction, storage, and treatment; and an optimization routine to determine the least costly combination of infiltration/inflow reduction, increased storage, and increased treatment.

4. This analysis then adjusts for underreported replacement needs. The development of this underreported replacement needs estimate is somewhat complex. This analysis assumes that

capital stock (wastewater treatment facilities, sewer systems, and rolling stock) has an average depreciation period of 60 years, an assumption developed by the Bureau of Economic Analysis. To model this assumption, this analysis assumes a replacement need of 3.3 percent (1/30) of net capital stock on an annual basis (roughly equal to 1.6 percent (1/60) of the non-depreciated capital stock constructed in the 60-year depreciation period). To simulate the turnover in capital stock over different periods of time, this analysis also developed scenarios in which net capital stock is replaced at annual rates of 4 percent and 2.9 percent, which translate roughly into a turnover of capital stock in 50 years and 70 years, respectively. The additional scenarios show how aggregate estimates are affected if the capital stock turns over at different rates.

Before this underreported replacement needs estimate is completed, however, it is reduced to account for replacement needs that are reported in the CWNS and modeled in the SSO estimate. Alternative scenarios used in this analysis assume that ¼, ½, or ¾ of the SSO estimate reflects replacement costs.

Data on the net capital stock from 1972–1990 are derived from the Consolidated Performance Report, a report that incorporates data from the Bureau of the Census Government Finances Data Series.[19] The analysis uses an iterative process to derive net capital stock values for each year by adding new stock and depreciation to the previous year's net capital stock value.[20]

Equation for each year's Underreported Replacement Needs Estimate

$$R = D*K - S*A/T$$

Where:

R = replacement need
D = depreciation rate for net capital stock
K = net capital stock
S = replacement costs in SSO estimate
A = annual reported capital investment needs
T = reported capital investment needs for 2000–2019

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In this analysis, the 20-year clean water capital investment need estimate ranges from $331 billion to $450 billion.

3.2.2 Capital Financing Costs And Payments

While some systems may purchase infrastructure with current revenues, many use debt financing for at least a portion of their infrastructure investments. According to the Bureau of Economic Analysis, clean water systems have historically used debt to finance 90 percent of their capital stock with municipal bonds or government loans. In this analysis, alternative scenarios assume that 75 percent, 85 percent, or 95 percent of capital investments will be financed.

This analysis distinguishes between capital investment needs (discussed in section 3.2.1), capital costs (including financing costs), and expected payments for capital investments (a measurement of cash flow needs). Although considerations of payment needs are most important for this infrastructure challenge, each estimate has value in policy discussions. However, investments must be

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[19] Corps of Engineers, *Consolidated Performance Report on the Nation's Public Works: An Update* (IWR Report 94-FIS-13, December 1994).

[20] Equation for Net Capital Stock

$K_t = K_{t-1} + I_t - D*K_{t-1}$

Where: K_t = net capital stock in year t,
I_t = capital investment (i.e., need) in year t, and
D = annual depreciation of net capital stock (expressed as a fraction)

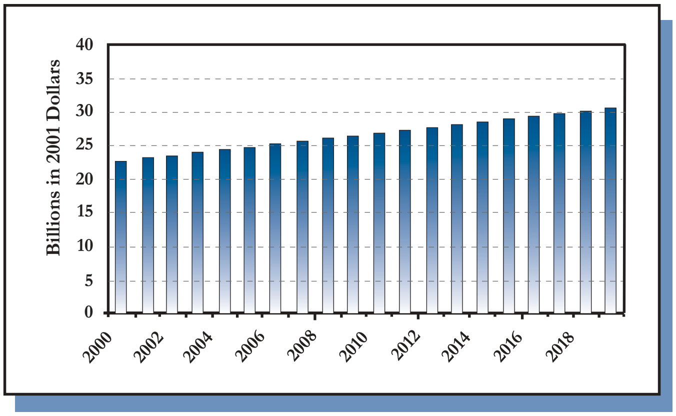

Figure 3–1: Projected Capital Costs (Average Scenario)

compared with investments, costs with costs, and payments with payments.

To estimate payments for capital investments and the resulting financing costs, the model makes the following assumptions:

1. Systems use municipal bonds or government loans to finance 75 percent, 85 percent, or 95 percent of their capital investments.

2. Systems borrow at a real interest rate of 2.5, 3.0, or 3.5 percent.

3. Loans have a term of 20, 25, or 30 years.

4. Systems will make level debt service payments over the life of the loan. The payment is given by:

$$p = \frac{k * (1 + r)^{n}}{\left(\frac{(1 + r)^{n} - 1}{r}\right)}$$

where:

p = the amount of the annual payment;
k = the value of the infrastructure purchased;
r = the real interest rate; and
n = the duration of the loan.

5. Each annual investment is simulated as a separate bond.

6. Debt service for old debt instruments does not include investments paid with EPA grants.

7. The amount not financed (for example, 15 percent of the total each year) is paid for in the year in which the infrastructure is purchased.

With these varied assumptions, if associated financing costs are accounted towards the year in which an investment is made, the capital financing cost ranges from 21.4 percent to 60.0 percent.[21] As a result, the capital cost estimate (including financing costs) ranges from $402 billion to $719 billion (Figure 3–1).

The term “payment” is used to indicate cash flows, e.g., when debt service payments for the investments are actually paid. Since a portion of the total need is purchased each year over the 2000–2019 period, and since a portion of each year’s purchase is financed over a 20-year period, all interest and principal payments are not paid for in full by 2019. However, an estimate of payments for capital investments must also include payments related to existing debt (Figure 3–2). The estimate of payments for capital investments in this twenty-year period ranges from $321 billion to $454 billion. These payments service existing debt, service debt incurred from 2000–2019, and cover pay-as-you-go expenditures. The total estimate of payments needed for capital investments is compared to current spending levels in section 3.6 to estimate clean water’s capital gap. It is important to note that these

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[21] For example, if annual capital financing needs are $100, and 75 percent of these needs are financed at a real interest rate of 3 percent over twenty years, an amortization schedule with level debt service will result in total payments of $100.82. The cost of borrowing ($100.82 - $75.00 = $25.82) is 25.8 percent of the annual capital financing needs. This ratio holds for any volume of annual capital financing needs.

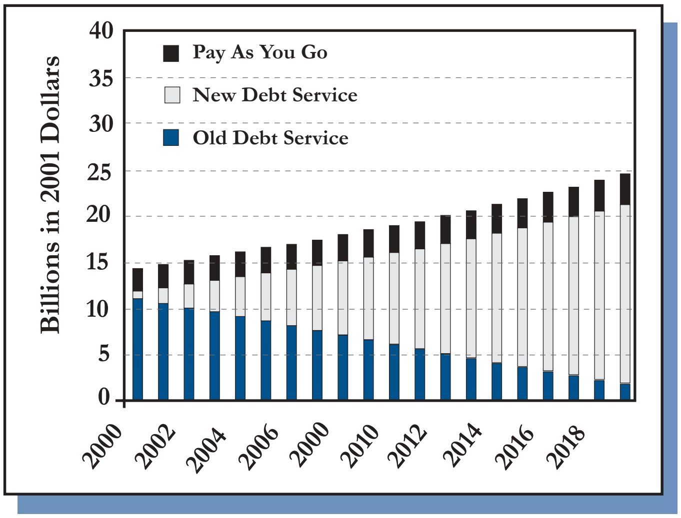

Figure 3–2: Projected Capital Payments (Average Scenario)

estimates assume that the local governments fund the entire increase in projected capital costs. Should state or federal sources provide local governments with grants or low-cost loan assistance, the total projected local payments would decrease because less capital would need to be financed.

3.3 Estimate Total O&M Needs

This analysis estimates future O&M needs by considering the ratio of O&M expenditures to net capital stock. According to O&M outlay data derived from the Bureau of the Census Government Finances Data Series for local government expenditure for sewerage, this ratio grew in linear fashion from 1972-1996. O&M needs grew from 3.7 percent of net capital stock in 1972 to 7.4 percent of net capital stock in 1996. This linear trend might be expected to continue if O&M costs were to continue to largely reflect service and treatment costs—and net capital stock were to continue to grow due to increasing service and treatment. However, this model assumes that O&M costs related to the maintenance of aging systems will increase, and it assumes that capital stock increases will increasingly reflect a different kind of expenditure—the eventual replacement of aging infrastructure.

By itself, an aging infrastructure should result in increasing O&M expenditures because of the increased need for repairs. However, a model that estimates O&M as a fixed percentage of net capital stock would project declining O&M as the net value of an aging capital stock declines, exactly the opposite of what should happen. Assuming an increasing ratio of O&M to net capital stock, which

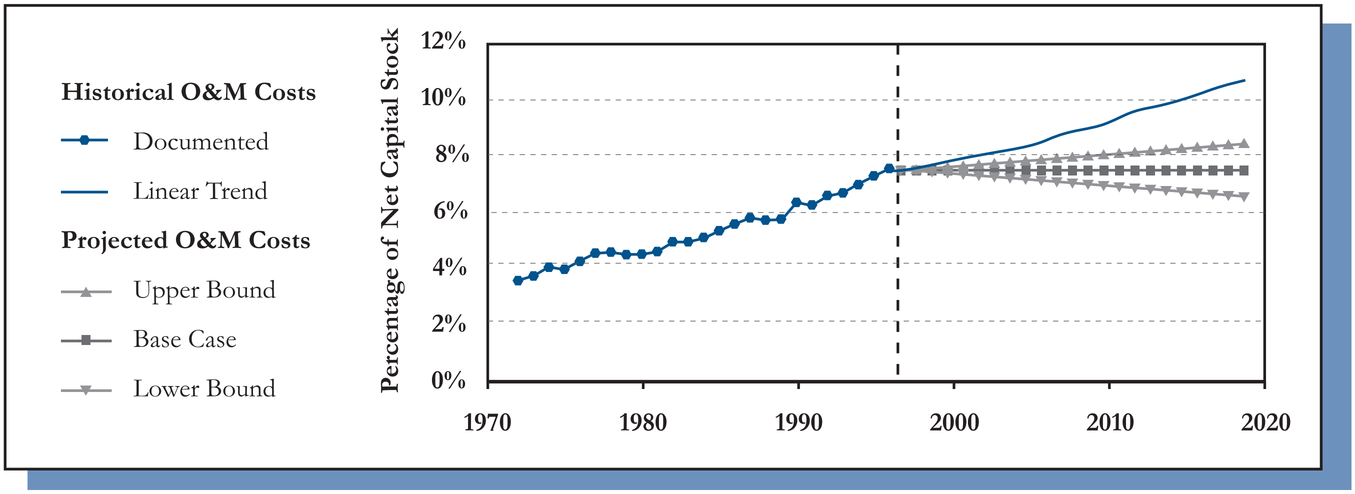

Figure 3–3: Annual Operations and Maintenance Cost Measured as a Percentage of Net Capital Stock (Average Scenario)

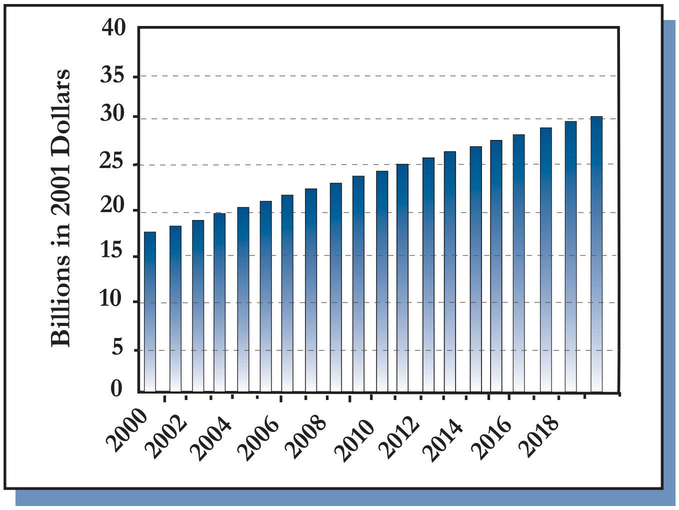

Figure 3–4: Projected O&M Payments (Average Scenario)

is consistent with recent data, can overcome this problem.

Conversely, a major pipe replacement campaign, as contemplated in the capital needs assessment, should moderate the growth in O&M expenditures because old leaky pipes are being replaced by new lower maintenance pipes. In this case, however, a model that estimates O&M as a fixed percentage of net capital stock would project increasing O&M because the projection is driven by the major increases in net capital stock from the pipe replacement program. Again, this is exactly the opposite of what should happen. Under this scenario, a decreasing ratio of O&M to net capital stock is arguably most appropriate.

However, given the uncertainty about what will actually happen in practice to the ratio of O&M to net capital stock, the base case of this analysis assumes that the ratio of O&M to net capital stock is frozen at the level from the last actual data on O&M and net capital stock (Figure 3-3). The upper bound case assumes a linear increase over the 20-year period to a level in 2019 that is one percent above the base case O&M to net capital stock ratio, while the lower bound case assumes a one percent decline in the ratio over the 20-year period.

In this analysis, the O&M needs estimate for 2000-2019 ranges from $406 billion to $562 billion (Figure 3-4). This analysis assumes that clean water systems will not finance any O&M costs. The estimate of payments needed for O&M is compared to current spending levels and to a baseline of revenue growth in section 3.6 to estimate clean water's O&M gap.

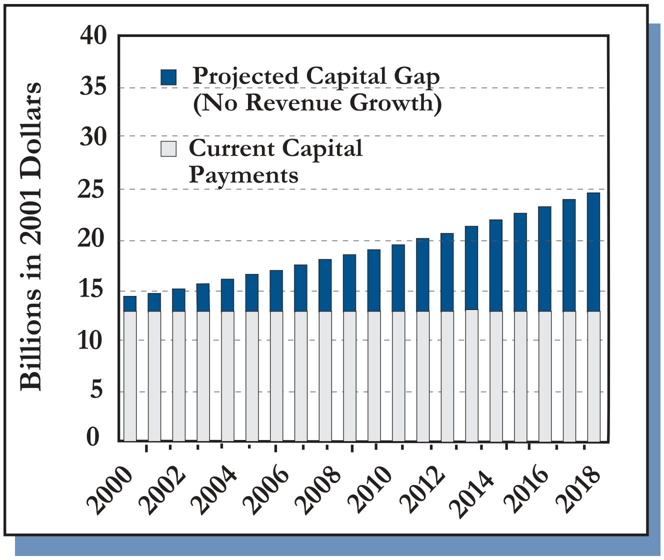

Figure 3–5: Capital Payment Gap (Average No Revenue Growth Scenario)

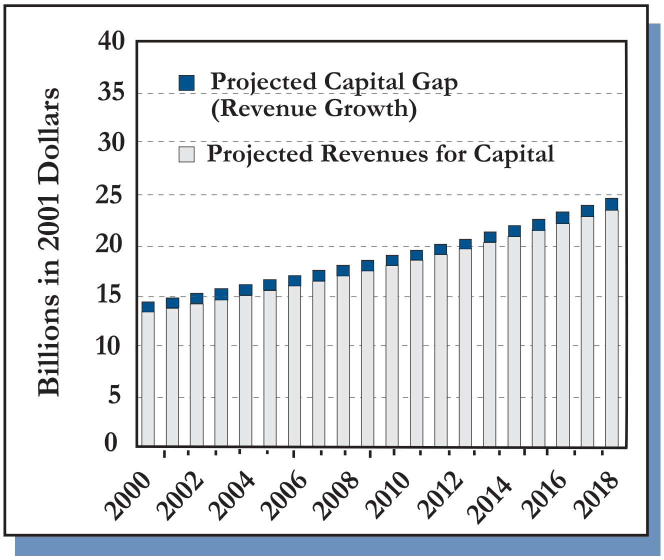

Figure 3–6: Capital Payment Gap (Average Revenue Growth Scenario)

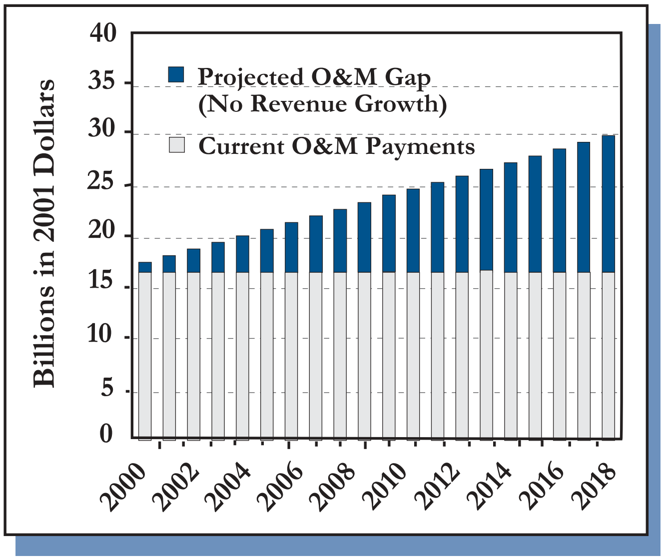

Figure 3–7: O&M Gap (Average No Revenue Growth Scenario)

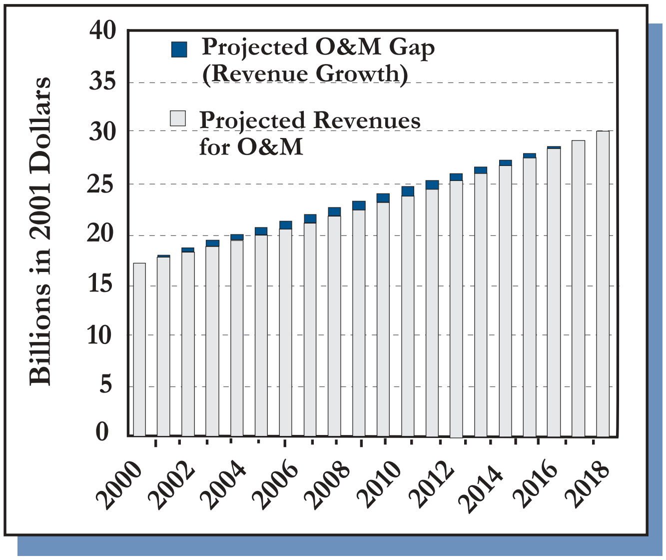

Figure 3–8: O&M Gap (Average Revenue Growth Scenario)

3.4 Estimate Current Spending

In order to calculate the gap, the projected payments for capital investments and O&M are compared to current levels of spending.

3.4.1 Payments for capital investments

In 2001 dollars, historical payments for capital investments from local government have been relatively flat. This analysis uses an estimate of FY 1996 capital payments ($13.0 billion) to establish a current level of spending. This figure is based on (a) data for local government capital investments from 1973–1996 derived from the Bureau of the Census Government Finance Data Series for local government expenditures, (b) estimates of federal grants based on annual appropriation bills and the CRS report *Water Infrastructure Financing: History of EPA Appropriations 1986-1998*, and (c) an assumption that historical capital investment has been financed as described in section 3.2.2.

3.4.2 Payments for O&M needs

As discussed in section 3.5, O&M spending has steadily increased over the past two decades. For this reason, this analysis uses estimated FY 1996 O&M spending ($16.7 billion) as the baseline for current spending. Spending for O&M needs from 1973–1996 is reported in the Bureau of the Census Government Finance Data Series for local government expenditures.

3.5 Estimate the Total Payment Gap

The annual capital payment gap is the difference between the estimated payments and projected spending in each year. The total payment gap over the 20 years is the sum of the annual payment gaps. In this analysis, the estimates of the clean water capital payment gap range from 73 billion to 177 billion with a point estimate of $122 billion for the no revenue growth scenario (Figure 3-5), and the estimates range from $0 billion to $94 billion with a point estimate of $21 billion[22] for the revenue growth scenario (Figure 3-6).

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[22] The actual range is $-39 to $94 billion with a point estimate of $21 billion. Under the assumptions used for certain scenarios, the models predict a surplus of infrastructure funds, or rather, a negative gap. In these scenarios, total spending and/or revenues will exceed the total need over the next 20 years. The report excludes these negative values in the text, because systems generally would not collect revenues in excess of their current estimated infrastructure needs. However, it should be noted that doing so would free infrastructure funds for situations where gaps remain.

(1) Capital Investment Needs (not financed)-- w/o Revenue Growth Assumptions:	The total capital investment need is derived from the Clean Water Needs Survey and analytic adjustments that account for costs that are generally not captured in the survey process.					
	Needs (20 years)		Gap (20 years)		Average Annual Needs Gap	
	Range	Average	Range	Average	Range	Average
	$331 to $450	$388	$158 to $277	$215	$8 to $14	$11
(2) Capital Costs (financed)-- w/o Revenue Growth Assumptions:	Capital costs financed are an estimate of the present value of the infrastructure investments. These estimates include all capital and finance costs, regardless of when these costs are incurred.					
	Total Costs (20 years)		Total Costs Gap (20 years)		Average Annual Cost Gap	
	Range	Average	Range	Average	Range	Average
	$402 to $719	$532	$192 to $442	$295	$10 to $22	$15
(3) Operations & Maintenance Costs -- w/o Revenue Growth Assumptions:	Future O&M needs are established by extrapolating from historical data. All O&M costs are considered paid from current year revenues and not financed.					
	Total O&M (20 years)		Total O&M Gap (20 years)		Average Annual O&M Gap	
	Range	Average	Range	Average	Range	Average
	$406 to $562	$482	$72 to $229	$148	$4 to $11	$7
(4) Payments -- w/o Revenue Growth Assumptions:	Payments are a measurement of cast flow. The annual payment gap is the difference between yearly projections of payments and current spending. The total payment gap over 20 years is the sum of the annual payment gaps.					
	Total Payments (20 years)		Total Payment Gap (20 years)		Average Annual Payment Gap	
	Range	Average	Range	Average	Range	Average
Capital	$321 to $454	$381	$73 to $177	$122	$4 to $9	$6
Capital/O&M	$736 to $1007	$862	$154 to $397	$271	$8 to $20	$14
(5) Payments -- w/ Revenue Growth Assumptions:	The payment gap in this scenario assumes that the economy grows at a real rate of growth of three percent, and municipal wastewater expenditures grow at an identical rate. A real rate of growth is a rate of growth above inflation.					
	Total Payments (20 years)		Total Payment Gap (20 years)		Average Annual Payment Gap	
	Range	Average	Range	Average	Range	Average
Capital	$321 to $454	$381	$0 to $94 [23]	$21	$0 to $5 [24]	$1
Capital/O&M	$736 to $1007	$862	$0 to $143 [25]	$31	$0 to $7 [26]	$2

Table 3–2: Investment Needs, Costs, and Payments 2000–2019 (Billions of Dollars)

The estimates of the O&M payment gap range from $72 billion to $229 billion with a point estimate of $148 billion for the no revenue growth scenario (Figure 3-7), and the estimates range from $0 billion to $80 billion with a point estimate of $10 billion[27] for the revenue growth scenario (Figure 3-8).

This analysis considered three possibilities for six assumptions (e.g., real interest rates for municipal borrowers of 2.5 percent, 3.0 percent, and 3.5 percent). The analysis considered all of these possibilities to generate hundreds of permutations of these payment gaps. A point estimate was obtained

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[23] The actual range is $-39 to $94 billion with a point estimate of $21 billion. See Footnote 22 for further explanation.

[24] The actual range is $-2 to $5 billion with a point estimate of $1 billion. See Footnote 22 for further explanation.

[25] The actual range is $-94 to $143 billion with a point estimate of $31 billion. See Footnote 22 for further explanation.

[26] The actual range is $-5 to $7 billion with a point estimate of $2 billion. See Footnote 22 for further explanation.

[27] The actual range is $-55 to $80 billion with a point estimate of $10 billion. See Footnote 22 for further explanation.

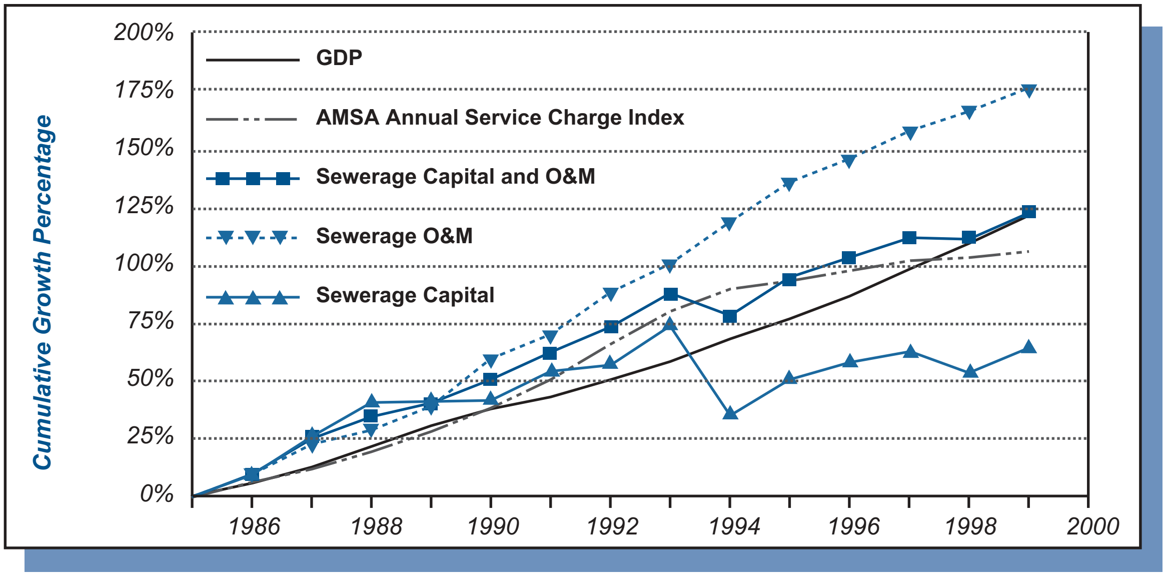

Figure 3–9: Cumulative Growth in Sewerage Expenditures and Gross Domestic Product 1980-1999

by simply taking an average of all of the scenarios.

This report characterizes a "Gap" in the context of asset management practices. The annual capital payment gap and annual O&M payment gap identified above best represent this "Gap." Other reports have considered the "Gap" using a capital cost gap.

Each of these different estimates is represented in Table 3–2. Although the infrastructure challenge is best evaluated by considering the flow of payments, i.e., when and how much systems invest (in the table, row 4), the gap can also be evaluated by considering total capital needs (1), total capital costs (2), and O&M costs (3).

3.6 No Revenue Growth and Revenue Growth Scenarios

The no revenue growth and revenue growth scenarios in this analysis provide different alternatives for viewing the potential gap in spending. The no revenue growth scenario shows how much additional funding would be required to address projected needs without considering potential growth in revenues. However, that scenario does not consider how sewer revenues will increase if the national economy grows.

The revenue growth scenario provides this perspective, although it includes two types of uncertainties. The first is whether or not the economy grows, as projected, with a three percent real annual growth rate in gross domestic product (GDP). Although this growth rate is uncertain, it is consistent with (actually slightly below) the growth rate projections currently being used by both the Office of Management and Budget and the Congressional Budget Office. The second type of uncertainty is whether or not municipal spending on wastewater will actually keep track with the pace of growth in GDP.

While the actual outcome will reflect municipal policy decisions on the relative demands for various types of local services, recent historical experience (see Figure 3-9) has shown that overall sewer expenditures have tracked fairly closely with growth in GDP. Given that wastewater O&M costs have been exclusively a local responsibility and that capital conveyance system (pipe) projects have historically been largely a local responsibility, it is not unreasonable to assume that localities would make significant wastewater needs a priority to maintain their share of municipal revenue in a growing economy. It should be understood that neither the revenue growth scenarios nor the no revenue growth scenarios imply that needs and revenues are uniformly distributed across the country.

3.7 Key Variables

This analysis indirectly considers many factors that impact expenditure estimates in a positive or negative fashion. Figure 3–10 is a qualitative assessment that describes some of these factors. By far the most important factors listed are estimates of repair costs and maintenance costs—estimates that reflect assumptions about the current condition of the nation's wastewater infrastructure.

Factors likely to decrease the estimate	Factors likely to increase the estimate
Decreasing labor costs due to integration of services	Increasing costs of chemicals and power
Regionalizing services	Increasing requirements
Competitive practices	Increasing repair costs
Asset management strategies	Increasing maintenance costs
Technology innovations	Population growth
Life extension strategies	Economic expansion
Growth in domestic economy	

Figure 3–10: A Qualitative Assessment of the Sensitivity of the Gap Estimate

Methods for Estimating Needs and Spending for Drinking Water

4.0 Purpose

The purpose of this analysis is to quantify the relationship between the estimated infrastructure needs of drinking water systems over the next 20 years and current levels of spending. In estimating future capital needs, the analysis excludes capital projects related to Drinking Water State Revolving Fund (DWSRF) ineligible needs, such as dams and future growth. The lack of a defensible means to quantify these costs is the primary reason for their exclusion. Although the following sections are limited to DWSRF eligible capital needs and spending, the potentially substantial costs associated with ineligible needs, most notably, future growth, should be borne in mind when considering the broader financial challenge with which water systems will need to contend. It is also important to note that the analysis excludes needs associated with regulations that EPA has not yet proposed.

The focus on capital needs and spending mirrors the level of federal involvement in drinking water infrastructure in terms of funding assistance. The DWSRF provides loans and other forms of financial assistance to water systems for capital improvement projects, consolidation, acquisition of existing infrastructure, and refinancing loans. The DWSRF does not provide loans for O&M. Nonetheless, water systems will face mounting costs related to O&M as the capital stock ages and as new infrastructure is added to the network. In recognition that the costs associated with O&M allow for a more complete picture of the challenges facing water systems, the last section of the chapter provides an analysis of the needs and spending associated with O&M.

The limitations of the data necessitate reporting the results of the analysis as a range. A range explicitly acknowledges the uncertainty of assumptions that can be used (with no clear distinction of validity) to estimate the capital and O&M needs. Within each range, however, the analysis provides a point estimate that represents the average of the hundreds of different scenarios that can be generated for each combination of assumptions.

4.1 General Steps–Capital Needs

The method for estimating the difference between capital payment needs and capital spending involves five primary steps, each of which is described in the following sections.

1. Estimate the total capital investment need for the next 20 years based on one of four scenarios, each of which uses some portion of data from the 1999 Drinking Water Infrastructure Needs Survey.

2. Allocate the total capital investment need by year.

3. Estimate capital cost and the capital payment needs by calculating debt service financing for a percentage of the capital investments.

4. Using data from the Congressional Budget Office, estimate current capital spending.

5. Compare the annual capital payment needs to annual capital spending. The difference is the annual capital payment gap.

	Current Need	Future Need	Total Need
Transmission and distribution lines			
Large systems	28.7	8.3	36.9
Medium systems	17.9	6.2	24.1
Small systems	14.1	2.0	16.1
Non-community water systems	0.3	0.1	0.4
American Indian/Alaskan Native	1.1	0.1	1.2
Subtotal	62.1	16.6	78.7
Treatment, storage, source and other needs			
Large systems	18.6	6.4	24.9
Medium systems	11.9	7.2	19.2
Small systems	8.2	6.9	15.1
Non-community water systems	0.9	1.9	2.7
American Indian/Alaskan Native	0.9	0.1	1.1
Subtotal	40.5	22.5	63.0
Cost of future regulations	0.0	9.3	9.3
Total	102.5	48.4	150.9
Total cost of regulations within total	16.6	14.7	31.2

Table 4–1: Reported Drinking Water Infrastructure Needs (Billions of 1999 Dollars)

4.2 The Drinking Water Capital Investment Need

4.2.1 Treatment, Source and Storage Needs ("non-pipe" needs)

The 1999 Drinking Water Infrastructure Needs Survey (DWINS) provides data to estimate the total capital need over the next 20 years. The total need is $150.9 billion in 1999 dollars. Table 4–1 summarizes the results of the needs survey.

Several adjustments to the reported need are necessary to capture more completely the capital needs over the estimation period. The estimation of annual non-pipe capital needs involves 4 steps.

1. The DWINS identifies non-pipe needs of $63.0 billion (for information about the annual allocation of non-pipe needs from 2000–2019, see section 4.3.)

2. The DWINS also identifies infrastructure needs required to comply with recently promulgated and proposed regulations: $9.3 billion. Because most systems had not yet identified the infrastructure needed to comply with these new regulations, the Needs Survey used the Economic Analyses, which EPA published when proposing or finalizing the regulations, to estimate compliance costs. The analysis assumes that water systems will need to install the infrastructure to comply with these regulations before the statutory compliance dates of the rules, i.e., within the next 5 years.

3. The analysis then adjusts the DWINS estimates to account for under-reporting. The methods used by the DWINS yield a conservative estimate of need. EPA sent questionnaires to a random sample of 2,556 medium sized systems serving between 3,300 and 40,000 people and to all 1,111 large systems serving more than 40,000. In completing the survey questionnaire, many of these systems relied exclusively on planning documents, such as Capital Improvement Plans (CIPs), that often covered just one to five years, rather than the 20-year scope of the survey. Thus, these systems likely overlooked eligible projects that will be needed beyond the time frame of their planning documents. In addition, planning documents generally reflect the financial resources available to the systems. Therefore, even though a system may need to replace most of its deteriorated distribution mains over the next 20 years, the CIP may include a much smaller portion owing to the projected availability of funding.

In 1997, EPA conducted 200 site visits to medium and large water systems that had responded to the first Needs Survey, which was completed in 1995. The purpose of the follow-up study was to investigate the accuracy of the responses. The study quantified the extent to which medium and large systems under-reported their needs in comparison to the needs identified during the site visits. The estimate of need for medium and large systems is multiplied by 1.49 to account for under-reporting. This adjustment was developed directly from the follow-up study (i.e., systems under-reported the needs associated with treatment, storage, and source needs by a factor of 1.49). The total non-pipe capital need (for current and future needs of small, medium, and large systems), as adjusted for under reporting, is $84.4 billion. The adjustments are shown in Table 4–2.

EPA conducted site visits to assess the needs of small systems serving fewer than 3,300 people, as these systems generally lack the specialized personnel and planning documents required to complete a questionnaire. Because professional water system engineers conducted on-site inspections of small systems, it is assumed that

	Unadjusted Need	Adjustment Factor	Adjusted Need
Pipe Needs			
Large systems	$36.9	1.61	$59.2
Medium systems	$24.1	1.61	$38.7
Small systems	$17.7	NA	$17.7
Subtotal	$78.7		$115.6
Non-Pipe Needs			
Large systems	$24.9	1.49	$37.0
Medium systems	$19.1	1.49	$28.4
Small systems	$18.9	NA	$18.9
Subtotal	$63.0		$84.4
New Regulations	$9.3	NA	$9.3
Total Need	$150.9		$209.3
Total Need (2001 Dollars)	$157.2		$218.0

Table 4-2: Adjustment of Needs (Billions of 1999 Dollars)

the estimate of the need for small systems requires no adjustment for under-reporting.

4. The 1999 DWINS needs are reported in 1999 dollars. After adjusting the reported need for inflation to 2001 dollars, the total non-pipe need is $97.6 billion.

4.2.2 Transmission Lines and Distribution Mains

The analysis developed four options to estimate transmission line and distribution main needs.

1. In the first option, pipe needs were obtained from the 1999 Needs Survey. Transmission lines and distribution mains account for most (55 percent) of the reported need.

The transmission and distribution needs are multiplied by 1.605 to account for under-reporting. This factor was derived from the 1997 follow-up study (i.e., systems under-reported their transmission and distribution needs by a factor of 1.605). The adjustment of the transmission and distribution needs (for underreporting and adjustment to 2001 dollars) yields an estimate of $120 billion over the next 20 years. By comparison, AWWA uses a pipe replacement model that produces a total need of $250 billion, but over 30 years.[28] Using AWWA's methods to determine the value of pipe replacement over the next 20 years generates an estimate of $52 billion (i.e., most of the need falls beyond the next 20 years).

The advantage of using the Needs Survey is that it reflects actual needs identified and documented by water systems, as opposed to a pipe replacement model which would substitute these needs with a modeled estimate. Also, the set of assumptions required to build a pipe replacement model simplify reality without necessarily contributing more worth to the analysis. The disadvantage of this method is that the estimates can only be apportioned into current and future needs. Thus, the option will not reflect the aging in capital stock that is expected to occur over the next 20 years, and instead distributes the total need according to a specified time frame.

2. For option 2, the analysis substitutes the transmission and distribution need from the 1999 Needs Survey estimate with an estimate based on a pipe replacement model. The non-pipe needs estimated by the Needs Survey would be adjusted for under-reporting and added to the modeled pipe estimate to obtain the total capital need. The non-pipe needs are distributed according to current/future time frames or spread evenly over 20 years.

The advantage of this option is that pipe replacement needs can be assigned to each year in the estimation period according to the projected aging of the transmission and distribution network. The disadvantages are that the assumptions required to build the model represent a simplification of reality and that the estimates substitute actual needs identified by water systems with modeled needs.

For option 2, the need for transmission lines and distribution mains was estimated using a pipe inventory model instead of the DWINS results. The steps involved in modeling the replacement of pipe include (A) estimating the current inventory of pipe, (B) estimating its vintage (i.e., the year in which each mile of pipe was installed), (C) estimating the year the pipe must be replaced as a function of its age, and (D) estimating the cost of replacing the pipe.

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[28] American Water Works Association, *Dawn of the Replacement Era: Reinvesting in Drinking Water Infrastructure*, May 2001.

A. The current inventory of distribution mains is estimated using data from the 1995 Community Water System Survey (CWSS). The CWSS reports the miles of distribution mains in place for a representative sample of community water systems. The total miles of pipe in place is estimated to be approximately 1.5 million miles.

The CWSS does not ask water systems to provide data on transmission lines. To account for transmission lines, the miles of pipe need reported in the DWINS for transmission lines are compared to the miles needed for distribution lines. The ratio of total miles of pipe to distribution mains in the DWINS is 1.25. Therefore, the length of distribution mains reported in the CWSS is multiplied by 1.25 to produce an estimate of the total inventory of pipe currently in place: 2.0 million miles.

To verify the model, the results were compared to the AWWA estimate of pipe inventory for large systems serving over 50,000 people.[29] AWWA's estimate of 650,000 miles for these systems compares favorably to the model's estimate of 610,000 miles.

B. To approximate the age of the current inventory of pipe, the model used the age distribution of replacement pipe values reported for 20 cities in the AWWA report *Dawn of the Replacement Era*.[30] While the 20 cities in the sample were not selected at random, the cities likely represent a broad range of systems of various ages from across the country. More importantly, the study provides the only available data on the age of pipe from a number of systems. The analysis assumed that the age of pipe nationally is distributed identically to the age of pipe in the 20 cities in the AWWA report. Figure 2–11 shows the assumed distribution of the age of the pipe currently in inventory.

C. Age is an important determinative factor in governing when pipe must be replaced. This method assumed that pipes installed before 1910 last an average of 120 years. Pipe installed from 1911 to 1945 are assumed to last an average of 100 years. Pipe installed after 1945 are assumed to last an average of 75 years. In estimating when the current inventory of pipe will be replaced, the model assumes that the actual life span of the pipe will be distributed normally around its expected average life; that is, pipe expected to last 75 years will last 50 to 100 years, pipe expected to last 100 years will last 66 to 133 years, and pipe expected to last 120 years will last 80 to 160 years.

This assumption greatly simplifies reality, as the deterioration rates of pipe will vary considerably as a function of climatic conditions, pipe material, soil properties, and corrosiveness of the drinking water. Pipe of the same material, for example, can last from 15 years to over 200 years depending on the soil characteristics alone. In the absence of data that would allow for the development of a national model to estimate pipe life (i.e., accounting for local variability of pipe deterioration), the application of a normal distribution to an average life expectancy provides a reasonable approximation of replacement rates.

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[29] American Water Works Association, *Infrastructure Needs for the Public Water Supply Sector,* December, 1998.

[30] American Water Works Association, *Dawn of the Replacement Era: Reinvesting in Drinking Water Infrastructure,* May, 2001.

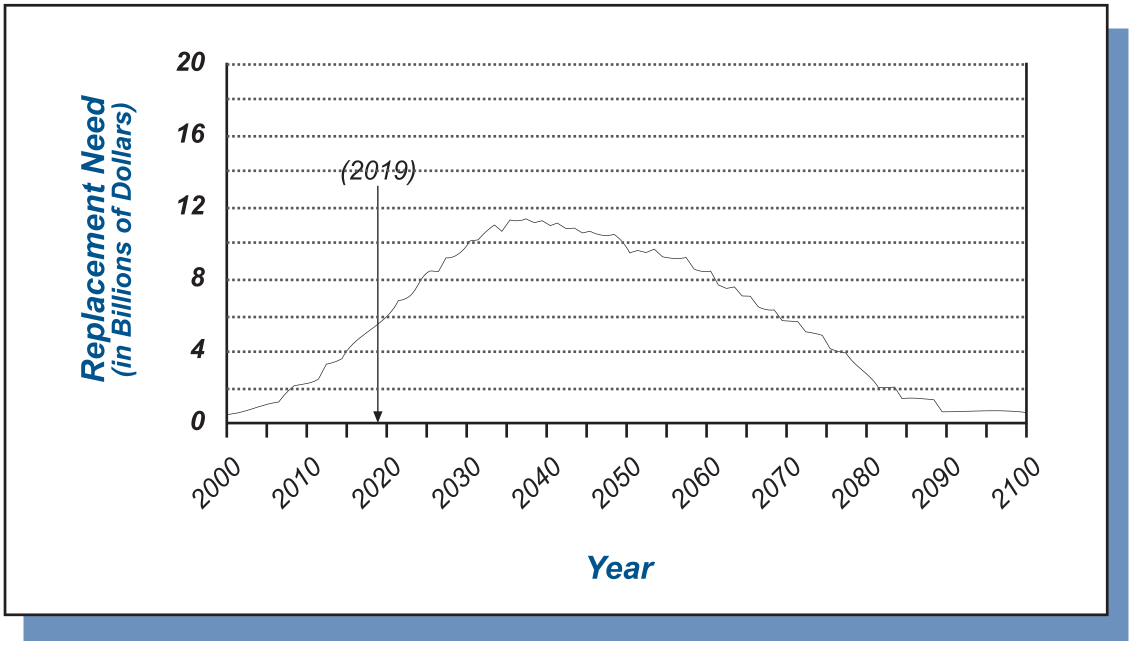

Figure 4–1: Pipe Replacement Model Replacement Need Estimate

In this analysis, when pipe reaches the end of its life, based on the year of its installation and its expected life span, it is removed from inventory and replaced. The model thus provides an estimate of the total amount of pipe that must be replaced over the next 20 years as well as an estimate of the amount of pipe that must be replaced each year. (Note: the model actually provides estimates of the amount of pipe required through 2075).

The pipe replacement model considers one factor: physical deterioration. The model does not account for other factors, most notably inadequate capacity, that may have equal importance to or greater importance than deterioration in determining pipe replacement rates. In the 1999 Drinking Water Needs Survey, many systems cited inadequate capacity to serve existing consumers as the reason for pipe replacement. As communities grow, pipe installed decades ago can no longer deliver the quantity of water necessary to satisfy the present demand—let alone future growth. Even though the physical condition of the pipe may be excellent, its lack of capacity requires its replacement. The use of a normal distribution around the average design life may unintentionally account for some degree of replacement arising from under-capacity. This method, however, likely understates the true pipe replacement need due to the exclusion of a capacity-related variable.

D. The total capital need for transmission lines and distribution mains is calculated by multiplying the length of pipe replaced in parts A through C by the cost per foot of pipe. The cost per foot, derived from the DWINS, is $58.1, including valves, meters, and other pipe-related equipment that are installed with the pipe. Figure 4–1 shows the model's estimate of the cost of the pipe that will need to be replaced each year through 2075. The last year of the estimation period, 2019, is marked with a line on the graph.

> The simple aging model applied to the historical inventory of pipe reveals that most of the projected replacement needs occur beyond the 20-year period of this analysis—with peak annual replacement costs of $11.4 billion occurring around 2040. According to the model, most of the pipe replacement needs occur beyond the next 20 years. Through 2019, the total cost of replacing transmission lines and distribution mains is $52 billion. The cost increases to $249 billion if the timeframe is extended to 2029. Through 2075, the cost is over $540 billion. This finding helps to explain the relatively low pipe replacement needs that are forecast to occur within the estimation period under option 2.

3. Under option 3, the analysis applies a constant replacement rate to the total inventory of pipe, as determined under option 2. This method assumes that pipe will require replacement every 50, 75, or 100 years (which translates into replacement rates of 2 percent/year, 1.3 percent/year, and 1 percent/year, respectively). The total inventory of pipe is multiplied by the replacement rate to estimate the annual replacement need. The amount of pipe is then multiplied by the average cost per foot as derived from the Needs Survey. Option 3 uses the 1999 Needs Survey data, with an adjustment for underreporting, to estimate non-pipe needs.

4. Option 4 uses the estimate from the AWWA survey of pipe replacement needs.[31] In this study, AWWA estimated that the total pipe replacement need over the next 20 years is $352 billion. The methods AWWA used to obtain this estimate are similar to those discussed under option 3, except that AWWA used different estimates of total inventory and cost per foot. Option 4 uses the 1999 Needs Survey, as adjusted for underreporting, to estimate non-pipe needs.

4.3 Allocate Capital Investment Need by Year

To apportion the total capital investment need, including all pipe and non-pipe components, over the estimation period, some scenarios use the distinction between current and future needs identified in the 1999 Needs Survey. Current investment needs are spread evenly over the 2000–2003 period—i.e., 25 percent of the current need is purchased each year through 2003. The future need is then spread evenly over the next 16 years, or 6.25 percent per year. There is no empirical basis for these timeframes other than that they serve to distinguish between current and future needs. The cost of complying with recently promulgated or proposed regulations is spread out over the next 5 years, or 20 percent per year through 2004.

Alternate scenarios distribute non-pipe needs evenly over the 20-year period. These scenarios may provide a more realistic investment profile, given that the current/future split would have systems investing at a rate far greater than present levels. However, this approach ignores the timing of the needs as identified and documented by water systems for the Needs Survey.

4.4 Calculate Financing Costs

While some systems may purchase infrastructure out of current revenues, many will finance at least a portion of the purchase through borrowing. According to the 1995 Community Water System Survey (CWSS), approximately 35 percent of the capital purchased between 1987 and 1995 was financed through borrowing from private sources or through government loans.

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[31] American Water Works Association, *Infrastructure Needs for the Public Water Supply Sector,* December, 1998.

To estimate the cost of financing the capital investment, the model makes the following assumptions:

1. Systems will rely on government loans or private sector borrowing to finance 35 percent of the capital investment. While the share of capital investments financed may increase above the historical rate as the need for investment grows (although some systems would increase revenue by increasing user rates), the analysis assumes the historical rate would continue. This assumption will tend to produce conservative estimates of the cost of capital. As an alternative option, the analysis assumes that in response to the greater need for capital investment, systems will increase the proportion of needs that are financed to 75 percent.

2. Systems will borrow at an average nominal interest rate of 5.9 percent, which, with an annual inflation rate of 2.8 percent, yields a real interest rate of 3.0 percent. The nominal interest rate is derived from an average of the Federal Reserve Bond Buyer Index for general obligation debt over the past 10 years. The annual inflation rate is determined by taking the average rate of increase in the construction cost index over the last 10 years.

3. The terms of the loans will be 20 years. As an alternative option, the term of the loans will be 30 years.

4. Systems will make constant payments over the life of the loan. (For the sake of simplicity, it was assumed a single payment is made each year.) The payment is given by:

$$p = \frac{k * (1 + r)^{n}}{\left(\frac{(1 + r)^{n} - 1}{r}\right)}$$

where:

p = the amount of the annual payment;
k = the value of the infrastructure purchased;
r = the real interest rate; and
n = the duration of the loan.

5. The amount not financed is paid for in the year in which the infrastructure is purchased.

Because a portion of the total need is purchased each year over the 2000–2019 period, and because a portion of each year's purchase is financed over a 20 year period, the total cost of the capital, including all interest and principal payments, is not paid for in full by 2019. For example, capital purchased in 2019 that is financed with a loan will not be paid for in full until 2038. Estimates of the capital payments (2000–2019) for new infrastructure range from $178 billion to $475 billion with a point estimate of $310 billion ($15.5 billion per year).

4.5 Estimate Current Spending

4.5.1 Capital Spending

In order to calculate the gap, projected payment needs are compared to current spending. To quantify the relationship between needs and spending over time, the analysis takes current spending, calculated as the average spending over the last 10 years, and assumes no real growth. The spending projections are not an estimate of what spending will be; rather, they are simply a baseline to which the projected need may be compared (Figure 4–2).

By holding capital spending constant, the analysis describes how the projected need compares to current spending, for example, if the projected need is $13.2 billion per year, how does that compare to what water systems presently spend? The method implies that systems would spend the same resources they spend today without making assumptions about how they would increase (or decrease) their spending

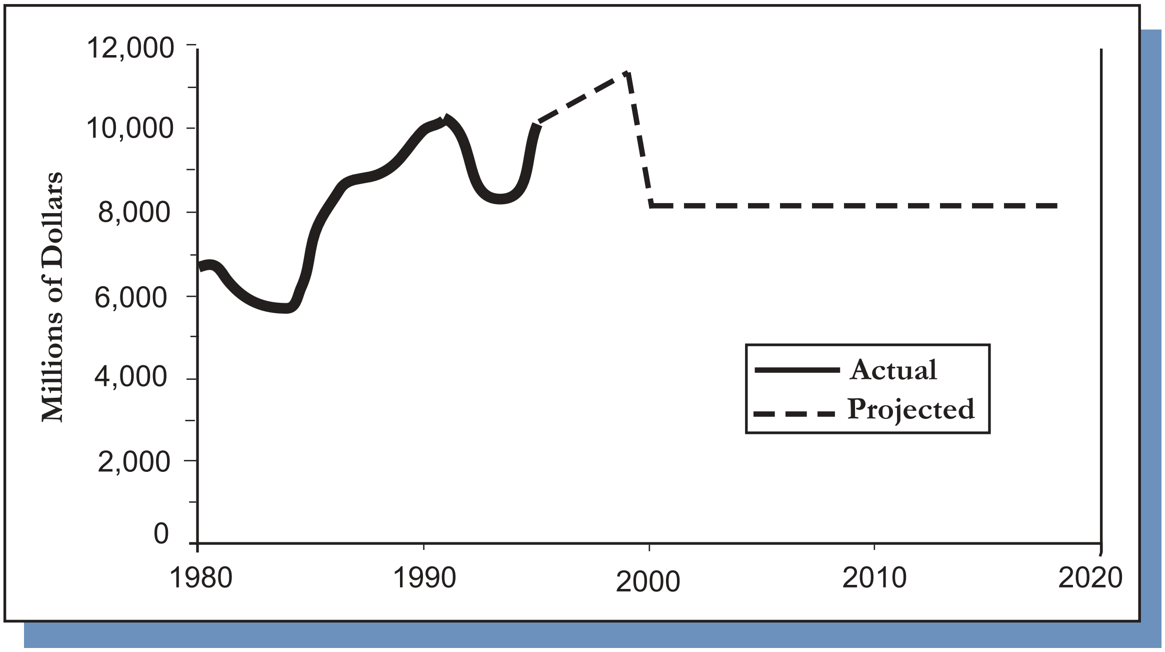

Figure 4–2: Projected Drinking Water Capital Spending (adjusted for privates and DWSRF ineligibilities for 2000 –2019)

with regard to need. This is equivalent to how OMB and CBO project discretionary spending for baseline budget estimates.

The level of certainty associated with the annualized projections of spending, and thus the funding gap, decreases considerably over the 20-year estimation period. To a large extent, this decline owes to the assumption that spending will remain constant over the next 20 years. This assumption likely will underestimate the actual future spending. Actual spending on capital should reflect the need for such spending. Therefore, if the expectation that a large portion of the nation's capital stock will require replacement is correct, then this prediction should be mirrored in the spending data: that is, water systems will need to, and thus will, spend more to replace or operate and maintain an increasingly deteriorated capital stock. The spending projections will not capture the increased rates of spending that presumably will occur in response to the aging capital stock. However, the method provides a baseline against which to compare the need for greater investment with current levels of spending.

An alternative option would increase spending based on a linear regression of historical rates. This method, however, should not be considered, in a technical sense, a baseline for spending. The problem is that the real growth of the last 10 to 20 years stems from the decisions of systems regarding their needs. These are essentially policy decisions—and if the spending projections assume real growth based on historical trends, then the projections would reflect future policy decisions. This, in turn, complicates the evaluation of the future need predicted by the model as the analysis would compare future need to some unknown set of policy decisions, rather than to the more straight-forward baseline of current spending. Also, if the analysis reveals that no capital gap exists, it then could be reasonably, but erroneously, inferred that the *status quo* for spending would suffice to meet future capital investment needs. This conclusion, however, would ignore the fact that in reality systems would need to increase their spending to eliminate the gap.

The method for estimating current spending is as follows:

1. The first step is to estimate the amount of capital that would be purchased. Government spending for drinking water data from the Congressional Budget Office's report *Trends in Public Infrastructure*[32] forms the basis of the projections. Data on government spending on infrastructure for 1977 through 1995 are adjusted to constant dollars using the construction cost index, published by the Engineering News-Record. Government spending is increased by 1/3 to account for private sector spending, as described earlier. This adjustment is based on the ratio of households served by public and private systems, as described in the November 1998 Regulatory Impacts Analysis of the Stage 1 Disinfection By-Products Rulemaking analysis.

2. Capital spending is then adjusted to account for "unallowable" spending. This adjustment is necessary so that the analysis can compare the needs from the Needs Survey to the spending data. Without this adjustment, the spending data would contain spending on projects that would not have been accepted by the Needs Survey due to their ineligibility for Drinking Water State Revolving Fund (DWSRF) assistance. Such projects include dams, raw water reservoirs, future growth, and fire flow. Consequently, the spending data are reduced by 20 percent, based on a review of 20 capital improvement plans that were submitted by water systems for the 1999 Needs Survey. It is important to recognize that although water systems may have considerable capital needs related to DWSRF ineligible projects, the gap analysis excludes these needs.[33]

4.5.2 Capital Payments

The estimate of capital spending is a projection of the annual investment in the capital stock based on an average of the last ten years. As with the future capital need, systems may choose to finance a portion of this investment. In order to compare future needs to the projection of current spending, it was assumed that the projected spending would be financed in a similar manner: that is, 35 percent or 75 percent would be financed at a real interest rate of 3 percent per year over a 20- or 30-year period. To account for debt service payments for capital purchased before 2000, this method assumes that past capital purchases were financed in a similar fashion. These payments are included in both current spending and the total need because the future need will include this debt service on past investments.

4.6 Estimate the Total Capital Payment Gap

The annual payment gap is the difference between the estimated payment need and current spending in each year. The total gap over the 20 years is the sum of the annual gaps. This analysis estimates that the drinking water capital payment gap is between $0 billion and $267 billion with a point estimate of $102 billion[34] in the no revenue growth scenario (Figure 4-3), and it estimates that the gap is between $0 billion and $205 billion with a point estimate of $45 billion[35] in the revenue growth scenario (Figure 4-4). Using all of the possible

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[32] Congressional Budget Office, *Trends in Public Infrastructure*, May 1999.

[33] By statute, the Needs Survey is used to allocate DWSRF monies to the states. In general, the eligibility criteria developed for the DWSRF are intended to promote the public health objectives of the Safe Drinking Water Act.

[34] The actual range is $-17 to $267 billion with a point estimate of $102 billion. Under the assumptions used for certain scenarios, the models predict a surplus of infrastructure funds, or rather, a negative gap. In these scenarios, total spending and/or revenues will exceed the total need over the next 20 years. The report excludes these negative values in the text, because systems generally would not collect revenues in excess of their current estimated infrastructure needs. However, it should be noted that doing so would free infrastructure funds for situations where gaps remain.

[35] The actual range is $-94 to $205 billion with a point estimate of $45 billion. See Footnote 34 for further explanation.

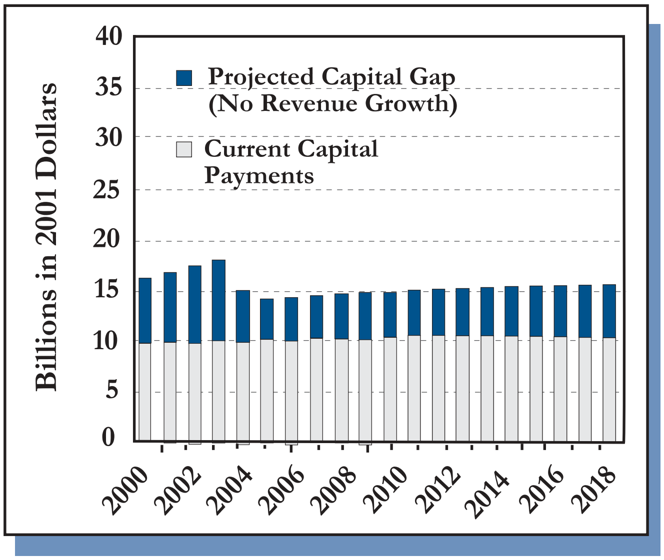

Figure 4-3: Capital Payment Gap (Average No Revenue Growth Scenario)

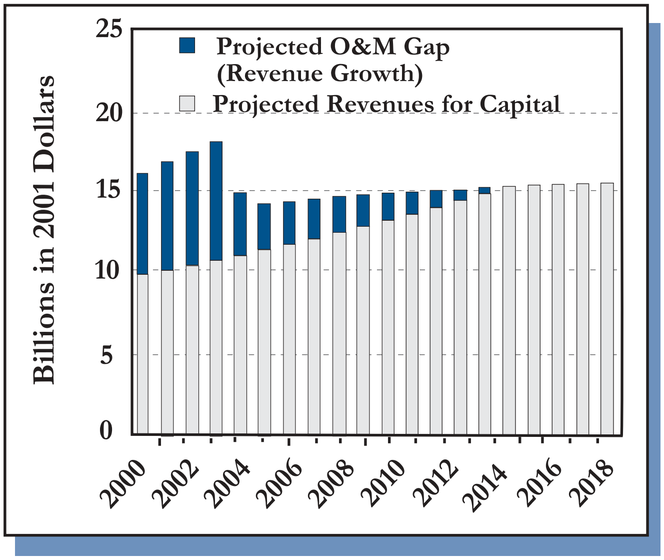

Figure 4-4: Capital Payment Gap (Average Revenue Growth Scenario)

combinations of assumptions described earlier, the analysis generated 216 permutations for estimating the capital payment gap. The extreme values of these scenarios comprise the lower and upper limits of the range. A point estimate was obtained by simply taking an average of all of the scenarios.

In understanding the significance of the findings, it is important to recognize that the analysis holds spending constant based on the average spending from the last ten years. Therefore, any funding gap that is forecast by the analysis ought not to be considered an inevitability, but rather a potential outcome should water systems not make the investments that will be required to replace and maintain their aging capital stock.

4.7 Estimate the Operations and Maintenance (O&M) Gap

Developing a defensible, quantitative relationship between O&M needs and capital stock presents a challenging task. However, as discussed in Chapter 2, it is important not to discount the significance of O&M needs when discussing the financial viability and operating challenges confronting drinking water and clean water systems. Therefore, this analysis attempts to quantify the O&M needs, spending, and gap.

4.7.1 General Steps–O&M Needs

The methods for estimating the difference between O&M needs and spending involves three primary steps.

1. Estimate annual operations and maintenance needs (O&M) as a function of the capital stock, which itself is a function of the projected capital need.

2. Using data from the Congressional Budget Office, assume that current levels of O&M spending will continue through the estimation period.

3. Compare the annual need for O&M to spending. The difference is the annual gap.

4.7.2 Estimate O&M Needs

The analysis assumes that O&M needs are a function of the future capital stock. The projection of future O&M needs involves three steps.

1. The analysis quantifies the historical relationship between O&M spending and the total value of the drinking water capital stock. The Census Bureau provides data on O&M spending. The data of the drinking water capital stock were obtained from the Bureau of Economic Analysis (BEA). The data cover the period from 1979 to 1997 and are limited to publicly owned water systems. These data are increased by 1/3 to account for privately owned systems.

O&M spending is calculated as a proportion of the total capital stock for each year from 1979 through 1997. The historical relationship between O&M spending and capital stock is projected through 2019, using a simple linear regression. The model predicts O&M spending as a share of the capital stock to be 11.9 percent in 2000, and projects that the proportion will increase only slightly to 12.4 percent by 2019.

Alternative scenarios adjust this relationship to phase in a 10 percent efficiency increase over a 10-year period. Anticipated efficiencies include staff reductions, outsourcing, consolidation, and other operational improvements in the industry, although these factors are expected to be somewhat offset by increased demands related to an aging infrastructure.

2. The next step is to estimate the future capital stock. The capital stock in any given year is equal to the capital stock in the previous year plus new investment minus depreciation:

$$K_t = K_{t-1} + I_t - D_{t-1}$$

K_t is the capital stock in period t,
I_t is capital investment (i.e., need) in period t, and
D_{t-1} is depreciation in period t-1.

The model starts with the current capital stock. New investment is equal to the capital need estimated in steps 1 and 2, which is added to the current stock. Depreciation is then deducted.

Data from BEA are used to estimate annual depreciation of the net capital stock. BEA provides data on depreciation for publicly owned systems, which is increased by 1/3 to account for privately owned systems. A depreciation rate is estimated as a proportion of the net capital stock. As with the O&M spending data in the previous step, a linear model is used to project the depreciation rate through 2019. Annual depreciation is then calculated as the product of the depreciation rate and the net capital stock. The net capital stock depreciates at approximately 1.5 percent per year.

3. The final step calculates the annual O&M need as the product of the O&M percentage calculated in the first step and the capital stock estimated in the second step.

4.7.3 O&M Spending

The method for estimating baseline O&M spending is similar to that of capital spending, except that there are no DWSRF eligibility adjustments for O&M spending. The analysis assumes that all O&M spending will be required to ensure the continued provision of drinking water. Some portion of the O&M spending will occur for DWSRF ineligible projects (e.g., maintenance of dams). However, the additional assumptions required to eliminate ineligible O&M spending from the analysis would not be justified, given that these expenditures likely represent a small fraction of total O&M spending. As with capital spending, the O&M spending is held constant, and thus the same caveats apply that were discussed earlier.

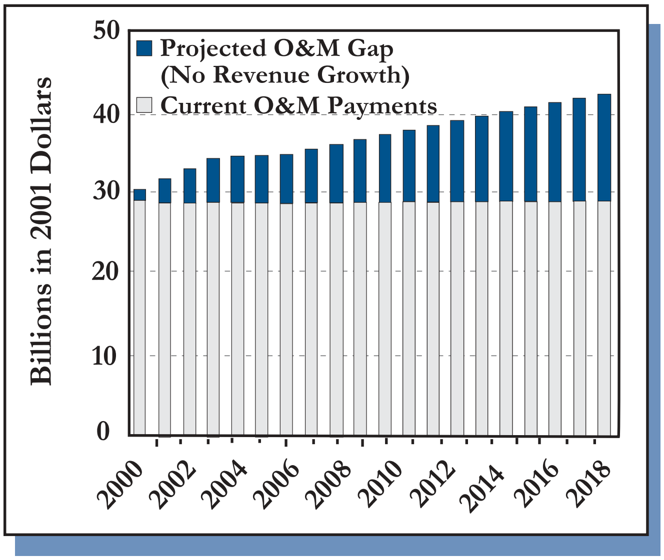

Figure 4-5: O&M Gap (Average No Revenue Growth Scenario)

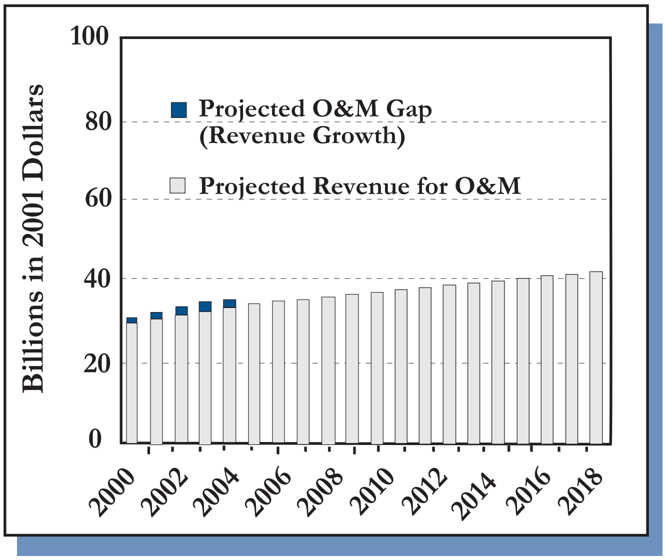

Figure 4-6: O&M Gap (Average Revenue Growth Scenario)

4.7.4 The O&M Gap

This analysis estimates that the drinking water O&M gap is between $0 billion and $495 billion with a point estimate of $161 billion[36] in the no revenue growth scenario (Figure 4-5), and it estimates that the gap is between $0 billion and $276 billion with a point estimate of $0 billion[37] in the revenue growth scenario (Figure 4-6). As with the methods for estimating the capital gap, the analysis generated 216 permutations for estimating the O&M payment gap based on all of the different combinations of scenarios resulting from the different assumptions outlined earlier. The extreme values of these scenarios comprise the lower and upper limits of the range. A point estimate was obtained by taking an average of all of the scenarios.

It is important to recognize that the O&M gap exists as an artifact of the methods used to estimate the capital gap. The O&M needs increase substantially over the estimation period, due to the extent to which the capital stock increases. The capital stock, in turn, increases as a result of the new capital investments needed by water systems. However, the size and timing of these capital investments are determined by the methods used to estimate the capital need. Also, the O&M gap will be larger if capital needs are purchased earlier in the projection period (i.e., applying the current/future distinction from the Needs Survey). Purchasing capital early in the estimation period increases the capital stock. This, in turn, will increase the O&M need throughout the period.

Also, although we would expect O&M needs to increase in response to an aging capital stock, the method for estimating O&M needs uses the historical relationship between O&M spending and capital stock as the basis for projecting future costs. Thus, while O&M needs increase, as will likely occur given the aging of the nation's infrastructure, the driver for this increase in the analysis is the annual capital need, and not an accelerating replacement rate of the existing stock. The constraints imposed by the limited data prevent the development of a quantifiable relationship between O&M needs and

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[36] The actual range is $-67 to $495 billion with a point estimate of $161 billion. See Footnote 34 for further explanation.

[37] The actual range is $-286 to $276 billion with a point estimate of $-58 billion. See Footnote 34 for further explanation.

the national capital stock inventory; for this reason, the analysis uses the method described earlier.

In addition, the analysis assumes that the historical proportion of O&M spending to capital stock is a reasonable predictor of the future proportion of O&M spending to capital stock. One complicating factor is that new capital stock would require less O&M spending than the historical projections would predict (i.e., new equipment requires less O&M than older equipment). Alternatively, the O&M spending required for the existing capital might increase at a faster rate than that predicted by historical trends, particularly if a large proportion of the capital stock reaches an age at which greater O&M must be invested. The difficulty of quantifying these factors necessitates the simplifying assumption that the historical rate of O&M spending to capital stock represents a reasonable, but approximate, basis for estimating O&M needs. It is significant to note that the clean water and drinking water analyses assume that systems will realize efficiencies in O&M that will reduce the proportion of O&M spending to net capital stock. Thus, the analyses presume that improvements in O&M practices will offset the effects of an aging capital. Without this assumption, the O&M needs would increase greatly in magnitude over the estimates presented here.

In understanding the significance of the findings, it is important to recognize that the analysis holds spending constant based on the average spending from the last ten years. Therefore, any funding gap that is forecast by the analysis ought not to be considered an inevitability, but rather a potential outcome should water systems not increase spending to meet increased levels of O&M needs.

Conclusion

5.0 Findings

This report estimates the gap between the projected need and current spending for clean water and drinking water infrastructure over the next 20 years using data available from EPA, the Census Bureau, and the Congressional Budget Office. In broad terms, the gap analysis concludes that clean water and drinking water systems will need to use some combination of increased spending and innovative management practices to meet projected needs. This analysis estimates that the clean water capital payment gap is between $73 billion and $177 billion with a point estimate of $122 billion in the no revenue growth scenario, and it estimates that the capital payment gap is between $0 billion to $94 billion with a point estimate of $21 billion[38] for the revenue growth scenario. The analysis estimates that the drinking water capital payment gap is between $0 billion and $267 billion with a point estimate of $102 billion[39] in the no revenue growth scenario, and it estimates that the gap is between $0 billion and $205 billion with a point estimate of $45 billion[40] in the revenue growth scenario.

It is important to recognize that the funding gaps occur only if capital and O&M spending remains unchanged from present levels. This assumption clearly understates future spending and ignores other measures, such as asset management processes or capacity development, that systems could adopt to reduce both capital and O&M costs. In reality, increasing needs will likely prompt increased spending. However, the analysis presents an approximate indication of the funding gap that will result if we ignore the challenge posed by an aging infrastructure network; a significant portion of this infrastructure network is beginning to reach the end of its useful design life.

A panel of industry experts evaluated a draft of this report, and to the extent possible, the panel's critiques and comments are incorporated into this final report. The major points made by the reviewers are summarized in Appendix B. The reviewers agreed that the Gap Analysis provides an important starting point for the discussion about the magnitude of drinking water and clean water infrastructure funding issues. The general consensus was that the document represents a reasonable effort to quantify the infrastructure gap, given the limitations imposed by the available data. This praise, however, also contains the principal criticism of the analysis; the poor quality of the data severely constrains any effort to quantify the infrastructure funding gap with great accuracy. EPA acknowledges the uncertainty associated with the analysis. Nonetheless, in proposing these provisional estimates, the report encourages a policy discussion of the challenges confronting the nation's clean water and drinking water systems. Most experts familiar with the industry agree that these challenges must be met if we are to continue to advance environmental and public health protection.

5.1 Suggestions for Future Research

In developing this analysis and reading the comments from the peer reviewers, EPA noted that further research would help future efforts to quantify the infrastructure gap. Although far from an exhaustive list, the research areas identified below

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[38] The actual range is $-39 to $94 billion with a point estimate of $21 billion. Under the assumptions used for certain scenarios, the models predict a surplus of infrastructure funds, or rather, a negative gap. In these scenarios, total spending and/or revenues will exceed the total need over the next 20 years. The report excludes these negative values in the text, because systems generally would not collect revenues in excess of their current estimated infrastructure needs. However, it should be noted that doing so would free infrastructure funds for situations where gaps remain.

[39] The actual range is $-17 to $267 billion with a point estimate of $102 billion. See Footnote 38 for further explanation.

[40] The actual range is $-94 to $205 billion with a point estimate of $45 billion. See Footnote 38 for further explanation.

offer opportunities to improve the estimates.

- The inventory of the nation's clean water and drinking water capital stock and the condition of the capital stock should be more fully explored. Data providing an improved picture of the remaining life of these critical capital assets and data identifying the different classes of inventory (e.g., treatment, pipe, storage) would provide a foundation for progressing to the next step—assessing the condition of the nation's infrastructure. These data would greatly improve decision-making about investment needs for maintaining, upgrading, and expanding infrastructure.

- The relationship between O&M needs and capital stock is not fully understood. A more refined approach than the one adopted in this analysis would investigate how O&M needs vary as a function of gross (not net) capital stock and the age or condition of the capital stock. These data, other than in purely speculative form, are not yet available.

- Clean water and drinking water systems will incur significant costs over the next 20 years as they expand capacity to serve current and future growth. Methods for estimating capital investment needs associated with growth and changes in service standards were excluded from the analysis.

- This analysis would benefit from research into an array of issues that ultimately will determine, or at least influence, the scale of future capital investment needs. These issues will also determine how future capital investment needs are met. These issues include, but are not limited to, topics such as the following:

    - Implementation of best management practices, including asset management processes and capacity development

    - Restructuring, integrating, and amalgamating service providers to seek economies of scale in the provision of services

    - Pricing policies and their effect on demand elasticity for water

    - Demographic shifts within the United States

    - Efficiencies gained or lost due to the installation of the latest technology

    - Trends in operating costs (e.g., of chemicals and energy)

    - Criticality analysis (i.e., which components of a system should take precedence for investment due to age, condition, and importance)

    - Effects of non-like-for-like replacement of assets

APPENDIX A

Comparing the Gap between Clean Water and Drinking Water: Numbers and Methodologies

1.0 Comparison between the Clean Water and Drinking Water Capital Payment Gap

This analysis estimates that the clean water capital payment gap over the next 20 years is $122 billion in the no revenue growth scenario and $21 billion in the revenue growth scenario. The analysis estimates that the drinking water capital payment gap is $102 billion in the no revenue growth scenario and $45 billion in the revenue growth scenario. These figures represent point estimates within a range, as described in Chapters 3 and 4.

The methods used in this analysis (e.g., the modeled replacement need) preclude the calculation of standard errors about these estimates to determine whether the difference between the drinking water and clean water gaps are statistically significant. The difference in gaps likely reflects differences in the methods applied by the analyses. The following sections discuss the similarities and differences in the methods used by the clean water and drinking water analyses in calculating the funding gap.

The methods for estimating the capital gap for clean water and drinking water, as described in Section 5.1, were harmonized to the extent to which the data allowed for consistencies between the two analyses. As Section 5.2 explains, however, limitations of the available data necessitated the use of divergent methods for estimating needs and spending.

1.0.1 Similarities in Methods

With respect to the similarities, both analyses used their respective Needs Surveys as a starting point for identifying capital needs. The clean water analysis used the results from the 1996 Clean Water Needs Survey (the next survey is due out in 2002), while the drinking water analysis used the data from the 1999 Drinking Water Needs Survey. These surveys produce highly credible data, as each need submitted by a system was accompanied by documentation describing the purpose of the project. The documentation requirement imparts a conservative bias to the estimates, but it also allows EPA to determine whether each need meets the eligibility criteria for State Revolving Fund assistance; this is critical for the drinking water program, as the law requires EPA to use the survey results to allocate SRF monies to the states.

The treatment of spending data is also similar between the clean water and drinking water analyses. Data from the Congressional Budget Office and the Census Bureau are used to determine historical levels of spending on capital. The drinking water analysis, however, applies an adjustment factor to account for privately owned systems and Drinking Water State Revolving Fund (DWSRF) ineligible projects. Both of the analyses hold spending constant over the estimation period, which allows for the comparison of projected needs to baseline spending. Both analyses also use a real rate of growth of three percent when considering revenue growth scenarios.

1.0.2 Differences in Methods

1.0.2.1 Capital Needs

The analyses differ in the methods used to calculate capital needs. Clean water capital need estimates are derived from a single method that determines needs using the Clean Water Needs Survey, a Sanitary Sewer Overflow needs estimate, and a modeled replacement need estimate based on a constant replacement rate for the net capital stock. The clean water analysis assumes that the needs survey fails to capture the true extent of the 20-year need associated with replacement. The analysis considers a range for many key variables; for example, the analysis considers scenarios in which clean water systems finance 75 percent, 85 percent, or 95 percent of capital needs.

The drinking water estimates use four approaches to calculate replacement needs. A full description can be found in Chapter 4. One option adjusts the results of the Drinking Water Infrastructure Needs Survey based on the results of a follow-up survey. Three other options replace the DWINS estimates of transmission and distribution needs with estimates from pipe inventory models.

The use of these replacement estimates differs from the clean water approach in that only the pipe portion of the total infrastructure need is modeled. Pipes comprise the majority of a system's capital stock, and thus modeling the replacement of pipe likely captures most of the needs associated with replacing old and deteriorated equipment. The non-pipe needs are derived from the Needs Survey with an adjustment for underreporting. The difficulty of distinguishing between new and replacement needs in the Needs Survey explains the decision not to model non-pipe needs in a manner similar to the clean water approach. A replacement term could be developed for these needs; however, the documented needs from the Needs Survey were considered a more accurate, and less speculative, measure of non-pipe needs.

It is important to note that the range of needs and gaps are provided to explicitly acknowledge variations within the estimates, but are not intended to support comparative analysis between the clean water and drinking water industries. The drinking water analysis was able to use data sets that were not available to clean water, e.g., data sets of pipe inventory and age of assets. These data allowed drinking water to use four different methods to estimate capital needs and vary assumptions within each method, whereas the clean water analysis used a single method and varied assumptions within that method. The broader array of methods available to the drinking water analysis generated a broader range of needs and gaps. As such, the resulting ranges provide insight into the impact of varying assumptions within each industry, but the data and methods cannot be used to conduct a valid comparison of the funding gaps facing the clean water and drinking water industries.

1.0.2.2 Financing Costs

The clean water and drinking water methods assume that systems will finance a proportion of their capital needs and spending. The drinking water analyses use a real interest rate of 3.0 percent, while the clean water analyses consider real interest rates of 2.5 percent, 3.0 percent, and 3.5 percent. The drinking water analysis assumes that the average loan term is 20 years or 30 years, while the clean water analysis considers average loan terms of 20 years, 25 years, and 30 years. The drinking water analysis assumes that water systems will finance either 35 percent or 75 percent of their capital needs; the clean water analysis assumes that clean water systems will finance 75 percent, 85 percent, or 95 percent of their capital needs.

1.1 Comparison between the Clean Water and Drinking Water and O&M Payment Gap

The analysis estimates that the O&M gap for clean water over the next 20 years is $148 billion for the no revenue growth scenario and $10 billion for the revenue growth scenario. The drinking water O&M gap is $161 billion in the no revenue growth scenario and $0 billion[41] in the revenue growth scenario. These figures represent point estimates within a range, as described in Sections 3 and 4.

1.1.1 Similarities in Methods

The clean water and drinking water analyses use similar approaches for estimating O&M needs. Both analyses assume that the ratio of O&M spending to net capital stock will remain constant through the estimation period, and this ratio is multiplied by the projected capital stock to calculate O&M spending for each of the next 20 years.

The treatment of spending data is also similar between the clean water and drinking water analyses. Data from the Congressional Budget Office and the Census Bureau are used to determine historical levels of spending on O&M. Both of the analyses hold spending constant over the estimation period, which allows for the comparison of projected needs to baseline spending. In the revenue growth scenarios, both analyses use a real rate of growth of three percent.

1.1.2 Differences in Methods

There are two major factors that explain the difference in drinking water and clean water O&M estimates. First, much of the difference between the O&M needs for drinking water and those of clean water results from the different methods used to allocate capital needs over the estimation period. To understand the meaning and validity of these results, it is necessary to revisit the discussion in the previous section.

In describing the methods used to calculate the O&M needs, Chapter 4 cautioned that the drinking water O&M gap may exist largely as an artifact of the methods used to estimate the capital gap. For clean water and drinking water, the O&M needs increase substantially over the estimation period, due to the extent to which the capital stock increases. The capital stock, in turn, increases as a result of the new capital investments needed by water systems.

It is important to recognize that the scale and timing of new capital projects are determined by the methods used to estimate the capital need. Under one scenario for estimating the capital needs of drinking water systems, the analysis applies the current/future distinction from the 1999 Drinking Water Needs Survey. The clean water analysis cannot use this distinction, as the 1996 Clean Water Needs Survey did not differentiate between current and future needs. The clean water analysis, however, does account for the timing of certain needs by using of a replacement model that predicts the costs of replacement will increase over the next 20 years.

The upper bound of the range for O&M needs for drinking water greatly exceeds that of clean water largely due to the timing of new capital investments. In the upper bound scenarios, most of the new capital investment occurs within the first 5 years for drinking water, whereas the highest levels of investment occur at the end of the estimation period for clean water. The “front-loading” of needs means that the drinking water capital stock increases significantly over the first 5 years in contrast to the steady, but more modest, increase in capital stock (i.e., new capital needs) for clean water.

Thus, the upper limit of the O&M need for drinking water is larger than for clean water, because capital needs are purchased earlier in the projection period. Purchasing capital earlier in the estimation period increases the capital stock. This, in turn, increases the O&M need throughout the period. When the drinking water analysis distributes the needs evenly over the 20-year period, the O&M gap declines significantly.

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41 The actual estimate is $-58 billion. Under the assumptions used for certain scenarios, the models predict a surplus of infrastructure funds, or rather, a negative gap. In these scenarios, total spending and/or revenues will exceed the total need over the next 20 years. The report excludes these negative values in the text, because systems generally would not collect revenues in excess of their current estimated infrastructure needs. However, it should be noted that doing so would free infrastructure funds for situations where gaps remain.

APPENDIX B

Critiques and Comments from the Peer Review Panel

1.0 The Peer Review Process

EPA submitted the methods and data used in this analysis to a panel of peer reviewers drawn from academia, think tanks, consulting firms, and industry. The peer reviewers submitted more than 50 pages of comments to EPA. In general, the reviewers found that the analysis represented a commendable and credible effort to quantify the infrastructure gap, but this appendix summarizes the critiques and comments of the peer review panel.

1.1 Major Points about the Capital Estimates

The basic need estimates were based, in some measure, on 1- to 5-year capital works programs rather than 20-year assessments. Given the level of documentation required by the Needs Surveys, some form of adjustment is necessary. Experience with capital works programs suggests that even with a 5-year capital program, years 1-3 are usually sound, but the proposals for years 4 & 5 fall-off as it is too far away for people to focus on those needs. Therefore it is common for models to take over from the established plan as early as the fourth year and definitely for the 5-20 year window.

When the gap analysis establishes future needs for capital investment and O&M, it assumes that historical investment trends will continue. This assumption may be faulty. Significant additional modeling to assess the sensitivity of investment requirements to age, condition, and criticality would shed light on the priority and risk-based nature of decisions responding to the anticipated investment spike.

The practice of adjusting historical infrastructure expenditures to today's dollars can provide very misleading signals regarding asset replacement. Original sites may have changed markedly with respect to access, work site congestion, or other cost drivers, and as a result, the replacement cost of an asset may have increased. For this reason, additional repair and/or operating costs may be economical alternatives to replacement.

The data sets used in the analysis are, for the most part, those that are generally used in a high-level study of this nature. The findings of the analysis paint a reflective, high-level picture. The use of "useful life" matrices for water utility assets could be greatly improved by moving towards "survival curves" for various asset classes. The 'Kanew' technique (from an AWWA Research Foundation project in the mid-1990's) and the 'Nessie Curve' approach to investment decision-making are reflected in the approach to the analysis. These approaches form a good starting point for an understanding of the investment waves, which will travel through the utility in time. The report generally postulates that the need to replace pipe will generally echo the original installation wave. However, while this is true for age-based replacement strategies in which each pipe material has the same lifecycle properties, it may not adequately model the effects of non-like-for-like replacement of assets that incorporates the effects of innovation. Some innovations will result in shorter or longer lifecycles.

Depreciation and replacement rates are not the same thing. A composite depreciation rate (which drives the estimates in this report) masks important variations that are relevant to this analysis. An asset can be fully depreciated on the books and still fully functional, or an asset can have significant remaining book life and be unable to perform its service function. There are alternate ways to calculate the depreciation rate of a class of assets, some of which, such as optimal deprival value, are based upon the criticality of the asset to the operation of the system. To properly value the asset base, criticality of risk-based factors should be featured in the calculation. This change would improve the quality of the estimates.

Comprehensive capital estimates should assess the interaction between water infrastructure investment and growth. Initial capital costs of infrastructure and life cycle costs of infrastructure can be significantly impacted by patterns of urbanization.

This analysis fails to ascertain the overall impact of regulations and how such changes in regulation might impact costs factors associated with meeting service and environmental objectives.

1.2 Major Points about the O&M Estimates

It is generally accepted that the ratio of O&M costs to capital investment increases as the system ages. It is also true that as this aging infrastructure is renewed, the O&M costs of the renewed system will frequently be reduced. In this report, the estimates for O&M may be reasonable on an aggregate basis, considering that the analysis makes assumptions based on the entire clean water and drinking water industries. However, if certain components of these industries, e.g., very small systems, are isolated for analysis, then it might be argued that O&M needs are higher for those groups than the pro rata portion of the expenditures presented in the report.

The analysis develops a relationship between net capital stock and O&M expenditures that is problematic. While there may be a good correlation between net capital stock and O&M at this time, and while that relationship may hold for some time to come, this relationship will almost certainly break down when main replacement needs start to escalate. Furthermore, the out-year O&M estimate is very much influenced by the changes in capital stock. If investment plans do not materialize in accordance with the planned capital expenditures, the effect on O&M expenses is difficult to model, if not impossible. To the extent that relevant data is available, it would be more telling to model O&M expenditures as a function of gross capital stock and separate the data between main and non-main expenditures.

There may be a case for a significant reduction in O&M costs, which may be achieved relatively early in the modeling period. However, any reduction is likely to come off a baseline that is almost certainly trending significantly upwards. Further, some costs such as energy and chemicals that are significant elements in a utility's cost structure may increase, not fall. The mix of these cost components will vary significantly depending upon the 'age' of the system (in simplistic terms), the rate at which it is adding or losing customers, and the 'mix' of assets employed (network versus treatment). It is true that if old pipes are replaced, O&M will decline. However, clean water and drinking water systems will replace only a small percentage of the nationwide pipe network from 2000–2019. The bulk of the pipes in the system will age but remain in place. As a whole, the pipe network will be older, and therefore nationwide O&M costs should increase.

The use of net capital stock as a predictor of O&M is somewhat troubling. O&M is a variable cost and capital stock is only one determinant. Demand is the big variable and demand is a function of a range of factors. Per-capita demand has flattened, and this affects these ratios.

More attention should be paid to the impact of cost reduction opportunities, in at least five areas: efficiency practices (least-cost), technological innovation (capital & O&M), market-based approaches (bidding), industry restructuring (consolidation), and integrated resource management (supply and demand side).

In the future, reserves will be tougher to establish and maintain as operating costs increase, and citizen backlash against rate increases may also limit the appropriate accumulation of reserves for capital replacement. In addition, states have become more prescriptive regarding the establishment of system development charges (impact fees and the like).

1.3 Major Points about the Financing Forecast

While a huge overnight change in the market structure is unlikely, private sector finance in the form of acquisitions, delegated services contracts, build-operate-transfer, concessions, etc. will increase over the period covered by the analysis. This may reduce the cost of capital for some water utilities because risk is deflected onto a third party (the 'concessionaire').

The suggestion that a significant portion of clean water and drinking water spending must be funded from revenues, i.e., from working capital, should be seriously questioned. Any movements in rate structures, demographic changes, funding of unforeseen events, etc. may have a major impact upon the ability of utilities to fund investments from working capital. It is inevitable that some proportion of costs will be financed, in order to 'smooth-out' the price shocks—shocks likely caused by treatment plants rather than the mains networks. Consequently, it is appropriate to recognize financing as a mechanism without dealing with how that financing will be achieved or supported (i.e. debt to equity treatments, including the use of retained earnings) ahead of the other report.

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