A Retrospective Assessment of the Costs of the Clean Water Act: 1972 to 1997

Final Report

Prepared for

U.S. Environmental Protection Agency
Office of Water
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EPA Work Assignment Manager

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DISCLAIMER

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LIST OF ACRONYMS

BOD	biological oxygen demand
CGE	computable general equilibrium
CIRs	*Current Industrial Reports*
CPI	consumer price index
CWA	Clean Water Act
EIA	Energy Information Administration
EO	Executive Order
FFPC	federal funding for pollution control
FY	fiscal years
GDP	gross domestic product
GF	government finances
GPRA	Government Performance Results Act
IRDS	Industrial Research and Development Survey
NPDES	National Pollutant Discharge Elimination System
NSF	National Science Foundation
O&M	operation and maintenance
OLS	ordinary least squares
OMB	Office of Management and Budget
PACE	pollution abatement cost and expenditure
POEUs	publicly owned electric utilities
POTWs	publicly owned treatment works
R&D	research and development
R&M	regulation and monitoring
SCB	*Survey of Current Business*
SRF	State Revolving Fund
TS	total sanitation

TSS	total suspended solids
WPA	water pollution abatement

EXECUTIVE SUMMARY

In 1972, Congress enacted the Federal Water Pollution Control Act, commonly known as the Clean Water Act (CWA), to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Subsequently amended in 1977 and reauthorized in 1987, the CWA has generally been credited with reversing a century-long trend in water quality degradation. To achieve these results, however, the Act has imposed certain costs on society.

This study assesses the magnitude of these costs in recent years, now that the CWA has been in place for over a quarter century. To properly account for these costs, it is important to stress that some of the costs that are currently being incurred to reduce water pollution would have existed even without the CWA. Although the CWA established a discharge permit system and provided significant federal financial assistance for constructing public treatment facilities, significant public and private investments in water pollution control existed prior to 1972. These expenditures would most likely have continued to grow after 1972 even if the CWA had not been enacted. Therefore, the approach taken in this study is to, not only estimate recent nationwide costs of water pollution abatement (WPA), but also to simulate and deduct from these estimates the WPA costs that would have been incurred without the CWA.

The analysis was been conducted in seven primary steps, as outlined in Figure ES-1. In the first three steps, we identified the primary affected entities and the types of costs incurred to meet CWA objectives and requirements, and we collected WPA expenditure data corresponding to these categories. To distinguish CWA costs from those of more recent statutes that primarily address nonpoint source pollution, this assessment focuses primarily on *point source* abatement efforts. The results are summarized in Figure ES-2 which shows that public sewerage expenditures, followed by private (i.e., industrial) WPA expenditures, made up the large majority of WPA expenditures in both 1980 and 1990. The figure also shows that operation and maintenance (O&M) spending for WPA accounted for an increasing share of these expenditures between 1980 and 1990. The most recent year for which reasonably complete WPA expenditure

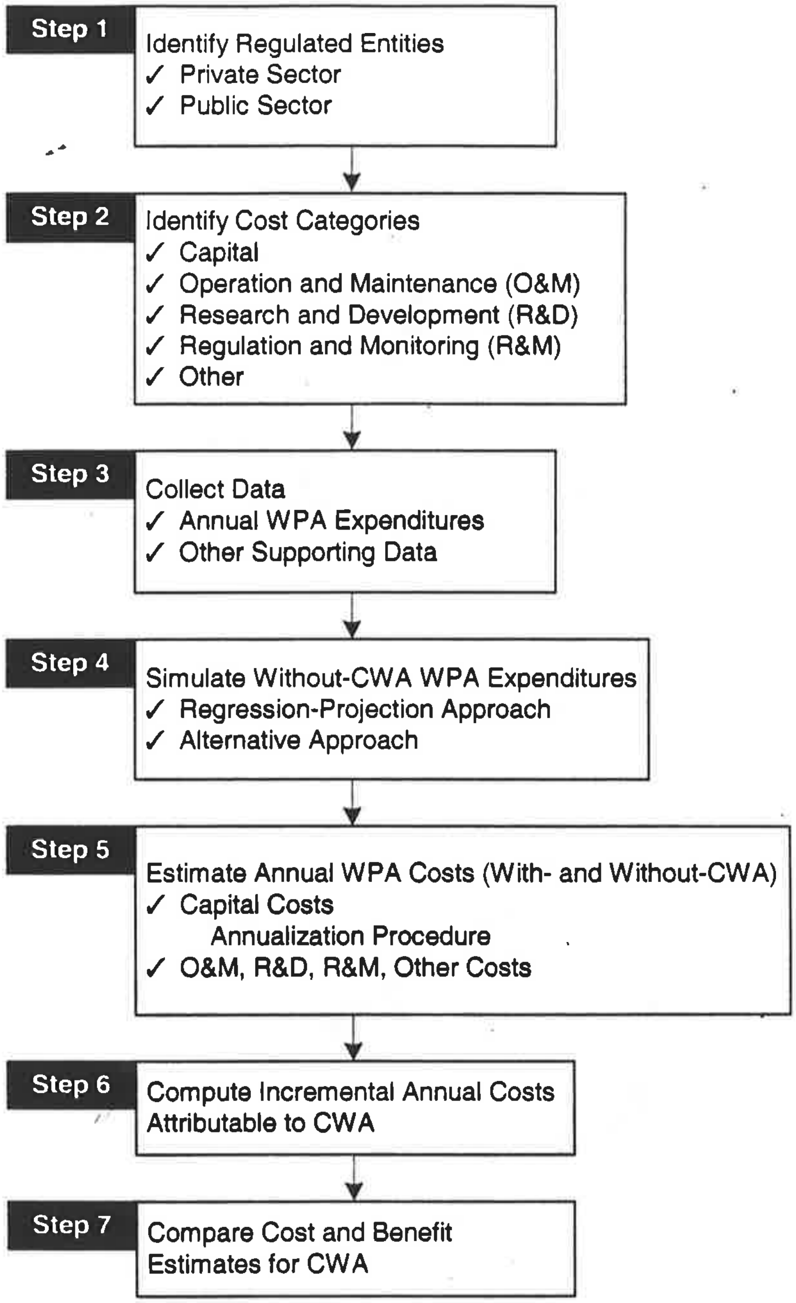

Figure ES-1. Outline of Methodology for Assessing CWA Costs

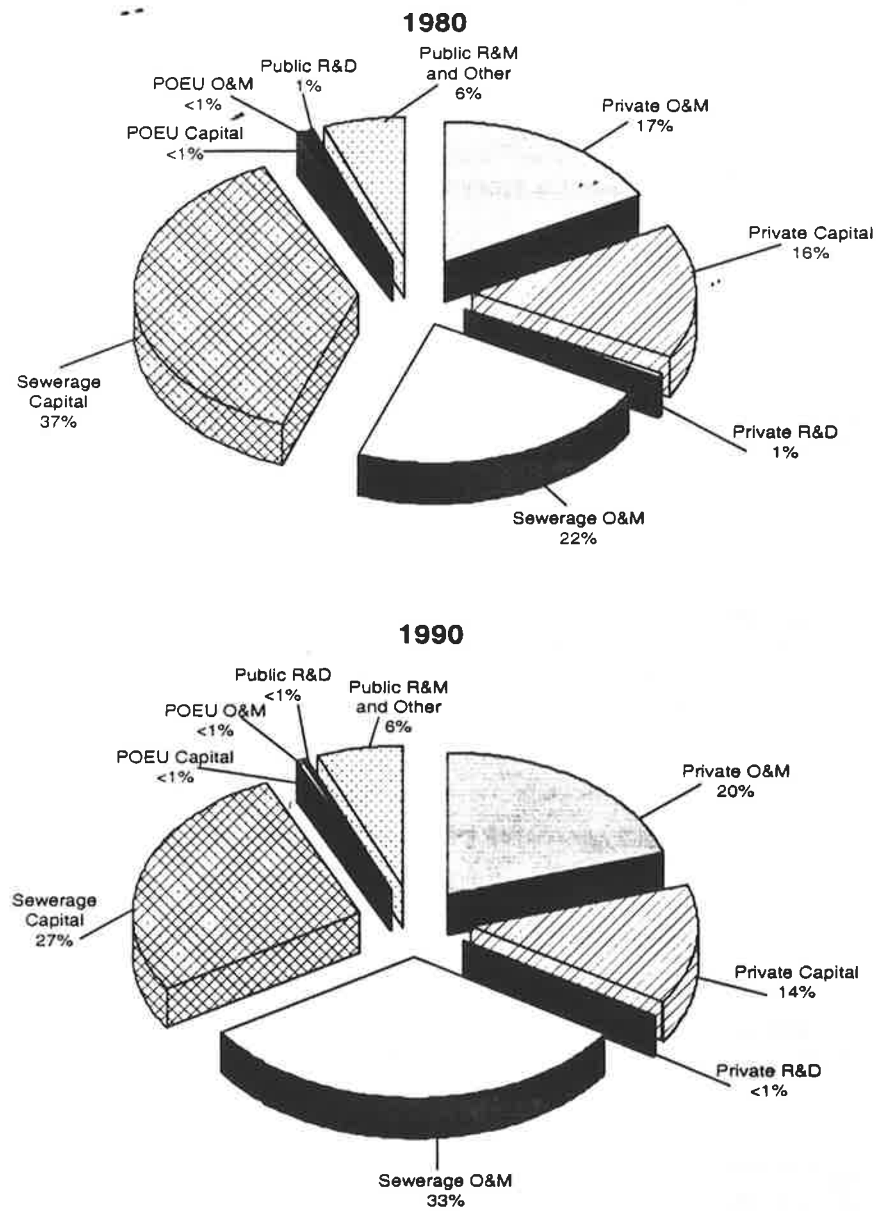

Figure ES-2. Distribution of Estimated Water Pollution Abatement Expenditures, 1980 and 1990

data are available is 1994; however, for this analysis most spending estimates were projected forward to 1997.

The fourth step in the analysis was to simulate what expenditures in the identified categories would have been without the CWA. The most defensible approach for conducting these simulations is to identify and measure the main determinants of WPA expenditures prior to 1972 and to extend these observed relationships into subsequent years. Although historical (i.e., pre-1972) data on WPA expenditures are somewhat limited, this approach was feasible for estimating without-CWA trends in the larger spending categories. An alternative approach, which is most likely to understate without-CWA expenditures, was used to estimate these trends in the smaller WPA spending categories.

The fifth step was to convert annual WPA *capital expenditure* estimates for both scenarios into annual WPA *capital cost* estimates. This distinction is important because it recognizes that annual expenditures on WPA capital are not necessarily the most appropriate estimates of the true opportunity *costs* of this capital. Annual WPA capital costs were therefore estimated by annualizing. This annualization was done using a 3 percent discount rate and alternative assumptions regarding the useful life of capital and summing WPA capital expenditures from previous years (20 years for private-sector capital and 30 years for public-sector sewerage capital).[1] For the other categories (e.g., O&M, R&D), the expenditure estimates were used directly to approximate costs. The results for both the with-CWA and without-CWA scenarios (for 1994 and 1997) are summarized in Table ES-1. In both cases, sewerage costs are the largest component, followed by private capital and O&M.

The sixth step was to estimate the annual costs that are specifically attributable to the CWA. Once all costs were appropriately annualized for both the with-CWA and without-CWA scenarios, this step simply requires taking the difference between the two scenarios. The results are also summarized in Table ES-1. Although the total actual WPA costs for the categories

[1]Results using a 7 percent discount rate are also presented in the analysis.

Table ES-1. Incremental Annual Costs of the CWA Assuming a 3 Percent Discount Rate (1997 $million)

	1994 Costs			1997 Costs		
	Actual (A)	**Without-CWA (B)**	**Incremental (C)=(A)–(B)**	**Actual (D)**	**Without-CWA (E)**	**Incremental (F)=(D)–(E)**
Industry						
Capital	6,490.3	2,520.9	3,969.4	6,345.0	2,694.6	3,650.4
O&M	7,492.1	5,946.1	1,546.1	8,005.2	6,356.0	1,649.2
R&D	80.7	60.2	20.5	97.6	76.1	21.5
Offsets	–312.1	–121.2	–190.9	–267.5	–113.6	–153.9
Public						
Sewerage, Capital	13,308.0	10,676.4	2,631.6	13,979.9	11,375.9	2,604.0
Sewerage, O&M	15,035.5	10,912.8	4,122.8	17,171.4	11,704.8	5,466.6
Electric, Capital	114.6	14.3	100.3	103.3	14.3	89.0
Electric, O&M	10.6	9.5	1.1	11.9	9.5	2.3
R&D	144.4	93.7	50.7	124.0	91.5	32.5
R&M and Other	2,259.3	1,891.4	367.9	2,707.5	1,962.0	745.5
Total	**44,623.3**	**32,003.9**	**12,619.4**	**48,278.1**	**34,171.0**	**14,107.1**

studied amount to almost $45 billion in 1994, it is estimated that about 72 percent of these costs would have been incurred without the CWA. The incremental annual costs of the CWA are estimated to be $12.6 billion in 1994 (the last year for which reasonably complete WPA expenditures are available). By extrapolating from observed trends in WPA expenditures, the total WPA costs in 1997 are estimated to be approximately $48 million, with $14.1 billion of these costs attributable to the CWA. These incremental costs are not insignificant; however, they represent less than 0.2 percent of total gross domestic product (GDP) in 1994 and 1997.

Although these cost estimates are reasonably robust with respect to alternative model assumptions (e.g., discount rate and capital life assumptions), they must be interpreted as best estimates within a range of uncertainty. The most significant source of this uncertainty comes from the characterization and estimation of without-CWA conditions, which, for obvious reasons, cannot be observed. Additional uncertainty is associated with cost estimates beyond 1994, which are partially based on extrapolations from previous years. The overall extent of uncertainty in the CWA cost estimates is difficult to summarize here in a way that is both meaningful and concise; nevertheless, it is explored and described in more depth as part of the analysis.

The final step was to compare these estimates to preliminary estimates of the annual benefits attributable to the CWA. The purpose of this comparison was to gain a rough sense of how the CWA has contributed to net societal welfare in recent years; however, the results of this comparison must be interpreted with great caution. The CWA benefits were estimated in a separate study under a strict set of assumptions, and they only apply to a subset of the nation's surface waters and water pollutants. Nonetheless, these partial estimates, which amounted to approximately $11 billion per year in the mid-1990s, are relatively close in magnitude to the CWA cost estimates from this study. Although these results are suggestive, more detailed analysis, particularly of the benefits, will be needed to draw stronger conclusions regarding the benefit-cost performance of the CWA.

SECTION 1
INTRODUCTION

In 1972, Congress enacted the Federal Water Pollution Control Act, commonly known as the Clean Water Act (CWA), to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Subsequently amended in 1977 and reauthorized in 1987, the CWA has generally been credited with reversing the trend in water quality degradation that began with the industrialization of the U.S. economy in the 1800s and was epitomized by the burning of the Cuyahoga River near Cleveland in 1969. This reversal has been achieved through pollution control measures that have imposed certain costs on society.

The CWA reached its 25-year milestone in 1997, providing a useful vantage point from which to evaluate the changes that have come about as a result of the Act. The specific purpose of this study is to assess the annual costs of the CWA after 25 years.[1] A companion study (RTI, 2000) provides a partial assessment of the benefits of the nation's water pollution control programs since 1972. At this stage, the benefits assessment only accounts for how reductions in conventional water pollutant discharges have affected water quality conditions in the nation's primary rivers and streams. Future efforts will provide a more complete assessment of CWA benefits by addressing a broader range of pollutants and surface water resources. Nonetheless, important preliminary policy insights can be gained by comparing the results of this study with the initial benefit estimates.

Analysts are increasingly using benefit-cost analysis to evaluate federal regulations and programs. It is now an integral component of various statutory and administrative requirements imposed by Congress and the White House. For instance, President Clinton's Executive Order (EO) 12866, which modifies a similar order by President Reagan (EO 12291), requires federal agencies to submit detailed regulatory impact analyses of "major" proposed rules to the Office of

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[1]It is important to emphasize that this analysis does not attempt to assess the *cumulative* costs of the CWA since 1972; rather, it focuses on the *incremental* annual costs resulting from this legislation in recent years.

Management and Budget (OMB) for review. Although it counsels against relying solely on the results of a benefit-cost analysis for policy formulation, it calls for the economic analysis of all "significant" rules. It also directs decisionmakers to select the regulatory approaches that maximize net benefits (including qualitative nonmonetized benefits), unless this conflicts with the intentions of the relevant statute. Similarly, under EO 12893 (Principles for Federal Infrastructure Investments), executive departments and agencies with infrastructure responsibilities are instructed to base their infrastructure investment decisions on systematic analyses of their expected benefits and costs.

In addition to conducting benefit-cost assessments of proposed initiatives, EPA is interested in conducting retrospective analyses of its existing programs and regulations. The CWA itself, in Section 516(b), requires EPA to periodically provide Congress with detailed estimates of the national costs associated with its water pollution prevention and control programs. Such an assessment can also be used to satisfy the requirements of the Government Performance Results Act (GPRA) of 1993, which directs all federal agencies to clearly define their objectives and to measure their performance relative to these goals. Building on previous work conducted at EPA (Iovanna, 1998), this study contributes to this process by estimating the annual social costs that have resulted from implementing the CWA.

To present the approach and results of this analysis, this report is organized as follows. Section 2 contains a brief review of the evolution of federal water pollution control policy in the United States and its implications for this analysis. In Section 3 we describe the conceptual framework that guides our analysis. We identify the primary regulated entities and characterize types of water pollution abatement (WPA) costs they incur in Section 4. Section 5 describes actual trends in water pollution abatement expenditures for these affected entities, particularly since 1972. Section 6 compares these actual trends with our simulation of what water pollution abatement expenditures would have been without the CWA. In Section 7 we compare the with-CWA and without-CWA scenarios to estimate the incremental annual costs in the mid-1990s that can be attributed to the Act. In Section 8, we discuss and qualify the results of our analysis. Three appendices are also included to support the analysis. Appendix A provides a detailed description of the data and assumptions underlying our analysis. Appendix B provides a more detailed review and assessment of recent trends in public sewerage capital expenditures, which continue to account for a large portion of total water pollution abatement expenditures in the United States. Appendix C discusses the inflation adjustment used throughout the report to convert all dollar values into 1997 dollars. Appendix D examines the sensitivity of the CWA cost estimates with respect to specific assumptions that were made in the analysis, and it characterizes some of the uncertainty that is inherent in these total cost estimates.

SECTION 2
EVOLUTION OF WATER POLLUTION CONTROL POLICY

To place our analysis in its proper context, this section provides a brief history of federal water pollution control policy in the United States, and it discusses the role of the CWA in its evolution. Table 2-1 summarizes the relevant legislative milestones.

2.1 Legislative History

The CWA's roots stretch back to 1948, when Congress authorized the federal government to engage in research, investigations, and surveys to study water pollution problems under the Water Pollution Control Act. However, there was no federal authority to establish water quality standards, limit discharges, or engage in enforcement activity. The Water Pollution Control Act Amendments that followed in 1956 authorized states to establish criteria for determining desirable levels of water quality. The federal government was also granted discretionary authority to convene "enforcement conferences" for interstate waters. However, the discretionary nature of federal responsibility and the reliance on volunteerism and consensus on the part of conference participants meant that this Act made a limited contribution to establishing and enforcing meaningful pollution control requirements on individual dischargers (Freeman, 1990).

The Water Quality Act of 1965 was the first federal law to mandate that states establish ambient water quality standards for interstate water bodies and develop implementation plans to control pollution to meet these standards. States also had primary enforcement responsibility. Major revisions to these policies were made when Congress enacted the CWA in 1972. The CWA established national goals and deadlines for attaining fishable, swimmable, and boatable waters for the nation's inland waters. These goals were to be achieved through a system of technology-based effluent standards aimed primarily at point source dischargers of conventional pollutants (biological oxygen demand [BOD], total suspended solids [TSS], pH, fecal coliform, and oil and grease). An area of expansion for the CWA from past policy was the shift in primary implementation and enforcement responsibility from the states to the federal government. EPA would issue permits and monitor discharges through the National Pollutant Discharge Elimination

Table 2-1. Federal Water Pollution Control Laws

Title	Year of Enactment	Key Provisions
Water Pollution Control Act	1948	✓ Authorized federal research
Water Pollution Control Act Amendments	1956	✓ State responsibility to establish water quality criteria ✓ Discretionary federal responsibility to convene enforcement conferences
Water Quality Act	1965	✓ Ambient standards ✓ State implementation and enforcement responsibility
Federal Water Pollution Control Act (Clean Water Act)	1972	✓ Technology-based standards for conventional pollutants ✓ Federal share of municipal treatment plant construction costs set at 75 percent ✓ Federal implementation and enforcement responsibility
Coastal Zone Management Act	1972	✓ Directed towards coastal water pollution problems
Clean Water Act Amendments	1977	✓ Increased coverage to toxic pollutants
Municipal Wastewater Treatment Construction Grant Amendments	1981	✓ Reduced federal share of municipal treatment plant financing to 55 percent
Clean Water Act Reauthorization	1987	✓ Increased focus on nonpoint source pollution ✓ Federal support for municipal treatment plant construction converted from grant assistance to loans

Source: Adapted from Freeman, A. Myrick. 1990. "Water Pollution Policy." In *Public Policies for Environmental Protection*, Washington, DC: Resources for the Future.

System (NPDES). Under the CWA, the federal government also offered to pay 75 percent of the design and construction costs for municipal treatment plants.

The CWA Amendments of 1977 broadened the scope of water pollution control policy by calling for the regulation of toxic pollutants, in addition to the conventional pollutants that the CWA had previously targeted. The amendments also postponed some of the deadlines established in the 1972 Act. The Municipal Wastewater Treatment Construction Grant Amendments of 1981 reduced the federal share of wastewater treatment plant construction costs to 55 percent.[1]

The Water Quality Act of 1987 established new requirements for controlling nonpoint source pollution such as runoff from agricultural land, silviculture activities, and urban areas. It also further extended the deadlines for compliance with the effluent standards. The Coastal Zone Management Act of 1972 further expanded the scope of water pollution control policy towards coastal water pollution problems at the national level.

2.2 Implications for This Analysis

Although the CWA of 1972 established a discharge permit system and provided significant federal financial assistance for constructing public treatment facilities, it is important to stress that some state-driven pollution control existed prior to 1972. Therefore, to comply with the existing state and local regulations, individual dischargers would have continued to incur some water pollution abatement costs even if the CWA had not been promulgated in 1972. It is also possible that new state and local programs would have been initiated or existing programs would have been expanded to appease the growing public demand for environmental protection. Thus, to specifically assess the costs attributable to the CWA, it is essential to separate these costs from the water pollution abatement costs that would have been incurred without the Act. Furthermore, to distinguish CWA costs from those of subsequent statutes that have primarily addressed nonpoint source pollution, our assessment focuses primarily on the cost of *point source* abatement efforts.

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[1]Federal funding for the Construction Grants Program ended in 1990. The grants program was replaced by the State Revolving Fund Program, which provides low-interest loans for a variety of clean water projects, including municipal sewage treatment facilities.

SECTION 3
CONCEPTUAL FRAMEWORK

The cost of the CWA can be estimated from at least two distinct perspectives:

- *Before and after perspective*: How has the cost of water pollution control changed since 1972?
- *With and without perspective*: How does the current cost of water pollution control compare with what costs would have been in the absence of the CWA?

Figure 3-1 illustrates the difference between these two perspectives. It depicts the trends in water pollution abatement expenditures both in the presence of the CWA as well as in the absence of the CWA. Since both regulation and enforcement increased following the CWA, it is assumed that compliance costs would be higher in the presence of the CWA than in its absence.

Suppose the annual expenditures on water pollution control in the current period were $40 billion greater than in 1972. A "before-after" analysis would attribute the entire cost of these expenditures to the CWA. This approach provides an inappropriate characterization of the current costs of the CWA because it implicitly assumes that there would have been no additional water pollution control expenditures in the absence of the CWA. However, as described in Section 2, state and local governments implemented water pollution control policies prior to 1972, and historical data on pollution abatement activities indicate that significant investments in water pollution control were being made before the CWA's passage. It is, therefore, reasonable to assume that some of this investment would have continued even if the CWA had not been enacted.

Although it is more analytically demanding, the "with-without" perspective is more conceptually correct in the current context. The challenge in such an analysis is to develop a consistent and plausible characterization of the without-CWA conditions. The preferred method for developing such a characterization is to examine historical (i.e., prior to 1972) trends in water pollution abatement expenditures and to measure their relationship to other socio-economic and demographic indicators over the same period. These estimated relationships can then be used to

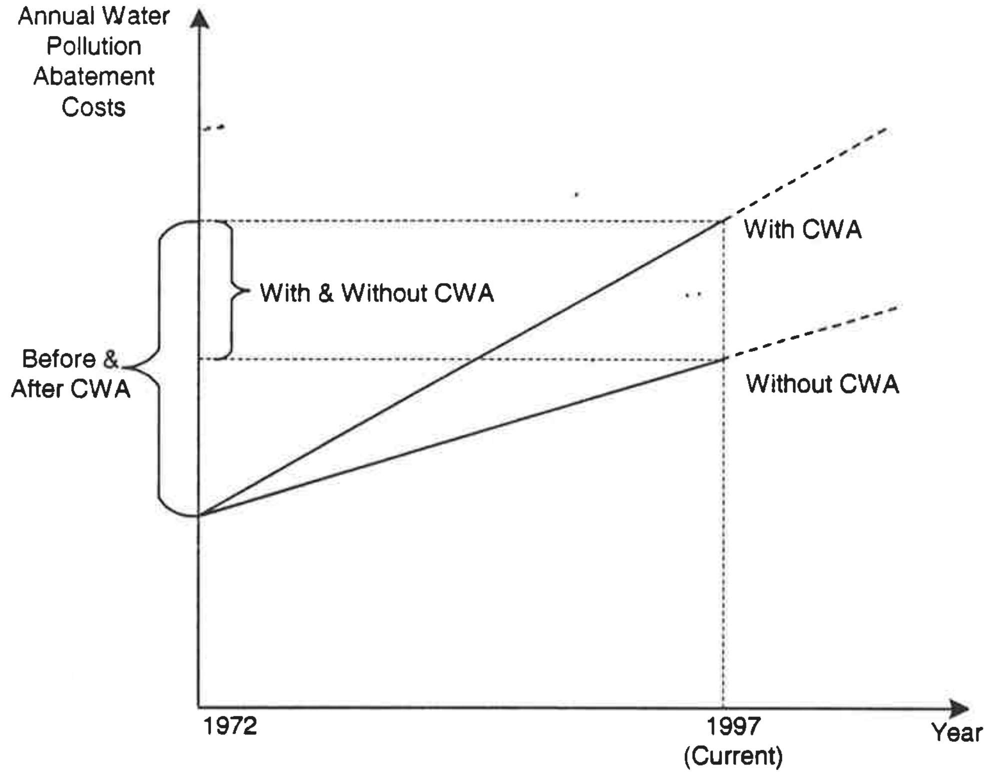


Figure 3-1. Alternative Paradigms for Estimating CWA Costs

project the observed trends beyond 1972 and to simulate what current conditions would be without the CWA. As described in more detail in Section 6, this is precisely the approach we use for estimating without-CWA public sewerage expenditures for the period 1972 through 1997.

When historical data on water pollution abatement expenditures are not available, an alternative approach must be used to simulate without-CWA trends. Unfortunately, this is the case for virtually all other major public and private categories of water pollution abatement (WPA) expenditures. The approach we took in these cases was to rely on the available with-CWA data for the period 1972 through 1997. For each category, we assumed that the year with the lowest (in absolute or relative terms) observed annual WPA expenditures is the best representation of what conditions over the entire period would have been without the CWA. This approach ensures that, for any given year and category, the observed (with-CWA) WPA expenditures are never less than the simulated (without-CWA) expenditures. Although this is clearly a strong assumption and one that is more likely to overstate the costs of the CWA, we believe it makes best use of the available data, is relatively easy to interpret, and is reasonable.

Figure 3-2 summarizes the main steps used to implement and derive cost estimates from these approaches. Each step is described in greater detail in the following sections. The first step involves identifying regulated (or otherwise affected) entities under the CWA. The primary distinction is between the public and private (i.e., industrial) sectors; however, as discussed in Section 4, these categories can be further disaggregated. The second step involves identifying cost categories. The primary categories are the capital costs associated with WPA plant and equipment and the costs of related operation and maintenance (O&M) activities. Other administrative and research related costs are also identified and described in more detail in Section 4.

Once these categories have been identified, the next (third) step is to collect the corresponding data, including data on actual pollution control activities as well as other socio-economic and demographic data needed for the analysis. The primary original source of information is the Census Bureau and the data it collects and reports on both public and private expenditures. A variety of other sources are also used, as described in Section 5 and in Appendix A. To make the expenditure data comparable across different years, all dollar values used in the analysis were converted to 1997 dollars using an inflation adjustment that is described in Appendix C.

The fourth step uses the data collected in the previous step and one of the simulation approaches described above to estimate WPA expenditures for the without-CWA scenario. This step is done separately for the different cost categories and is discussed in Section 6.

The fifth step is to convert annual WPA *capital expenditure* estimates for both scenarios into annual WPA *capital cost* estimates. This distinction is important because it recognizes that annual expenditures on WPA capital are not necessarily the most appropriate estimates of the true

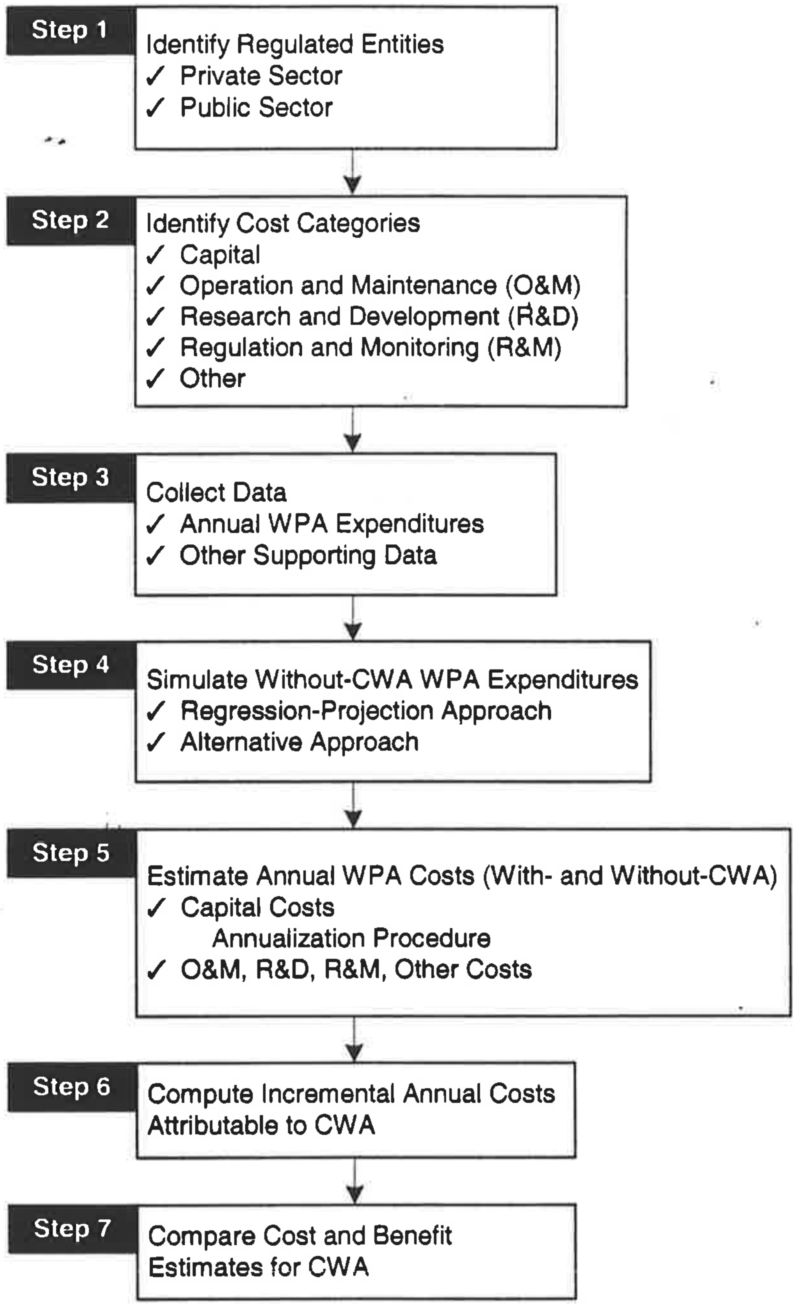


Figure 3-2. Outline of Methodology for Assessing CWA Costs

opportunity *costs* of this capital.[1] That is, with any large purchase of capital equipment, the true costs are not likely to be experienced as a lump sum in one year. Rather, the costs are likely to be borne over the course of several years, either in the form of loan payments to lenders or in the form of a foregone stream of earnings that could have been generated through an alternative investment. Therefore, a more appropriate estimate of the WPA capital cost for any given year can be derived by annualizing and summing WPA capital expenditures from previous years (this is described in more detail in the Section 6). This conversion procedure requires lengthy and continuous time series estimates of WPA capital expenditures from previous periods. Because of the limited availability of such historical data for many categories of WPA capital expenditures, estimates of WPA capital costs can in some cases only be derived for recent years.

Once all costs are appropriately annualized for both the with-CWA and without-CWA scenarios, the next (sixth) step is to compute the difference between the two scenarios. This provides the appropriate estimate of the annual costs that are attributable to the CWA. The final seventh) step is to compare these estimates to estimates of the annual benefits attributable to the CWA. As described previously, the benefits estimates are preliminary and only apply to a subset of the nation's surface waters and water pollutants; therefore, the comparison of costs and benefits must be interpreted with caution. Sections 7 and 8 address these final steps by reporting the results of the CWA cost estimation and discussing how they compare to estimates of CWA benefits.

[1]In contrast, for O&M and other cost categories, annual *expenditures* do provide a reasonable estimate of annual *costs*.

SECTION 4
IDENTIFICATION OF REGULATED ENTITIES AND POLLUTION ABATEMENT COST CATEGORIES

As outlined in the previous section, the first steps in assessing the costs of the CWA are to identify and categorize the primary entities that are affected by the CWA's requirements and the types of costs that are imposed on these entities. The categorization scheme for this study, which is described below, is designed to correspond with available data. These data are described in Section 5.

4.1 Regulated Entities

The CWA targets dischargers in both the private and public sectors. In the private sector, the CWA regulates discharges from both manufacturing and nonmanufacturing industrial facilities. In the manufacturing sector, the full range of industries (spanning Standard Industrial Classification [SIC] codes 20 through 39) are affected. In the nonmanufacturing sector, the affected industrial categories include mining, public electric utilities, cooperatively owned electric utilities, and other nonmanufacturing industries.[1] Table 4-1 lists affected industries and their associated SIC codes.

Under the CWA, pollution abatement efforts are also required of public enterprises.[2] Two public enterprises, in particular, are relevant to this study: publicly owned treatment works (POTWs) and publicly owned electric utilities (POEUs). POEUs include federal, municipal,

[1]The electric utility industry comprises public electric utilities, cooperatively owned electric utilities, and publicly owned electric utilities (POEUs). Public electric utilities are owned by private shareholders and represent a majority of the electric utility universe in the United States. Public electric utilities and cooperatively owned electric utilities are classified under the nonmanufacturing industrial sector in the current analysis. POEUs are owned by the government and are thus classified under the public sector in this report.

[2]Public enterprises are public-sector entities that are required to cover operating costs through charges to customers for services provided.

Table 4-1. Regulated Entities Under the CWA

Group	SIC Codes
Manufacturing Industries	
Food	20
Paper	26
Chemical	28
Petroleum and coal products	29
Other nondurables	21, 22, 23, 27, 30, 31
Primary metals	33
Machinery	35
Motor vehicles	37
Other durables	24, 25, 32, 34, 36, 38, 39
Nonmanufacturing Industries	
Mining	10, 12, 13, 14
Public and Cooperative Electric Utilities	Part of 491, 493
Other Nonmanufacturing	
Construction	15, 16, 17
Transportation	40-47
Services	492, 494-497, 70-89
Wholesale and retail	50-59
Finance etc.	60-67
Public Enterprises	
Publicly owned sewerage treatment plants	Part of 4952
Publicly owned electric utilities	Part of 491, 493

and power district/state project plants. These categories and their SIC codes are also provided in Table 4-1.

4.2 Cost Categories

Regulated entities incur several types of costs to comply with the CWA and control water pollution. The main cost categories of interest are

- pollution abatement capital expenditures,
- operation and maintenance (O&M) costs,

- research and development (R&D) costs,
- regulation and monitoring (R&M) costs,
- other current expenditures, and
- cost offsets.

The water pollution abatement capital expenditure category covers investments by industry and the public sector on end-of-pipe controls as well as on process changes. These regulated entities also incur annual expenditures to operate and maintain abatement capital. Both industry and the public sector also incur related R&D costs. In addition, the government incurs costs to monitor the regulated industries. The public sector also incurs "other current expenditures," including those for remedial actions, process changes, operations and administration, and the construction of sewerage treatment plants on Native American reservations.

In addition to increasing the costs of production, pollution control activities can also lead to revenue increases or cost savings that at least partially offset these costs. For example, some of the by-products from pollution control may have value, or certain efficiency gains may result in changing production processes to control releases. These are referred to as recovered costs or cost offsets, and they can be interpreted as a separate, but negative, cost category.[3]

[3]Cost offsets could also be categorized as a (positive) benefit category; however, we include them as a negative component in the cost assessment because of their direct connection to the regulated entities.

SECTION 5
ESTIMATES OF WATER POLLUTION ABATEMENT EXPENDITURES

To support our assessment of CWA costs, we collected two general types of data. Most importantly, we acquired data on actual annual water pollution control expenditures for each of the categories identified in the previous section. These data form the primary basis for estimating annual costs for both the with-CWA and without-CWA scenarios. The data sources and expenditure estimates are described in detail below. We also collected additional data to support our simulation model for estimating costs under the without-CWA scenario. These data are described in Section 6 and in Appendix A.

5.1 Public Sewerage Capital and O&M Expenditures

WPA expenditures by the public sector are primarily attributable to the construction, operation, and maintenance of sewerage systems. Data on both capital and O&M outlays were acquired from the Census Bureau's Government Finances (GF) data series for fiscal years 1958 to 1996.[1] In addition, historical data on *total* sanitation expenditures (which primarily include sewerage and solid waste management expenditures) are reported for selected years between 1902 and 1970 in the Census Bureau's Historical Statistics of the United States. As described in Appendix A, these data are used to estimate public sewerage capital and O&M expenditures for the years 1902 to 1957. Therefore, in contrast to the data on private WPA expenditures, there is a considerable amount of information regarding public WPA expenditures in the years preceding the CWA. Section 6 discusses how these data were used to simulate without-CWA conditions after 1972 for the public sector.

[1]Sewerage outlay data are also reported in the *SCB*. However, the GF was chosen because it is the more direct and consistent source.

Figure 5-1 shows the observed trends in public sewerage capital and O&M expenditures for calendar years 1957 through 1997.[2] As in the remainder of this report, real values are expressed in 1997 dollars, using a standard chain-type gross domestic product price index (see Table B-1 in Appendix B). Except for a short period of decline in the late 1960s, sewerage capital expenditures grew steadily between 1958 through 1971 from $3.3 billion to $6.9 billion. Then, in the 1970s, there was a marked increase in the growth of these expenditures. By 1980, they peaked at over $12 billion. Thereafter, they declined in the early 1980s and returned to around $10 billion per year in the late 1980s and early 1990s. A more detailed description and an assessment of these expenditures are provided in Appendix B.

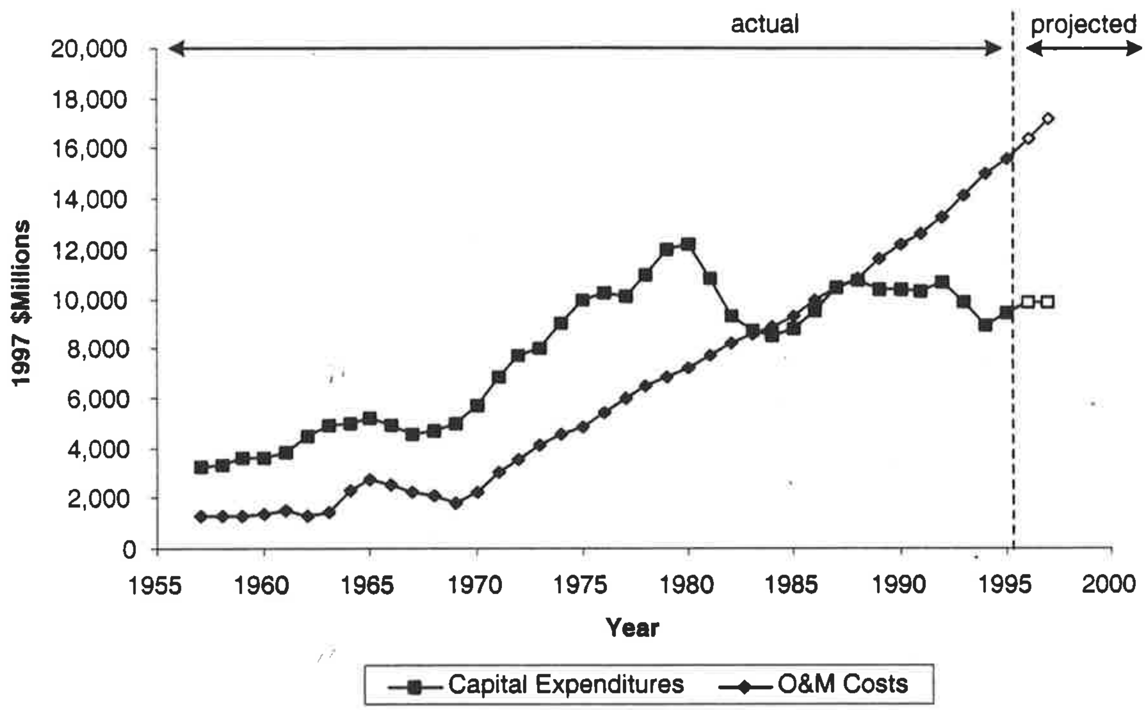


Figure 5-1. Public Sewerage Expenditures, 1957–1997 (1997 $millions)

[2]All annual sewerage capital and O&M expenditures values for 1902–1995 were converted from fiscal year to calendar year estimates. This conversion was accomplished by taking the average of fiscal year estimates for the same and following year (e.g., 1970 values were set equal to the average of the FY1970 and FY1971 estimates.)

The 1970s also saw a dramatic increase in the growth of annual O&M expenditures, and, in contrast to capital expenditures, these expenditures continued to grow after 1980. From 1957 through 1971, O&M expenditures grew from $1.3 billion to $3 billion per year (an average increase of about $120 million per year, despite 3 years of decline in the late 1960s); however, by 1995 they had grown to over $15 billion per year (an average increase of over $600 million per year from 1971 through 1995).

5.2 Private Capital and O&M Expenditures

The primary original source of data for private expenditures on water pollution abatement is the Census Bureau's Pollution Abatement Cost and Expenditure (PACE) survey. On an annual basis from 1973 through 1994 (except 1987), PACE's Form MA-200 has been used to collect relevant capital and O&M expenditure data from both the manufacturing and nonmanufacturing industrial sectors. These data have been periodically summarized and reported in the *Current Industrial Reports (CIRs)* (U.S. DOC, 1973-1994).

In addition to the data reported in the *CIRs*, the *Survey of Current Business* (*SCB*) has also periodically reported on both public and private pollution control expenditures. The pollution control expenditure data in the *SCB* reports are primarily based on PACE data, but they are also supplemented with a variety of other sources (see, for example, Vogan [1996] for a summary of these sources) and reported on a more aggregate level.

Appendix A includes tables with WPA expenditure data (in current dollars) from both the *CIRs* and *SCB* reports. For reasons that are also discussed in the appendix, we based our assessment of private costs on the aggregate estimates of private capital and O&M expenditures for 1972 through 1994 that were reported in the *SCB* (Vogan, 1996). In short, we concluded that the quality of the data and the expected gains in insight were not enough to justify conducting the analysis on an industry-by-industry basis.

Figure 5-2 reports the observed trends in real annual WPA capital and O&M expenditures in the private sector for the period 1972 through 1994. Additional values for 1995 through 1997 were extrapolated based on the data for earlier years. Capital expenditures grew in the early 1970s, but otherwise there was no clear upward trend in these expenditures between 1972 and

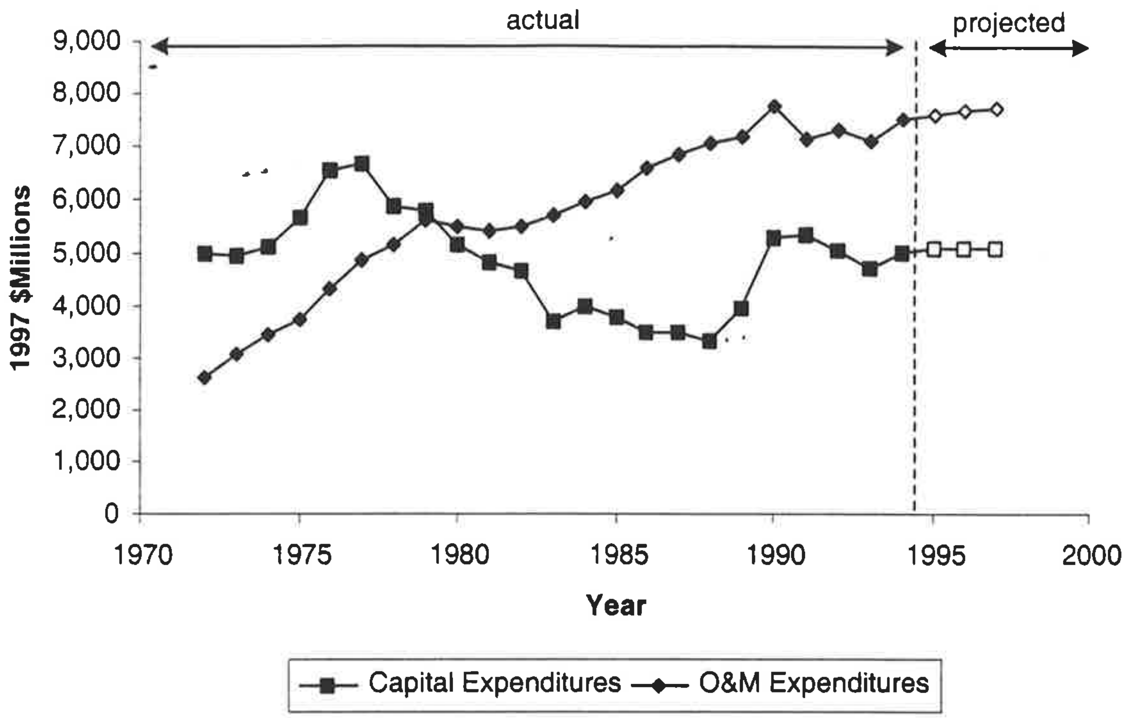


Figure 5-2. Private Water Pollution Abatement Expenditures, 1972–1997 (1997 $millions)

1994. They peaked in 1977 at $6.7 billion, by which time EPA had promulgated preliminary effluent guidelines and standards for over 20 industrial categories. However, as occurred with public capital (and R&M) expenditures, real private WPA capital expenditures declined through the early 1980s and then rebounded again in the late 1980s. By the mid-1990s, they had returned to their 1972 levels (around $5 billion per year).

For private O&M expenditures between 1972 and 1994, the pattern is one of relatively consistent growth. These expenditures increased by an average of $220 million each year, from about $2.6 billion in 1972 to almost $7.5 billion in 1994.

5.3 Capital and O&M Expenditures by Publicly Owned Electric Utilities

In addition to sewerage expenditures, the public sector also incurs WPA expenditures through POEUs. The BEA extrapolated pollution abatement capital and O&M expenditure data for these sources from PACE and the Energy Information Agency (EIA) Form 767, and they are reported in the *SCB* (Vogan, 1996) for the period 1972 through 1994. These data are reprinted in Appendix A. Figure 5-3 displays the trend in real capital and O&M expenditures in this category for 1972 through 1997, with the last 3 years extrapolated from the observed trend in the early 1990s. Starting at $10 million in 1972, O&M expenditures grew to $30 million by the early 1980s ; however, by the mid-1990s they were averaging below $13 million per year. As in other sectors, capital expenditures were more variable, peaking at $164 million in 1979 but declining to $11 million in 1994 (the last year of actual data).

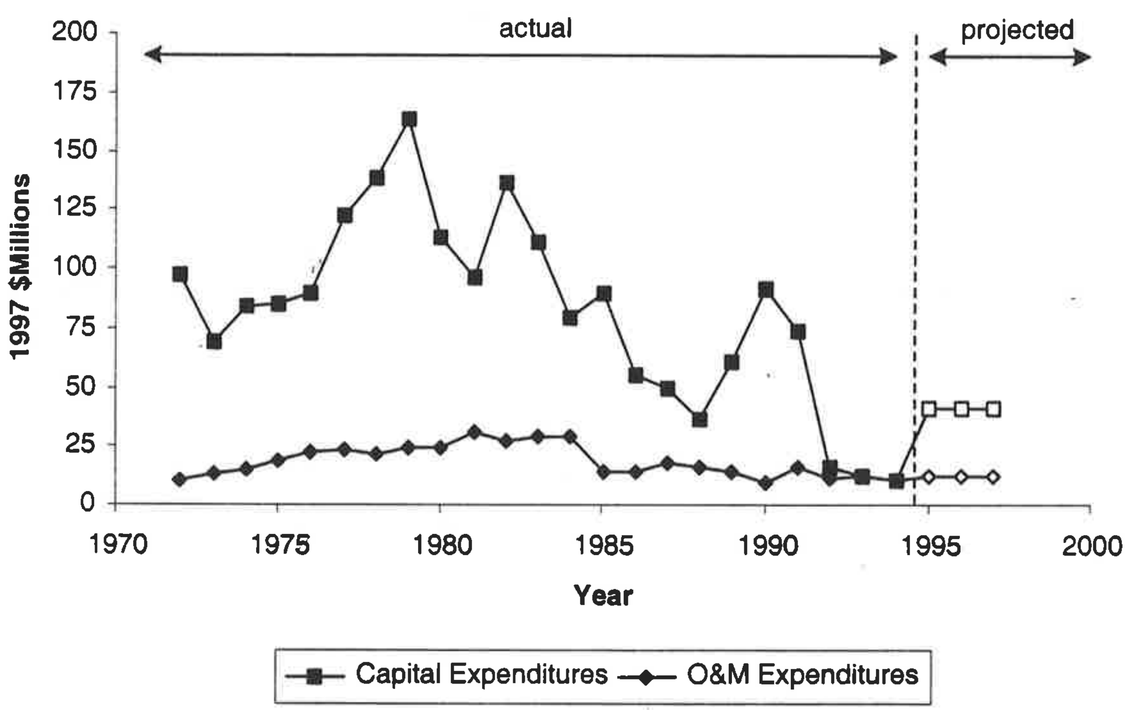


Figure 5-3. Water Pollution Abatement Expenditures by Publicly Owned Electric Utilities, 1972–1997 (1997 $millions)

5.4 Public and Private R&D Expenditures

For this report, data on public and private water pollution-related R&D expenditures were also acquired from the *SCB* (Vogan, 1996) for the years 1972 through 1994. For the private sector, these data were acquired through the National Science Foundation's (NSF's) Industrial Research and Development Survey (IRDS). For the public sector, this information is collected through the Federal Funding for Pollution Control (FFPC) survey. It is also collected and reported by state governments. The data reported in the *SCB* are also reprinted in Appendix A. Figure 5-4 shows the trend in public and private R&D expenditures from 1972 through 1997. Again, the last 3 years of data were extrapolated from the observed trend in previous years. Both series show a general decline from as much as $300 million for the public sector and $231 million for the private sector in 1973 to less than $150 million and $100 million, respectively, in the mid-1990s.

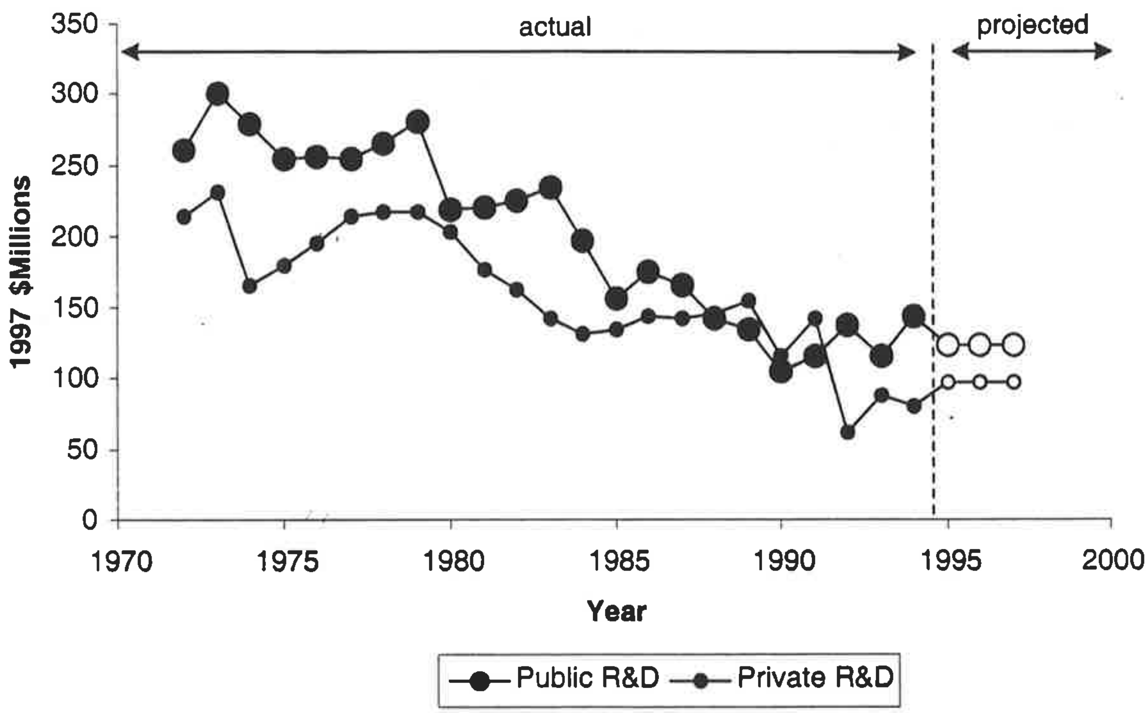


Figure 5-4. Public and Private R&D Expenditures for Water Pollution Abatement, 1972–1997 (1997 $millions)

5.5 Public R&M and Other Expenditures

Public-sector R&M and other not-elsewhere-classified expenditure data are also collected in the FFPC survey and reported in the *SCB* (Vogan, 1996) for the years 1972 through 1994. These data are also reprinted in Appendix A. Figure 5-5 shows the trend in real expenditures in these categories for the period 1972 through 1997 (last 3 years extrapolated). Overall, these expenditures grew from $1.3 billion to over $2.5 billion by the mid-1990s.

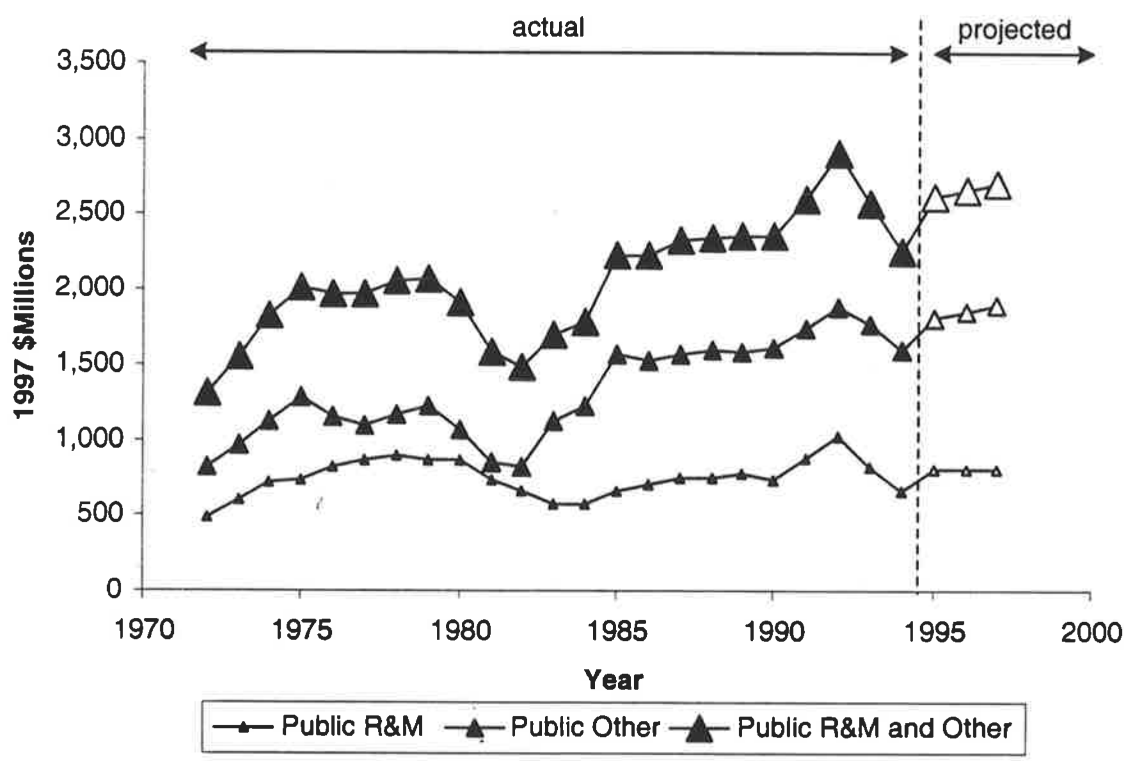


Figure 5-5. Public Water Pollution Abatement Expenditures for R&M and Other Costs Not Elsewhere Classified, 1972–1997 (1997 $millions)

5.6 Private Cost Offsets

Data for recovered costs resulting from pollution abatement activities are also included in PACE and in the *SCB* (Vogan, 1996) report; however, the data are only disaggregated by media (air, water, and solid waste) from 1980 through 1994 (except 1987). Extrapolating from the observed distribution of these costs for 1980 through 1994, EPA (1999a) has estimated the portion of recovered costs that are attributable to water pollution abatement for the period 1972 through 1994. These costs are also reprinted in Appendix A. Figure 5-6 shows the trend in real cost offsets from water pollution abatement for the period 1972 through 1997 (last 3 years extrapolated). These offsets peaked in 1980 at nearly $1 billion but have generally declined since then to less than $300 million per year in the mid-1990s.

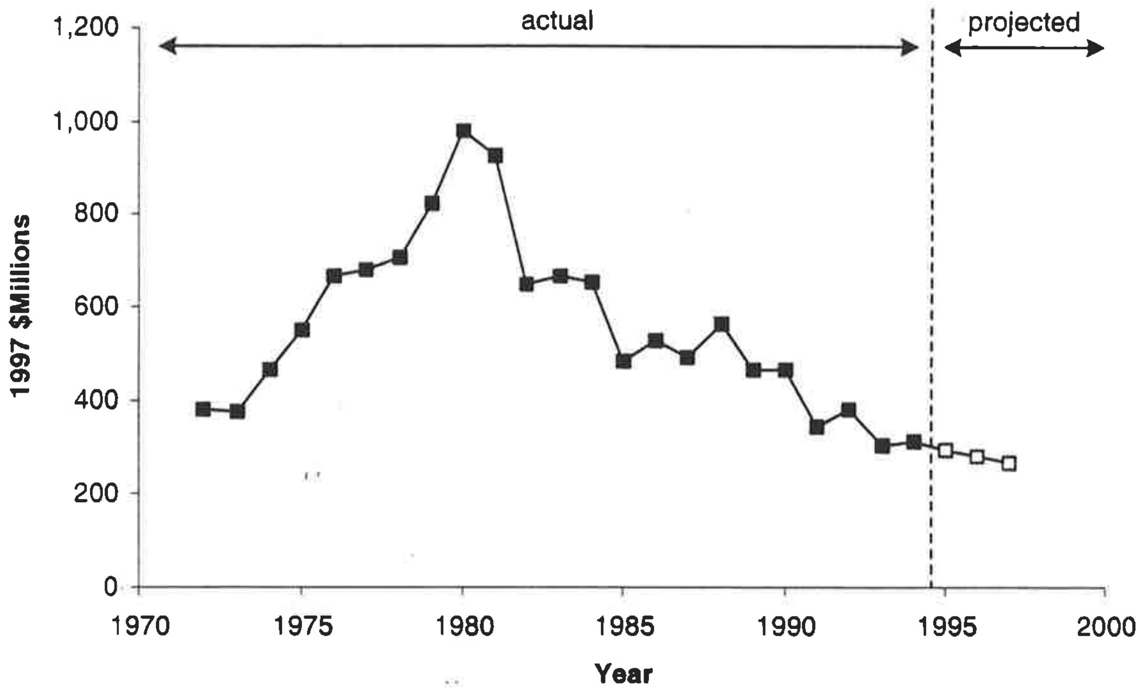
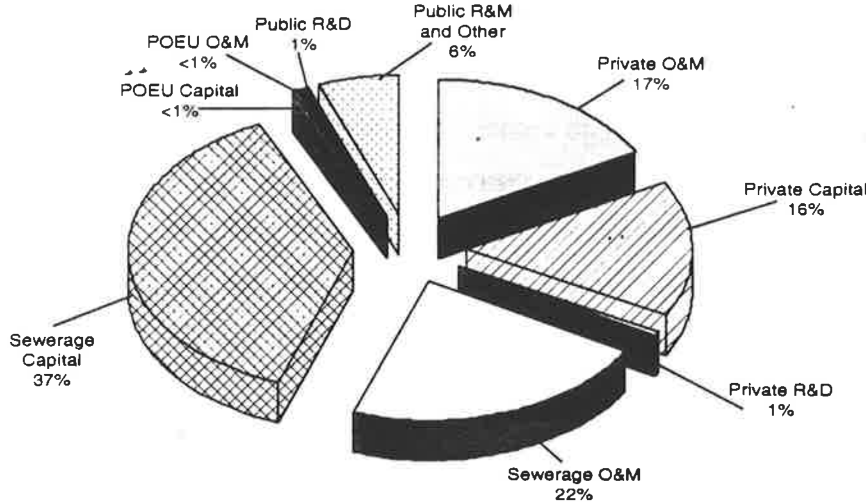


Figure 5-6. Private Water Pollution Abatement Cost Offsets, 1972–1997 (1997 $million)

5.7 Distribution of WPA Expenditures Across Categories

The previous discussion and figures describe how expenditures in each of the categories have varied since the enactment of the CWA; however, they do not provide a very concise picture of the relative magnitude of these expenditures. For two separate years, 1980 and 1990, Figure 5-7 shows how the total estimated annual expenditures on water pollution abatement were distributed across the cost categories. The sum of estimated expenditures (not including the cost offsets) over all of the evaluated categories increased from $34.6 billion in 1980 to $40.3 billion in 1990. In both cases, sewerage capital and O&M were the two largest categories, together accounting for 56 percent and 59 percent of all estimated expenditures in 1980 and 1990, respectively. Private capital and O&M expenditures were the next largest categories, together accounting for 33 percent and 34 percent of all estimated expenditures in the two periods, respectively. In both the private and public sectors, however, the distribution of expenditures shifted away from capital expenditures and towards O&M expenditures between 1980 through 1990.

1980



1990

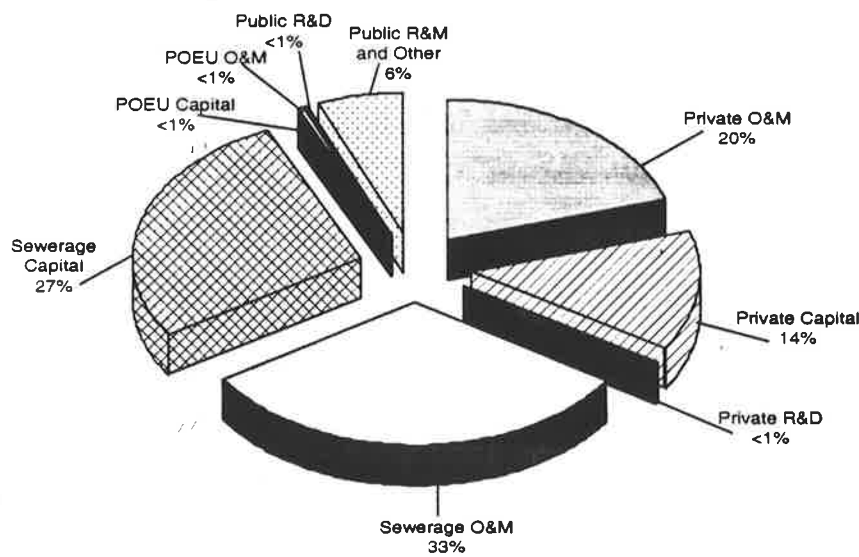


Figure 5-7. Distribution of Estimated Water Pollution Abatement Expenditures, 1980 and 1990

SECTION 6
SIMULATION OF WATER POLLUTION ABATEMENT EXPENDITURES FOR THE WITHOUT-CWA SCENARIO

As discussed in Section 3, to properly assess the costs that are attributable to the CWA, one must distinguish between actually observed conditions and those that would have occurred without the Act. In this section we discuss our simulation approach for estimating water pollution abatement expenditures under a without-CWA scenario. The specific estimation procedures and results for each cost category are discussed separately below.

6.1 Public Sewerage Capital and O&M Expenditures Without the CWA

In contrast to other categories of water pollution abatement expenditures, a considerable amount of historical data are available regarding total public sanitation expenditures (including solid waste management) before the enactment of the CWA. As discussed in more detail in Appendix A, we used these data to specifically characterize sewerage capital and O&M expenditures for selected years between 1902 and 1971. In combination with other historical data on housing starts and population, these data form the basis for simulating public sewerage expenditures for the without-CWA scenario.

6.1.1 Public Sewerage Capital Expenditures

To model real sewerage capital expenditures before 1972, we assume that.capital accumulation in this sector is primarily driven by the size of the population to be served and by fluctuations in economic activity (especially in the housing sector) . Therefore, we collected data on annual sewerage capital expenditures, population, and housing starts in the United States for 34 years over the period 1902 through 1971. We then used ordinary least squares (OLS) regression to estimate the following relationship:

$$SEWER\_K\_EXP = -542.7 - 9{,}195 \bullet D48 + 11.2 \bullet POP \quad (6.1)$$
$$\quad (-1.01) \quad (-10.62) \quad (2.56)$$

$$+ 55.8 \bullet POP \bullet D48 + 0.388 \bullet HOUSE\_STRT$$
$$(10.38) \quad (1.13)$$

$$+ 1.108 \bullet HOUSE\_STRT \bullet D48$$
$$(2.25)$$

Adjusted $R^2 = 0.99$

SEWER_K_EXP represents real annual sewerage capital expenditures (in 1997 $millions), POP represents total U.S. population (in millions), and HOUSE_STRT represents annual housing starts (in thousands of units). As shown in Figure 6-1, there was a notable increase in the growth rate in sewerage capital expenditures in the late 1940s, which coincided with the passage of the original Water Pollution Control Act of 1948. To account for this effect, we also included a dummy variable, D48 (equal to one after 1947) and interacted it with the other explanatory variables. Particularly, as of 1948, population and housing starts are found to have a positive and statistically significant (t-statistics are shown in parentheses) effect on sewerage capital expenditures.[1] According to the model, by itself each 1 million increment in population after 1947 increased annual sewerage expenditures by $67 million, and each 1 thousand increment in housing starts increased these expenditures $1.5 million. The adjusted R^2 statistic also indicates that the estimated model explains a large majority of the variation in capital expenditures.

[1] The Durbin-Watson statistic for this regression is 0.77, which indicates a high degree of serial autocorrelation in the regression errors. This indicates that the t-statistics overstate the significance of these variables; however, population and housing starts after 1947 continue to be statistically significant explanatory variables when the model is run with a Cochrane-Orcutt correction for autocorrelation. Because of their goodness-of-fit properties, the original models were retained for generating point estimates of without-CWA sewerage expenditures.

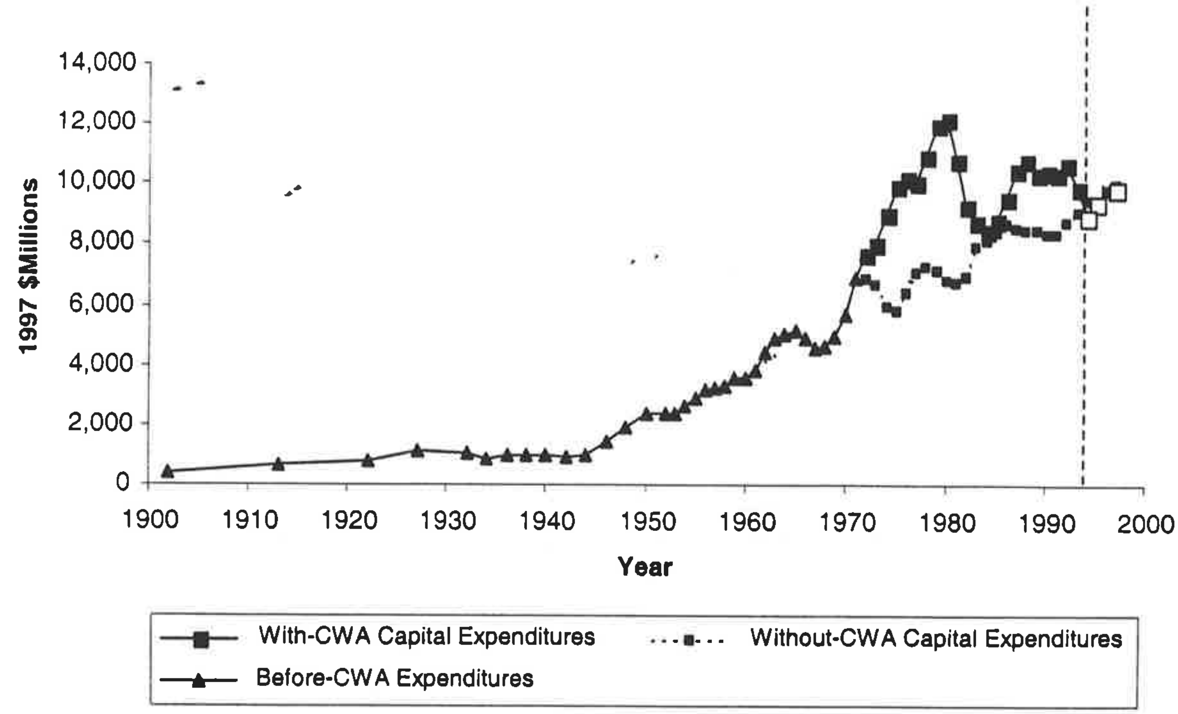


Figure 6-1. Annual Sewerage Capital Expenditures Under the With-CWA and Without-CWA Scenarios, 1902-1997 (1997 $millions)

To simulate what these expenditures would have been without the CWA, we assumed that the estimated relationship described above would have continued to hold after 1971. Therefore, we used Eq. (6.1) and more recent data on housing starts and population to develop without-CWA projections of sewerage capital expenditures for the period 1972 through 1997. Figure 6-1 shows the historical trend in observed sewerage capital expenditures for 1902 through 1971 (before-CWA expenditures), as well as the divergence between observed (with-CWA) and projected (without-CWA) expenditures for the period 1972 through 1997. Without the CWA, the model does not predict the same surge in public wastewater capital spending that actually occurred in the 1970s and late 1980s (see Appendix C for a more detailed discussion of these expenditures). The largest gap between the two post-1972 trends occurred in 1980, when with-CWA capital expenditures exceeded the corresponding without-CWA estimate by over $5 billion. In Section 7, these estimated sewerage capital *expenditures* for the two scenarios are used to estimate and compare their corresponding capital *costs*. Although with-CWA and without-CWA expenditures are predicted to be roughly equivalent by the mid-1990s, the same is not true of capital costs in this period. Because the model predicts persistently lower rates of capital spending without the CWA between 1972 and 1993, the sewerage capital stock is estimated to be $51 billion lower by 1997 (see Table A-11 in Appendix A). As a result, the estimated without-CWA sewerage capital costs are also distinctly lower in the mid-1990s.

6.1.2 Public O&M Sewerage Expenditures

A similar approach is used to estimate O&M sewerage expenditures for the without-CWA scenario. In this case, the model assumes that O&M expenditures on sewerage systems depends primarily on the size and age of the infrastructure to be operated and maintained. To implement this approach we estimated a relationship between real annual O&M expenditures and estimates of these characteristics of the sewerage capital stock between 1932 and 1994. The results are described in the following equation:

$$\underset{}{\text{SEWER\_OM\_EXP}} = \underset{(-9.34)}{-5{,}960.2} + \underset{(73.69)}{0.06 \bullet \text{KSTOCK}} + \underset{(7.22)}{363.4 \bullet \text{KAGE}} \qquad (6.2)$$

$$\text{Adjusted } R^2 = 0.99$$

SEWER_OM_EXP represents real annual sewerage O&M expenditures (in millions of 1997 dollars), KSTOCK is the estimated gross sewerage capital stock (in 1997 $millions), and KAGE is the estimated average age of this stock. As expected, O&M expenditures are positively and statistically significantly related to the size and age of the capital stock[2]. The R-squared statistic also indicates a very good fit for the model.

[2]The Durbin-Watson statistic for this regression is 0.33 which again indicates a high degree of serial autocorrelation in the regression errors. This suggests that the t-statistics overstate the significance of these variables; however, capital stock and age continue to be statistically significant explanatory variables when the model is run with a Cochrane-Orcutt correction for autocorrelation. Because of their goodness-of-fit properties, the original models were retained for generating point estimates of without-CWA sewerage expenditures.

To simulate what O&M expenditures would have been without the CWA after 1971, we first estimated what KSTOCK and KAGE would have been under this scenario, using our without-CWA capital expenditure estimates for 1942 through 1997. We then applied Eq. (6.2) to estimate without-CWA O&M expenditures for 1972 through 1997. Figure 6-2 shows the historical trend in observed sewerage O&M expenditures and the divergence between observed (with-CWA) and projected (without-CWA) expenditures for the period 1972 through 1997. The differences between with-CWA and without-CWA O&M expenditures are estimated to increase over the entire period, such that by the mid-1990s O&M expenditures are roughly $5 billion greater per year with the CWA than without the CWA.

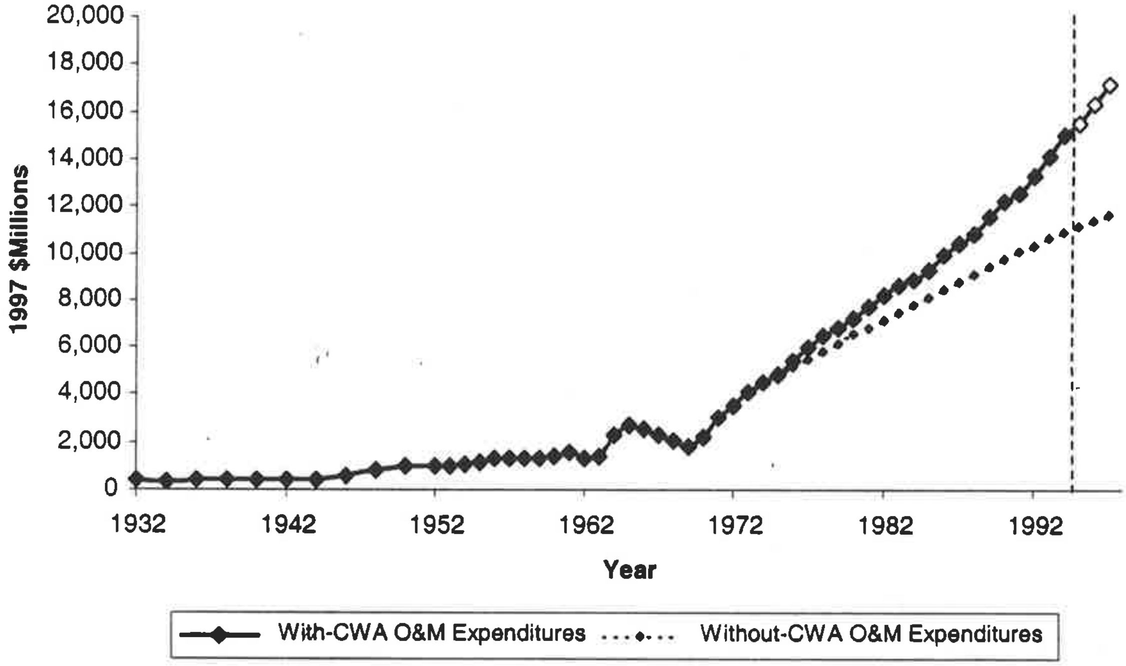


Figure 6-2. Annual Sewerage O&M Expenditures Under the With-CWA and Without-CWA Scenarios, 1932–1997 (1997 $millions)

6.2 Private Capital and O&M Expenditures Without the CWA

The primary limitation for estimating these expenditures is the lack of data on private WPA capital and O&M expenditures for years prior to 1972. Without such data we cannot extend the observed before-CWA trends in these expenditures to the period after 1972. In other words, a regression-based approach such as the one used to model and simulate without-CWA sewerage expenditures (as described in Section 6.1) is not feasible for private WPA expenditures. Instead, we must rely on alternative and less certain assumptions for characterizing the without-CWA scenario. As a result, there is somewhat more uncertainty associated with these private expenditure estimates.

6.2.1 Private Capital Expenditures

To simulate private industrial WPA capital expenditures without the CWA, we assumed that these expenditures would have represented a constant percentage of (and grown in direct proportion to) total industrial capital expenditures for the period 1972 to 1997.[3] According to a study for the Council on Environmental Quality, Clark (1977) cites evidence that, in 1965, private WPA capital expenditures was $225 million. This represented approximately 0.3 percent of total private investment in that year.[4] Assuming that this ratio would have persisted after 1972 and applying this to the data on total private capital expenditures, Figure 6-3 shows how the without-CWA estimates of private WPA capital expenditures compare to observed expenditures.[5] The largest differences are estimated for the 1970s (almost $5.1 billion in 1976), but by 1997 WPA capital expenditures with the CWA are estimated to exceed those without the CWA by $2.6 billion.

It is important to emphasize that the difference in WPA capital *expenditures* between the two scenarios does not necessarily represent the difference in capital *costs*. As discussed in

[3]This assumption is similar to the one used by Clark (1977) in a similar analysis of "baseline" pollution abatement expenditures.

[4]Total private investment is estimated by private gross nonresidential fixed investment from the National Income and Product Accounts (NIPA) (CEA, 2000).

[5]Results using an alternative value for this ratio (0.5 percent) are discussed in Appendix D.

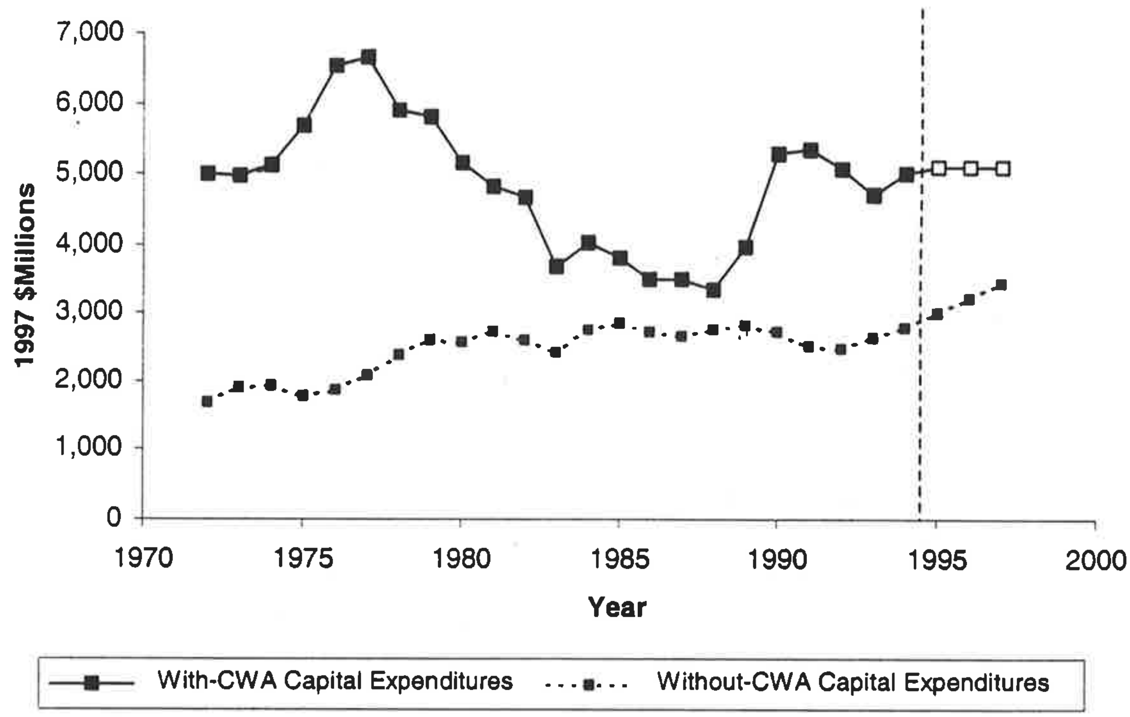


Figure 6-3. Annual Private Capital Expenditures for Water Pollution Abatement Under the With-CWA and Without-CWA Scenarios, 1972–1997 (1997 $millions)

Section 3, capital costs are a function of capital expenditures over the course of several previous years. Section 7 describes the calculation of these costs.

6.2.2 Private O&M Expenditures

To simulate private WPA O&M expenditures, we assumed that these expenditures would be incurred in proportion to the size of the WPA capital stock. Unfortunately, we do not have sufficient information with which to estimate this stock for the period 1972 through 1997. We instead assumed that O&M expenditures would have grown in proportion to the total private capital stock.[6] Using BEA data on total industrial capital expenditures for the period 1952

[6]The previous assumption that WPA capital expenditures would have represented a fixed proportion of total capital expenditures also implies that the WPA and total capital stocks are growing at roughly the same rate. Therefore, we are indirectly assuming that WPA O&M expenditures are increasing in proportion to the WPA capital stock.

through 1997, we estimated the annual growth rate of the gross industrial capital stock for the period 1973 through 1997 (see Appendix A for more details). We then applied the growth rate to WPA O&M expenditures, starting at the earliest (and lowest) observed real value ($2.6 billion in 1972). Figure 6-4 shows that, under these assumptions, without the CWA, O&M expenditures would have grown to $6.4 billion in 1997—$1.6 billion less than what was estimated for 1997 with the CWA.

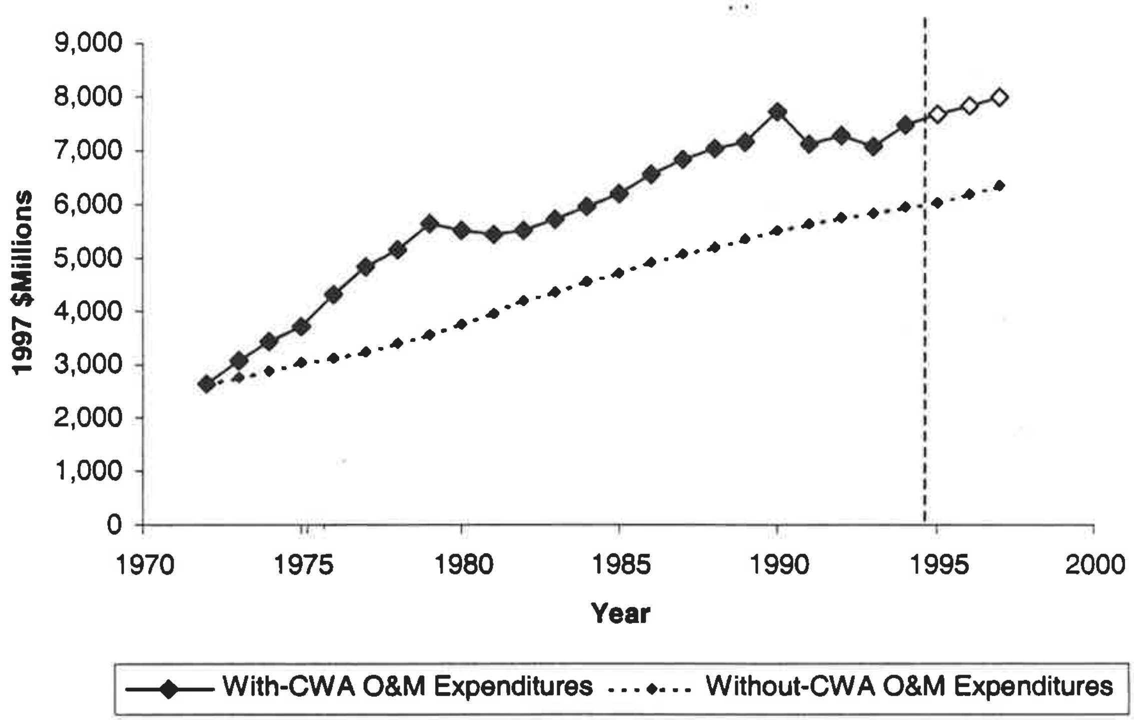


Figure 6-4. Annual Private O&M Expenditures for Water Pollution Abatement Under the With-CWA and Without-CWA Scenarios, 1972–1997 (1997 $millions)

6.3 Publicly Owned Electric Utilities' Costs Without the CWA

Because of data limitations, we relied on much stronger assumptions to characterize without-CWA WPA capital and O&M expenditures for POEUs. In particular, without data on pre-1972 expenditures, there is no reliable means for estimating pre-CWA trends and extending these to project how POEU spending would have grown without the CWA. Therefore, for both capital and O&M expenditures, we assumed that the lowest observed real value for the period 1972 through 1997 is the best approximation for what these expenditures would have been without the CWA. By ensuring that, in every year, WPA expenditures with the CWA are at least as great as they would have been without the Act. This assumption is most likely to underestimate without-CWA expenditures and to therefore somewhat overstate the incremental costs of the Act in this sector. For capital expenditures, this is $11 million per year and for O&M it is $10 million per year. As shown in Figure 6-5, similar to other cost categories, the greatest differences between scenarios occurs in the late 1970s and early 1980s; however, by the mid-1990s, with-CWA capital expenditure are $30 million greater than the estimated without-CWA capital expenditures, and the difference in O&M expenditures is just $2 million per year.

6.4 Public and Private R&D Expenditures for WPA

As shown in Section 5, both public and private R&D expenditures for WPA generally declined in real terms over the period 1972 through 1997. We compared these data to total public and private R&D expenditures for the same period and found a similar trend in the percentage of R&D expenditures devoted to WPA. To characterize without-CWA conditions we were again limited by a lack of pre-1972 data on these expenditures. We therefore made the conservative assumption that the post-1972 year with the lowest observed *percentage* of R&D expenditures going to WPA would best represent this scenario. For public R&D, this was 1990, with only 0.14 percent of R&D going to WPA. For private R&D, it was 1992 with only 0.06 percent. Figure 6-6 shows the difference between the with-CWA and without-CWA estimates. In the mid-1990s, the difference for both public and private R&D expenditures is in the vicinity of $30 million per year.

6.5 Public R&M and Other Expenditures for WPA

To estimate R&M and other expenditures by the public sector for WPA-related activities, we compared these expenditures to total public consumption expenditures over the period 1972 through 1997. Using a similar approach to characterize the without-CWA scenario for this category, we assumed that the year with the lowest observed *percentage* of public consumption expenditures going to R&M and other expenditures for WPA would best represent this scenario.

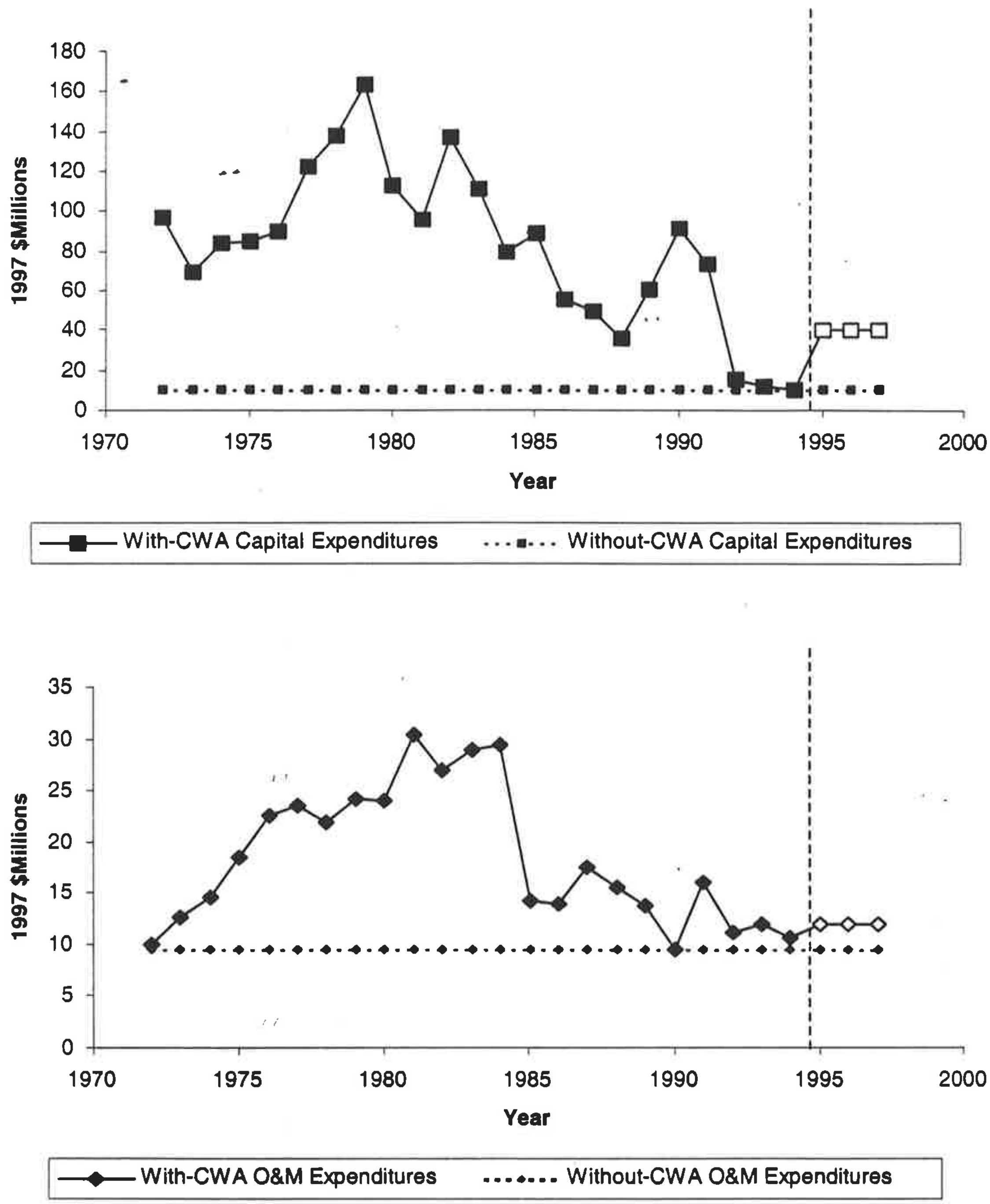


Figure 6-5. Water Pollution Abatement Expenditures by Publicly Owned Electric Utilities, With and Without the CWA, 1972–1997 (1997 $millions)

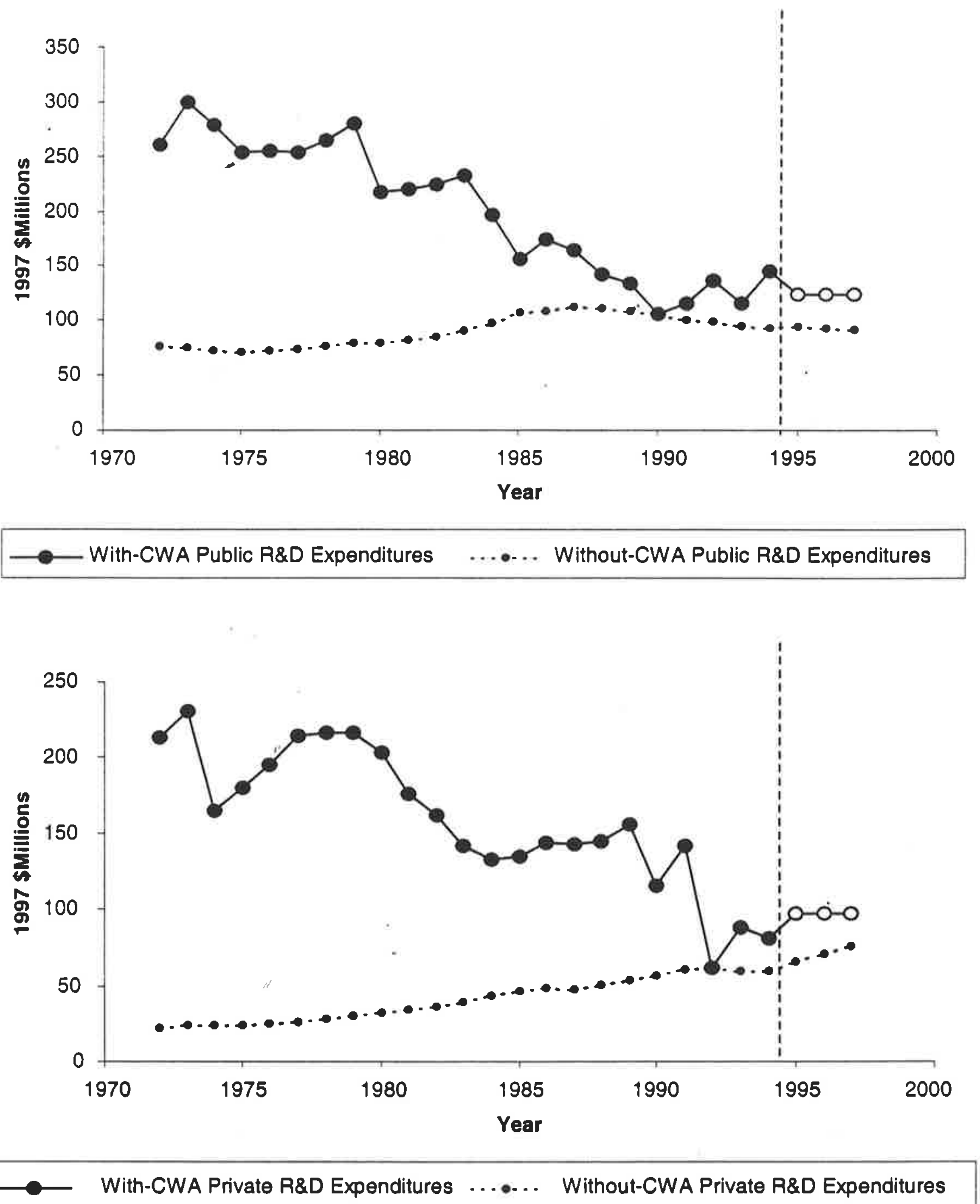


Figure 6-6. R&D Expenditures for Water Pollution Abatement, With and Without the CWA, 1972–1997 (1997 $millions)

In 1982, this percentage was 0.16 percent. Without-CWA expenditures in this category were, therefore, estimated assuming that they would be 0.16 percent of total public consumption expenditures in each year. Figure 6-7 compares the observed (with-CWA) and simulated (without-CWA) trends for this category and shows a difference of roughly $700 million in the mid-1990s.

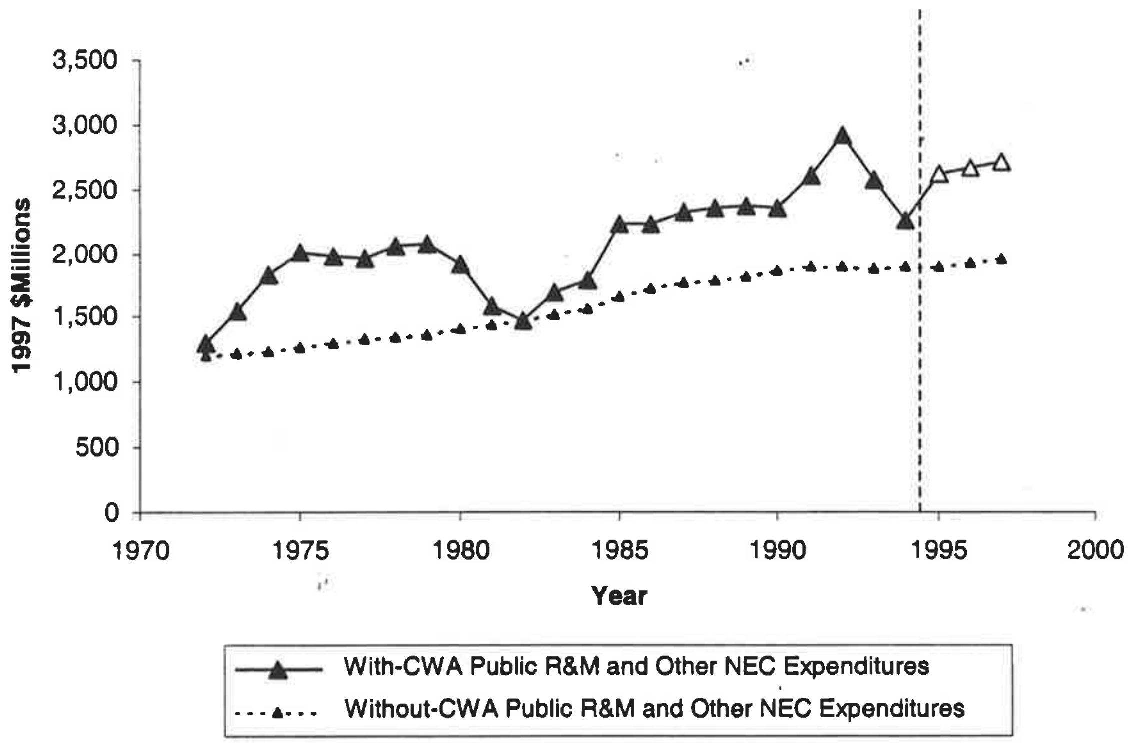


Figure 6-7. Public R&M and Other Expenditures Related to Water Pollution Abatement, With and Without the CWA, 1972–1997 (1997 $millions)

6.6 Summary and Discussion

Each of the previously described approaches for simulating without-CWA conditions has required assumptions about how behavior would have been different if the CWA had not been enacted. The most defensible assumption is that pre-CWA trends and relationships for WPA expenditures would have continued after 1972. For this reason, relatively more confidence can be placed on our without-CWA estimates for sewerage expenditures (and to some extent private capital expenditures), because they are based on extensions of observed historical relationships. These categories also account for a large portion of the estimated difference between the estimated with-CWA and without-CWA expenditures.

A lack of pre-CWA data required stronger assumptions to characterize POEU, R&D, R&M, and other expenditures for WPA under the without-CWA scenario. These were most likely to underestimate without-CWA expenditures and to therefore somewhat overstate the incremental costs of the Act. Even so, as shown in the next section, these categories accounted for less than 8 percent of the estimated difference in WPA costs between the two scenarios.

SECTION 7
THE COSTS OF THE CWA

This section describes our estimation of the annual incremental costs associated with the CWA, based on the previously estimated WPA expenditures for the with-CWA and without-CWA scenarios. To estimate the annual incremental costs, we first converted estimated capital *expenditures* (from the previous sections) into capital *costs* for the two scenarios. For reasons discussed in more detail below, this conversion was necessary because the true annual costs of these expenditures are generally spread over the productive life of the purchased capital. For the other cost categories (e.g., O&M, R&D, R&M), we assumed that no such conversion is necessary and that annual expenditures are an adequate measure of annual costs. Using the newly estimated WPA capital costs for the private sector, we then estimated cost offsets for the without-CWA scenario. To complete the cost assessment, we calculated the differences in estimated costs between the two scenarios for each cost category and for all the categories combined.

7.1 Capital Costs

Expenditures on capital equipment generate benefits and costs that extend over the productive life of the capital. In any given year, the true measure of the cost of installed capital is its *opportunity cost*—the gains that would have occurred in that year if the invested funds had been placed in their highest valued alternative use. This principle applies to both private and public investments (OMB, 1992). For this reason, all capital expenditures must be *annualized*—distributed over their productive life—to get at the true cost of capital.

There are two primary components to this annual cost. First, there is the depreciation cost, which is the fraction of the investment "used up" annually, starting in the year after the investment expense is incurred. In other words, the value of an asset is assumed to depreciate over time because its use results in wear and tear. Second, there is the annual interest cost associated with accumulated capital stock, either because it is financed or because the tied-up funds cannot be invested elsewhere to earn interest income.

A simple way to estimate the annual opportunity cost of installed capital, including both the depreciation and interest components, is to sum expenditures from previous years on capital that is still productive (i.e., calculate the gross capital stock) and annualize these expenditures (i.e., "amortize" the gross capital stock). This can be done using the standard annuity formula:

$$A = K \bullet [r / (1-(1+r)^{-t})] \tag{7.1}$$

where A equals the annualized cost, K is the gross capital stock, r is the discount rate, and t is the useful life of the capital. Using the capital expenditure estimates described in Section 6, we applied this formula to estimate private and public WPA capital costs for both the with-CWA and without-CWA scenarios. The results are described below, and Appendix A provides a more detailed description of how these costs were calculated. Appendix D describes how the cost estimates are affected by altering the assumed values of the useful life of capital (t).

7.1.1 Private WPA Capital Costs

For private WPA capital, we assumed a service life (t) of 20 years, implying that we need at least 20 continuous years of WPA capital expenditure estimates before we can estimate a gross capital stock and its corresponding annual capital cost. Our earliest estimates of private capital expenditures are from 1972; therefore, we are able to generate annual capital costs for 1992 through 1997. These costs are summarized in Table 7-1 under two different discount rate (r) assumptions—3 and 7 percent. Assuming a higher discount rate implies a higher opportunity cost for capital and results in higher capital cost estimates. With a 3 percent discount rate, the estimated WPA capital costs for 1992 through 1997 average $6.5 billion per year with the CWA and $2.6 billion per year without the CWA. With a 7 percent assumed rate, these estimates increase to $9 billion and $3.6 billion, respectively.

7.1.2 Public Sewerage Capital Costs

We used the same approach for public WPA capital costs; however, to account for the general durability of sewerage capital, we assumed a distinctly longer service lifetime of 30 years. Because of the availability of historical (pre-1972) data on public sanitation expenditures, we were also able to estimate a gross sewerage capital stock and corresponding capital costs for the

Table 7-1. **Annual Private Water Pollution Abatement Capital Costs Under the With-CWA and Without-CWA Scenarios, 1992–1997 (1997 $millions)**

	Discount Rate = 3%		Discount Rate = 7%	
Year	With-CWA	Without-CWA	With-CWA	Without-CWA
1992	6,504.0	2,443.4	9,133.8	3,431.4
1993	6,507.1	2,484.0	9,138.1	3,488.4
1994	6,490.3	2,520.9	9,114.5	3,450.1
1995	6,482.9	2,565.4	9,104.2	3,602.7
1996	6,442.3	2,627.4	9,047.1	3,689.7
1997	6,345.0	2,694.6	8,910.5	3,784.2

Table 7-2. **Annual Public Sewerage Capital Costs Under the With-CWA and Without-CWA Scenarios, 1992–1997 (1997 $millions)**

	Discount Rate = 3%		Discount Rate = 7%	
Year	With-CWA	Without-CWA	With-CWA	Without-CWA
1992	12,733.2	10,244.6	20,112.5	16,181.7
1993	13,051.6	10,463.0	20,615.4	16,526.6
1994	13,308.0	10,676.4	21,020.3	16,863.6
1995	13,509.2	10,903.5	21,338.1	17,222.3
1996	13,728.1	11,125.8	21,683.9	17,573.4
1997	13,979.9	11,375.9	22,081.7	17,968.5

1992 through 1997 period. Table 7-2 summarizes these costs for the with-CWA and without-CWA scenarios under the same two discount rate assumptions. Assuming a 3 percent discount rate, the estimated with-CWA capital costs for 1992 through 1997 are in a $12.7 to $14 billion per year range, whereas the without-CWA estimates are in a $10.2 to $11.4 billion per year range. With a 7 percent rate, these ranges increase to $20.1 to $22 billion with the CWA and $16.2 to $18 billion without the Act.

7.1.3 WPA Capital Costs for Publicly Owned Electric Utilities

To estimate capital costs for this sector, we reverted to a 20-year service life assumption for WPA capital and used the annual capital expenditure estimates for 1972 through 1997. Table 7-3 summarizes the capital cost estimates for the two scenarios for 1992 through 1997. For both discount rates, the with-CWA estimates are in a $100 to $200 million per year range, whereas the without-CWA estimates are $20 million or less per year.

Table 7-3. Annual Water Pollution Abatement Capital Costs for Publicly Owned Electric Utilities Under the With-CWA and Without-CWA Scenarios, 1992–1997 (1997 $millions)

	Discount Rate = 3%		Discount Rate = 7%	
Year	With-CWA	Without-CWA	With-CWA	Without-CWA
1992	123.9	14.3	174.0	20.0
1993	118.4	14.3	166.3	20.0
1994	114.6	14.3	160.9	20.0
1995	109.6	14.3	153.9	20.0
1996	106.6	14.3	149.8	20.0
1997	103.3	14.3	145.1	20.0

7.2 Cost Offsets

The final cost category to be estimated for the without-CWA scenario is the magnitude of recovered costs for the private sector due to WPA activities. We assumed that these costs are recovered in rough proportion to the size of the gross WPA capital stock. Based on the with-CWA estimates for 1992 through 1997, the real value of cost offsets in any of these years is equal to 0.3 to 0.4 percent of the estimated real value gross capital stock in that year (shown in Table A-4). To estimate without-CWA offsets, we applied the observed percentage in each year to our estimated without-CWA private WPA capital stock (see Appendix A for detail). Table 7-4 reports the cost offset estimates for the two scenarios for 1992 through 1997. The estimates range from $268 million to $379 million per year with the CWA and from $170 million to $214 million without the CWA.

Table 7-4. Private Cost Offsets With and Without the CWA, 1992–1997 (1997 $millions)

Year	With-CWA	Without-CWA
1992	379	143
1993	305	117
1994	312	121
1995	296	117
1996	282	115
1997	268	114

7.3 Incremental Annual Costs Attributable to the CWA

Using the cost estimates summarized in Section 5, Section 6, and above, the final step is to estimate the difference between WPA costs in the with-CWA scenario and WPA costs in the without-CWA scenario. This difference is interpreted as the (incremental) costs that are attributable to the CWA. Tables 7-5 and 7-6 summarize the results. The cost estimates are reported separately for each year from 1992 through 1997 and are broken down by cost category. Each table uses a different discount rate assumption, which implies different estimates for the capital costs across the three tables.

Assuming a 3 percent discount rate, the estimated incremental annual costs of the CWA range from $11.9 billion in 1992 to $14.1 billion in 1997. From 1992 to 1997 this represents an 18 percent increase, which is roughly the same as the rate of growth in gross domestic product over the same period. When a discount rate of 7 percent is assumed, these values increase to $15.0 billion in 1992 and $17.1 billion in 1997. It must be stressed that these annual values represent best point estimates of incremental costs. The sources and extent of uncertainty associated with these estimates is described in Section 8 and analyzed in more detail in Appendix D.

Figure 7-1 illustrates of how these incremental costs (*not* including cost offsets) are distributed across the cost categories (assuming a 3 percent rate of discount). This distribution is illustrated for 2 years:

Table 7-5. Incremental Annual Costs of the CWA (Assuming a 3 Percent Discount Rate) (1997 $millions)

	1992 Costs			1993 Costs		
	Actual	Without-CWA	Incremental	Actual	Without-CWA	Incremental
Industry						
Capital	6,504.0	2,443.4	4,060.6	6,507.1	2,484.0	4,023.0
O&M	7,276.6	5,763.4	1,513.2	7,079.7	5,859.3	1,220.4
R&D	61.4	61.4	0.0	88.0	60.0	28.1
Offsets	–379.3	–142.5	–236.8	–305.4	–116.6	–188.8
Public						
Sewerage, capital	12,733.2	10,244.6	2,488.6	13,051.6	10,463.0	2,588.6
Sewerage, O&M	13,309.2	10,405.1	2,904.1	14,171.6	10,668.6	3,503.0
Electric, capital	123.9	14.3	109.6	118.4	14.3	104.2
Electric, O&M	11.2	9.5	1.6	12.0	9.5	2.4
R&D	137.2	98.3	38.9	116.3	95.3	21.0
R&D and Other	2,913.1	1,893.7	1,019.4	2,581.5	1,887.2	694.3
Total	42,690.4	30,791.2	**11,899.1**	43,420.7	31,424.6	**11,996.1**
	1994 Costs			**1995 Costs**		
	Actual	**Without-CWA**	**Incremental**	**Actual**	**Without-CWA**	**Incremental**
Industry						
Capital	6,490.3	2,520.9	3,969.4	6,482.9	2,565.4	3,917.5
O&M	7,492.1	5,946.1	1,546.1	7,694.0	6,051.2	1,642.8
R&D	80.7	60.2	20.5	97.6	65.7	31.8
Offsets	–312.1	–121.2	–190.9	–296.5	–117.3	–179.2
Public						
Sewerage, capital	13,308.0	10,676.4	2,631.6	13,509.2	10,903.5	2,605.7
Sewerage, O&M	15,035.5	10,912.8	4,122.8	15,581.6	11,166.5	4,415.2
Electric, capital	114.6	14.3	100.3	109.6	14.3	95.3
Electric, O&M	10.6	9.5	1.1	11.9	9.5	2.3
R&D	144.4	93.7	50.7	124.0	95.3	28.6
R&D and Other	2,259.3	1,891.4	367.9	2,614.6	1,900.7	713.9
Total	44,623.3	32,003.9	**12,619.4**	45,928.8	32,654.7	**13,274.1**
	1996 Costs			**1997 Costs**		
	Actual	**Without-CWA**	**Incremental**	**Actual**	**Without-CWA**	**Incremental**
Industry						
Capital	6,442.3	2,627.4	3,814.9	6,345.0	2,694.6	3,650.4
O&M	7,852.5	6,197.3	1,655.2	8,005.2	6,356.0	1,649.2
R&D	97.6	70.4	27.2	97.6	76.1	21.5
Offsets	–281.6	–114.9	–166.8	–267.5	–113.6	–153.9
Public						
Sewerage, capital	13,728.1	11,125.8	2,602.3	13,979.9	11,375.9	2,604.0
Sewerage, O&M	16,357.2	11,417.0	4,940.2	17,171.4	11,704.8	5,466.6
Electric, capital	106.6	14.3	92.4	103.3	14.3	89.0
Electric, O&M	11.9	9.5	2.3	11.9	9.5	2.3
R&D	124.0	93.1	30.8	124.0	91.5	32.5
R&D and Other	2,661.0	1,926.8	734.3	2,707.5	1,962.0	745.5
Total	47,099.5	33,366.7	**13,732.8**	48,252.6	34,171.0	**14,107.1**

Table 7-6. Incremental Annual Costs of the CWA (Assuming a 7 Percent Discount Rate) (1997 $millions)

	1992 Costs			1993 Costs		
	Actual	**Without-CWA**	**Incremental**	**Actual**	**Without-CWA**	**Incremental**
Industry						
Capital	9,133.8	3,431.4	5,702.4	9,138.1	3,488.4	5,649.6
O&M	7,276.6	5,763.4	1,513.2	7,079.7	5,859.3	1,220.4
R&D	61.4	61.4	0.0	88.0	60.0	28.1
Offsets	–379.3	–142.5	–236.8	–305.4	–116.6	–188.8
Public						
Sewerage, capital	20,112.5	16,181.7	3,930.8	20,615.4	16,526.6	4,088.8
Sewerage, O&M	13,309.2	10,405.1	2,904.1	14,171.6	10,668.6	3,503.0
Electric, capital	174.0	20.0	153.9	166.3	20.0	146.3
Electric, O&M	11.2	9.5	1.6	12.0	9.5	2.4
R&D	137.2	98.3	38.9	116.3	95.3	21.0
R&D and Other	2,913.1	1,893.7	1,019.4	2,581.5	1,887.2	694.3
Total	52,749.5	37,722.0	**15,027.5**	53,663.4	38,498.3	**15,165.1**
	1994 Costs			**1995 Costs**		
	Actual	**Without-CWA**	**Incremental**	**Actual**	**Without-CWA**	**Incremental**
Industry						
Capital	9,114.5	3,540.1	5,574.3	9,104.2	3,602.7	5,501.5
O&M	7,492.1	5,946.1	1,546.1	7,694.0	6,051.2	1,642.8
R&D	80.7	60.2	20.5	97.6	65.7	31.8
Offsets	–312.1	–121.2	–190.9	–296.5	–117.3	–179.2
Public						
Sewerage, capital	21,020.3	16,863.6	4,156.7	21,338.1	17,222.3	4,115.8
Sewerage, O&M	15,035.5	10,912.8	4,122.8	15,581.6	11,166.5	4,415.2
Electric, capital	160.9	20.0	140.8	153.9	20.0	133.9
Electric, O&M	10.6	9.5	1.1	11.9	9.5	2.3
R&D	144.4	93.7	50.7	124.0	95.3	28.6
R&D and Other	2,259.3	1,891.4	367.9	2,614.6	1,900.7	713.9
Total	55,006.2	39,216.2	**15,790.0**	56,423.4	40,016.6	**16,406.7**
	1996 Costs			**1997 Costs**		
	Actual	**Without-CWA**	**Incremental**	**Actual**	**Without-CWA**	**Incremental**
Industry						
Capital	9,047.1	3,689.7	5,357.4	8,910.5	3,784.2	5,126.3
O&M	7,852.5	6,197.3	1,655.2	8,005.2	6,356.0	1,649.2
R&D	97.6	70.4	27.2	97.6	76.1	21.5
Offsets	–281.6	–114.9	–166.8	–267.5	–113.6	–153.9
Public						
Sewerage, capital	21,683.9	17,573.4	4,110.5	22,081.7	17,968.5	4,113.2
Sewerage, O&M	16,357.2	11,417.0	4,940.2	17,171.4	11,704.8	5,466.6
Electric, capital	149.8	20.0	129.7	145.1	20.0	125.1
Electric, O&M	11.9	9.5	2.3	11.9	9.5	2.3
R&D	124.0	93.1	30.8	124.0	91.5	32.5
R&D and Other	2,661.0	1,926.8	734.3	2,707.5	1,962.0	745.5
Total	57,703.3	40,882.5	**16,820.8**	58,946.8	41,859.0	**17,128.2**

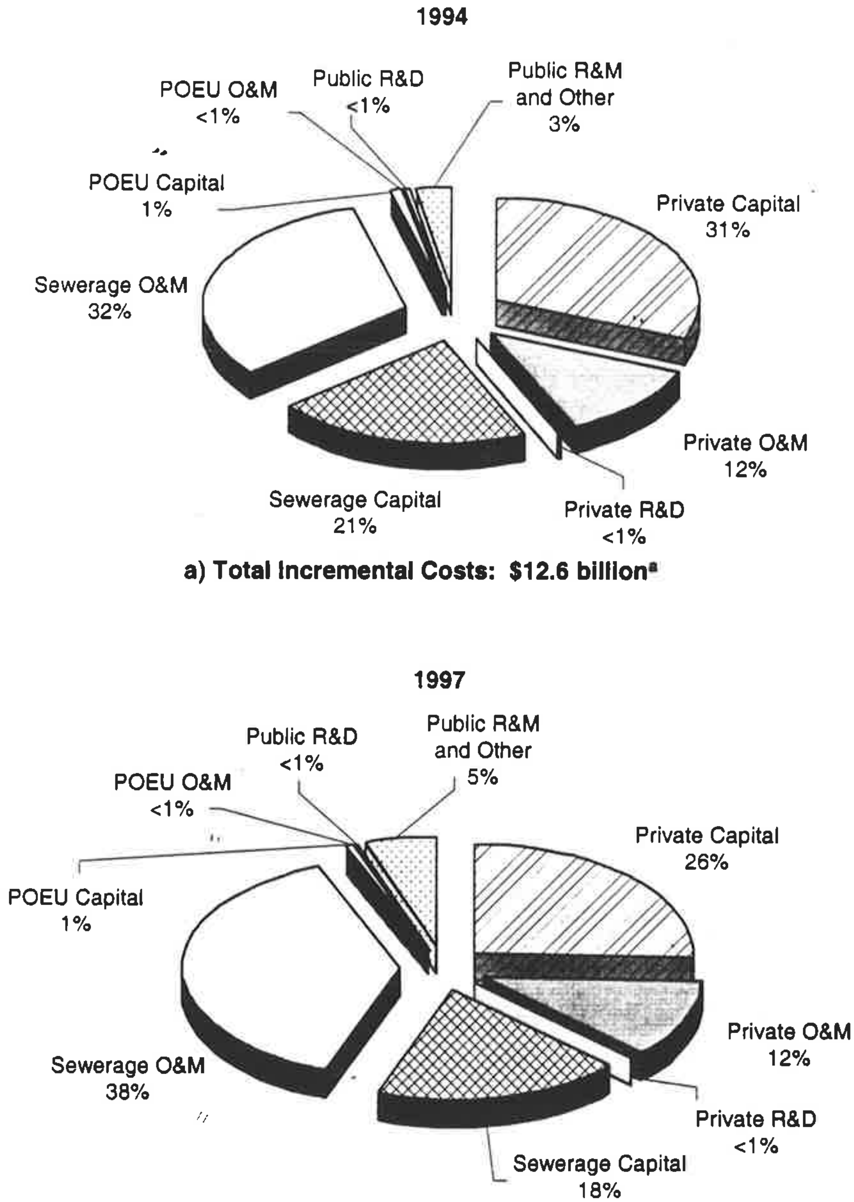


Figure 7-1. The Distribution of the Incremental Annual Costs Attributable to the CWA (3 Percent Discount Rate)

[a]Incremental cost offsets not deducted from the total.

- 1994, which is the last year for which PACE data were available, and
- 1997, which is the last year of our analysis and includes projected estimates for annual WPA expenditures.

In both cases, public sewerage costs, in particular O&M expenditures, account for over half of the estimated annual incremental costs attributed to the CWA. Private WPA capital and O&M costs are the other major categories, accounting for between 38 percent and 43 percent of the total estimated incremental cost.

SECTION 8
DISCUSSION OF RESULTS

The results presented in Section 7 indicate that by the mid-1990s the total costs of water pollution abatement in the United States were generally in excess of $40 billion per year. For the cost categories included in this analysis, which primarily account for point source controls, the combined cost estimates vary from $42.7 billion in 1992 to $48.3 billion in 1997 (assuming a 3 percent discount rate). However, we also estimate that almost three-fourths of these costs would have been incurred without the CWA, such that the costs specifically attributable to the Act are estimated to vary between $11.9 billion in 1992 and $14.1 billion in 1997. Although these incremental costs are not insignificant, they represent less than 0.2 percent of total gross domestic product (GDP) in those years.

To put these estimates into perspective, it is also useful to compare them to estimates of the annual benefits of the CWA. A recent study conducted for EPA (RTI, 2000) has partially estimated these benefits, by focusing specifically on point source controls for conventional pollutants and their effects on roughly 600,000 miles of U.S. rivers and streams. For the modeled dischargers and waterbodies, the study estimates benefits of approximately $11 billion per year in the mid-1990s. However, it is important to stress that these benefit estimates account only for about 50 to 60 percent of the total estimated reductions in conventional pollutant loads due to the CWA (many of which occur in coastal and Great Lakes waters). Furthermore, they do not account for reductions in other pollutants, such as toxics and nutrients. This suggests that the total benefits of CWA controls may be significantly higher than $11 billion and quite possibly larger than the estimated costs of the Act.

Although our analysis has provided specific point estimates of the costs of the CWA, inevitable uncertainties and limitations are associated with these estimates, and we made several simplifying assumptions to make the analysis more tractable. A more quantitative assessment of model sensitivity and uncertainty is provided in Appendix D. Nevertheless, several important caveats to consider when interpreting the results of this cost assessment are enumerated below, according to where they apply in the analysis.

With respect to the expenditure data:

- The direct costs of WPA calculated from expenditure data do not fully capture the economic adjustments and welfare changes (i.e., changes in consumer and producer surplus) associated with water pollution regulations. A general equilibrium analysis along the lines of Jorgenson and Wilcoxen (1990) or Hazilla and Kopp (1990) would be needed to study these welfare implications. Hazilla and Kopp have demonstrated that private compliance cost data can be either over- or underestimates of the true social costs. More recent work using computable general equilibrium (CGE) models (Goulder et al.,1999; Parry,1997) has further pointed out that environmental regulations can exacerbate the economic distortions caused by pre-existing taxes on labor and capital. This "tax-interaction" effect implies that additional social costs not captured in this analysis may be associated with clean water regulations. It must be emphasized, however, that considerable controversy remains regarding the magnitude of such an interaction effect. Hence, it is ultimately unclear how the absence of a general equilibrium analysis in this study affects its estimates of CWA costs.

- The data on public and private R&D expenditures for water pollution abatement do not distinguish between expenditures for point source and nonpoint source control technologies. To the degree that (1) these R&D expenditures have been directed towards nonpoint source controls, and (2) these nonpoint source controls are not motivated by CWA requirements, the R&D expenditure estimates will contribute to an overestimation of CWA costs.

- PACE data are self-reported and industry has an incentive to overreport WPA expenditures. This overreporting may lead to an upward bias in our cost estimates.

- PACE data predominantly account for end-of-pipe controls, and they may misrepresent true economic costs of environmental controls. Although the survey asks respondents to report more subtle costs like process changes, it is unlikely that these costs are accurately reported. On one hand, they may be impossible to assess and, thus, are excluded from survey responses. On the other hand, the entire expense of "cleaner" capital investments, which are part of the production process, may be inappropriately attributed to WPA. Morgenstern et al. (1997) have used a cost function modeling approach to compare expenditure data with economic costs in a number of manufacturing industries, and they found that expenditure data tended to overestimate costs. Despite these results, it is difficult to say conclusively whether expenditure data overestimate or underestimate costs.

With respect to estimation of the without-CWA scenario:

- The relative availability of historical (i.e., pre-1972) data on sewerage expenditures implies that we can most reliably estimate without-CWA expenditures for this category of WPA spending. However, because sewerage expenditures represent such a large portion of total WPA spending, the results of our analysis are particularly sensitive to how these without-CWA expenditures are estimated. The regression results summarized in Eq. (6.1) demonstrate a close statistical relationship between sewerage capital expenditures, housing starts, and population before 1972. This estimated relationship provides a solid basis for simulating without-CWA sewerage expenditures; nevertheless, our CWA cost estimates depend importantly on the assumption that this relationship would have persisted without the CWA. Alternative assumptions regarding these expenditures could significantly alter the results. For example, between 1956 and 1971, public wastewater capital expenditures were on average 0.8 percent of other public infrastructure capital expenditures (see Appendix B for more details). If this relationship had persisted, sewerage capital spending would have grown at a markedly lower rate after 1972. In this case, the incremental costs of the CWA in 1994 would have been roughly $6 billion (50 percent) larger than our current estimates. The results of this alternative approach are less defensible—they are based on less data and a weaker statistical relationship—but they demonstrate the sensitivity of the CWA cost estimates to the assumptions used in estimating the without-CWA sewerage expenditures.

- To estimate private WPA capital expenditures for the without-CWA scenario, we have assumed that these expenditures would have been equal to 0.3 percent of total private capital expenditures in each year after 1971. This is based on rather limited information regarding the relative magnitude of WPA capital spending in the 1960s and on the assumption that the pre-1970s relationship between WPA capital and total capital expenditures would have continued into the 1990s. An alternative but somewhat less defensible characterization of without-CWA private capital expenditures would have been to use the lowest observed ratio of WPA-to-total capital expenditures after 1971 (i.e., 0.5 percent). Using this alternative approach would lower the estimated incremental costs of the CWA in the mid-1990s by about $1.8 billion per year (see Appendix A and Appendix D).

- For categories lacking pre-1972 data on WPA expenditures (all categories except public sewerage costs and private capital costs), characterizing the without-CWA scenario required relatively strong assumptions. In most cases, we assumed that the year with the lowest (in relative or absolute terms) observed annual expenditures after 1972 would best represent without-CWA conditions. This assumption ensures that, in any given year, without-CWA expenditures are never estimated to be less than with-CWA expenditures. This assumption is likely to have exaggerated the effect of the CWA, particularly for categories that have experienced declining expenditures in the 1980s and 1990s (such as R&D expenditures). In these cases, expenditures without the CWA may simply have been spread out over a longer period, resulting in *higher* expenditures in *later* years relative to the with-CWA scenario. Although the assumptions required by this approach tend to overestimate the costs of the CWA, they were generally applied to the smaller cost categories and, therefore, should have had a relatively small impact on the total cost estimate.

- With less pollution abatement expenditures in the without-CWA scenario, there would most likely have been a shift toward consumption of goods produced by "dirtier" processes. Because compliance activities, albeit low, would most likely have expanded to cover the higher production by these polluting sectors, WPA expenditures would have been greater than those estimated for the alternative scenario. This implies an upward bias for the CWA cost estimates.

With respect to the capital cost calculation:

- The standard annualization procedure used to estimate capital costs implicitly assumes that depreciation of capital is lower in absolute, as well as in relative, terms early in its service life. However, alternative profiles may in some cases be more plausible. For example, a depreciation may follow a geometric pattern, in which the proportion lost as capital services are provided remains constant over the service life. This implies that the asset's value drops rapidly early on and tapers off in later years. In some cases an S-shaped depreciation would be most appropriate, in which case the asset depreciates slowly in a relative long initial facility period, then depreciation accelerates and finally levels off towards the end of its useful life. To the extent that the true depreciation of pollution abatement capital follows more of a geometric pattern and that more recent capital expenditures are larger than older investments, the estimated capital costs for both scenarios would be underestimated by the standard annuity formula. The net effect of an S-shaped depreciation is more uncertain and difficult to characterize. In either case, the net effect that these alternative depreciation procedures would have on the *incremental* cost of the CWA is uncertain.

- The estimation of capital costs depends importantly on the assumed productive life of capital. In this study, a 20-year life was assumed for all private and POEU WPA capital. A longer (30-year) life was assumed for sewerage capital to account for its relative durability. In practice, the useful life of capital is likely to vary considerably across sectors and types of WPA capital. The uniform useful life assumption is used to make the analysis tractable, and it provides a plausible mid-range value for WPA capital costs. Using a longer (or shorter) useful life assumption does not necessarily increase or decrease the annual cost estimates. On the one hand, a longer useful life assumption increases the gross capital stock estimate for any given year (K increases in Eq. [7.1] because capital is assumed to accumulate over a longer period), which leads to higher cost estimates. On the other hand, it spreads the cost burden of capital purchases over more years (t increases in Eq. [7.1]), which decreases costs. The net effect of a longer useful life assumption will therefore depend importantly on the long-term trends in capital expenditures (e.g., with long term growth in capital expenditures the second effect will tend to dominate and a longer useful life assumption will tend to decrease annual capital cost estimates). The effects of using specific alternative useful life assumptions on the CWA cost estimates are discussed in Appendix D and are found to be relatively small.

- The estimation of capital costs also depends importantly on the discounting assumptions used. Although it is widely acknowledged that future expenditures should be discounted relative to current expenditures, the choice of an appropriate social discount rate for conducting economic analyses of environmental regulations remains the source of significant controversy.[1] For this reason, we estimated costs using alternative rates between 3 percent and 7 percent. The lower rate approximates a "consumption rate" of interest, which is reflected in historical rates of return on relatively risk-free assets (adjusted for taxes and inflation). The higher rate corresponds to OMB's guidance on discounting (OMB, 1992)—it reflects the real opportunity cost of capital by approximating the average pre-tax rate of return on private investments. As shown in the previous section, the use of a higher discount rate results in higher CWA cost estimates.

With respect to the total cost estimates:

- It is important to emphasize that the total WPA cost estimates for both the with-CWA and without-CWA scenarios (in Tables 7-5 to 7-7) are underestimates in the sense that they do not account for all WPA activities in the United States. In particular, no attempt was made to estimate the annual costs of nonpoint source controls because, until relatively recently, CWA initiatives have primarily focused on point source controls. Therefore, the *net* effect of this omission may be a slight underestimation of the incremental costs of the CWA.

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[1]See, for example, Lind (1990) and EPA (1999b) for thorough reviews of this issue.

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APPENDIX A
BACKGROUND ON DATA, ASSUMPTIONS AND COST ASSESSMENT METHODOLOGY

This appendix provides additional background and details regarding the data, assumptions, and methodology used in the cost assessment. The discussion is divided into the cost categories originally identified in Section 4 and carried over into the analysis described in the subsequent sections.

A.1 Private Capital and O&M Expenditures

Table A-1 summarizes the available data for private WPA expenditures. PACE data, as reported in the *CIRs* and *SCB* reports, are available on an industry-by-industry basis for 1973 through 1994, with the exception of 1987. The *CIR* provides a relatively consistent source of data for the manufacturing sectors; however, data for the nonmanufacturing sectors are less comprehensive and more difficult to reconcile across sources of data. The "PACE Aggregate" column in Table A-1 is calculated by summing the industry-specific expenditure estimates for each year.[1] The "BEA Total" column shows the aggregate private capital expenditure data reported in the *SCB* (Vogan, 1996). These data are also based on PACE but are not reported on an industry-by-industry basis. A comparison of the two aggregate estimates reveals sizable differences in certain years—the BEA estimates are generally larger (almost 40 percent larger in 1982).

Although the *SCB* (BEA Total) source does not disaggregate WPA capital expenditures by industry, it does provide a reasonably consistent single data series, and it includes capital expenditure estimates for 1972 and 1987. For this reason and because the *SCB* is the only readily available source for other categories of WPA expenditures, we used these estimates in our analysis. The major drawback of this approach is that is does not allow us to conduct an industry-by-industry assessment; however, without historical (pre-1972) data on industry WPA

[1]For 1988 through 1994 this excludes the petroleum and coal estimate from the manufacturing sector to avoid apparent double counting with the petroleum and coal estimate from the nonmanufacturing sector.

Table A-1. Private Capital Expenditures for Water Pollution Abatement: 1972-1994 (current $millions)

	Manufacturing									
Year	Primary Metals	Transportation Equipment	Machinery	Other Durables	Chemical	Paper	Petroleum and Coal	Food	Other Non-Durables	All Manufacturing*
1972	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1973	84.7[a]	41.7[a]	15.6[a]	81.4[a]	214.6[a]	161.0[a]	96.1[a]	104.8[a]	28.0[a]	827.8[a]
1974	132.7[a]	41.5[a]	17.6[a]	91.2[a]	264.4[a]	193.2[a]	119.7[a]	111.7[a]	36.7[a]	1,008.8[a]
1975	187.5[a]	36.4[a]	20.8[a]	99.0[a]	385.7[a]	266.0[a]	155.7[a]	93.9[a]	34.9[a]	1,280.1[a]
1976	197.8[a]	53.6[a]	21.8[a]	109.3[a]	577.4[a]	278.6[a]	199.8[a]	97.6[a]	54.5[a]	1,599.2[a]
1977	250.7[a]	39.4[a]	42.4[a]	150.5[a]	603.8[a]	261.9[a]	196.0[a]	109.3[a]	41.1[a]	1,695.1[a]
1978	219.5[a]	57.9[a]	27.8[a]	129.6[a]	392.9[a]	189.2[a]	100.7[a]	99.6[a]	24.5[a]	1,262.9[a]
1979	227.7[a]	59.5[a]	38.2[a]	117.0[a]	367.2[a]	180.8[a]	119.6[a]	117.6[a]	26.4[a]	1,262.2[a]
1980	180.7[b]	60.7[b]	34.9[b]	113.7[b]	350.0[b]	111.2[b]	114.2[b]	133.0[b]	32.2[b]	1,146.5[b]
1981	144.1[b]	60.0[b]	28.0[b]	125.4[b]	322.2[b]	86.5[b]	131.7[b]	104.8[b]	24.0[b]	1,028.4[b]
1982	133.7[b]	36.5[b]	42.2[b]	122.6[b]	256.5[b]	93.7[b]	165.7[b]	110.9[b]	15.3[b]	977.4[b]
1983	100.2[b]	55.0[b]	19.0[b]	105.2[b]	187.4[b]	65.9[b]	164.7[b]	105.1[b]	13.3[b]	819.0[b]
1984	72.9[b]	116.9[b]	22.6[b]	185.7[b]	212.4[b]	68.2[b]	96.8[b]	91.8[b]	16.5[b]	887.8[b]
1985	84.3[c]	165.1[c]	35.1[c]	159.6[c]	271.5[c]	106.0[c]	88.4[c]	77.4[c]	19.4[c]	1,017.9[c]
1986	74.6[c]	81.8[c]	25.7[c]	173.0[c]	325.5[c]	96.9[c]	121.5[c]	108.2[c]	25.6[c]	1,038.7[c]
1987	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1988	100.6[c]	80.4[c]	33.2[c]	169.5[c]	487.8[c]	97.2[c]	203.7[c]	91.0[c]	25.8[c]	1,289.4[c]
1989	138.7[c]	84.6[c]	54.8[c]	233.6[c]	598.6[c]	261.0[c]	230.4[c]	183.6[c]	39.2[c]	1,824.5[c]
1990	166.8[d]	142.6[d]	41.3[d]	184.5[d]	995.0[d]	509.6[d]	400.8[d]	163.3[d]	47.5[d]	2,651.4[d]
1991	131.9[d]	94.7[d]	27.6[d]	276.0[d]	942.3[d]	552.7[d]	373.3[d]	359.5[d]	56.5[d]	2,814.6[d]
1992	123.5[d]	69.2[d]	31.7[d]	146.7[d]	1017.3[d]	373.4[d]	492.6[d]	202.6[d]	48.1[d]	2,509.8[d]
1993	92.0[d]	67.1[d]	20.2[d]	157.4[d]	937.9[d]	289.2[d]	567.2[d]	113.6[d]	46.8[d]	2,294.9[d]
1994	98.5[d]	60.8[d]	152.1[d]	239.6[d]	1005.6[d]	195.9[d]	466.9[d]	152.8[d]	56.7[d]	2,428.9[d]

(continued)

Table A-1. Private Capital Expenditures for Water Pollution Abatement: 1972-1994 (current $millions) (continued)

	Nonmanufacturing					
Year	Mining	Electric	Petroleum and Coal	All Non-manufacturing	PACE Aggregate[j]	BEA Total
1972	NA	NA	NA	NA	NA	1,501
1973	70[e]	410[e]		620[e]	1,447.8	1,570[g]
1974	60[e]	430[e]		630[e]	1,638.8	1,765[g]
1975	60[e]	400[e]		650[e]	1,930.1	2,145[g]
1976	100[e]	540[e]		850[e]	2,449.2	2,607[g]
1977	100[e]	650[e]		920[e]	2,615.1	2,827[g]
1978	230[e]	900[e]		1,310[e]	2,572.9	2,683[g]
1979	180[e]	1,010[e]		1,350[e]	2,612.2	2,873[g]
1980	110[e]	890[e]		1,140[e]	2,286.5	2,795[g]
1981	90[e]	810[e]		1,030[e]	2,058.4	2,848[g]
1982	110[e]	900[e]		1,170[e]	2,147.4	2,937[g]
1983	100[e]	750[e]		980[e]	1,799.0	2,422[g]
1984	180[e]	900[e]		1,230[e]	2,117.8	2,730[g]
1985	120[f]	870[f]		1,150[f]	2,167.9	2,670[g]
1986	130[f]	650[f]		930[f]	1,968.7	2,534[g]
1987	56[h]	599[h]	1,186.3[h]		NA	2,614[g]
1988	84[h]	526[h]	998.9[h]		2,694.6	2,581[g]
1989	113[h]	482[h]	1,174.5[h]		3,363.4	3,196[g]
1990	138[i]	673[i]	1,643.6[i]		4,705.4	4,430[g]
1991	120[i]	573[i]	1,503.3[i]		4,637.2	4,666[g]
1992	145[i]	567[i]	1,380.5[i]		4,109.4	4,532[g]
1993	161[i]	621[i]	1,115.1[i]		3,624.4	4,335[g]
1994	191[i]	606[i]	1,113.6[i]		3,872.0	4,720[g]

(continued)

Table A-1. Private Capital Expenditures for Water Pollution Abatement: 1972-1994 (current $millions) (continued)

NA = Not available.

* The manufacturing category is compiled separately by the PACE reports; it does not always equal the sum of the individual columns. It does not include SIC code group 23, Apparel and Other Textile Products.

[a] U.S. Department of Commerce. 1981. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1979." Table 1A. Pollution Abatement Capital Expenditures and Operating Costs, by Form of Abatement and Major Industry Group: 1973 to 1979. Washington, DC: Government Printing Office.

[b] U.S. Department of Commerce. 1986. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1984." Table 1. Pollution Abatement Capital Expenditures and Operating Costs, by Form of Abatement by Major Group: 1980 to 1984. Washington, DC: Government Printing Office.

[c] U.S. Department of Commerce. 1991. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1989." Table 1. Pollution Abatement Capital Expenditures and Operating Costs, by Form of Abatement for Major Groups: 1985 to 1989. Washington, DC: Government Printing Office.

[d] U.S. Department of Commerce. 1996. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1994." Table 1. Summary Capital Expenditures and Operating Costs, by Major Groups: 1990 to 1994. Washington, DC: Government Printing Office.

[e] Environmental Economics Division. February 1986. *Survey of Current Business*. "Plant and Equipment Expenditures by Business for Pollution Abatement." Table 1. New Plant and Equipment Expenditures by U.S. Nonfarm Business: Total and for Pollution Abatement.

[f] Rutledge, Gary L. and Nikolaos A. Stergioulas. November 1988. *Survey of Current Business*. "Plant and Equipment Expenditures by Business for Pollution Abatement, 1987 and 1988." Table 1. New Plant and Equipment Expenditures by U.S. Nonfarm Business: Total and for Pollution Abatement.

[g] Vogan, Christine R. September 1996. *Survey of Current Business*. "Pollution Abatement and Control Expenditures, 1972-94." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972-94.

[h] U.S. Department of Commerce. 1992. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1990." Table A. New Capital Expenditures for Companies in Mining, Petroleum, and Electric Utilities: Total and for Pollution Abatement 1987 to 1990. Washington, DC: Government Printing Office.

[i] U.S. Department of Commerce. 1996. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1994." Table 14. Summary New Capital Expenditures by Companies in Mining, Petroleum, and Electric Utilities for all Media: 1990 to 1994. Washington, DC: Government Printing Office.

[j] Calculated based on all available data from *Current Industrial Reports* for manufacturing and nonmanufacturing categories. For years 1973 through 1986, data for nonmanufacturing sector are from the BEA source (Vogan, 1996). For 1988 through 1994, total includes PACE nonmanufacturing data for the mining, electric utilities, and petroleum and coal sectors and PACE manufacturing data (minus the petroleum and coal sectors to avoid double counting).

expenditures, it is not clear that a disaggregated approach would have provided much greater insight.

Table A-2 reports real private capital and O&M WPA expenditures for 1972 through 1997. The estimates for 1972 through 1994 are based on data reported in the *SCB* (Vogan, 1996) and converted to 1997 dollars using the price index series reported in Appendix C. All price adjustments for this report were calculated using this chain-type price index. The estimates for 1995 through 1997 were extrapolated from the 1972 through 1994 series, as described in the footnotes to Table A-2.

Table A-3 summarizes the data used to estimate the without-CWA private WPA capital expenditures and reports the results of the simulation. Data on total industrial capital expenditures were acquired from BEA for 1972 through 1997 and, using the same capital expenditure data reported in Table A-2, these estimates were used to calculate the fraction of total industrial investment that was used for WPA capital purchases in each year. As shown in the third column, the lowest observed fraction was 0.49 percent in 1988. The last two columns calculate 0.3 percent and 0.5 percent, respectively, of total industrial capital expenditures in each year to simulate WPA capital expenditures for the without-CWA scenario.

Table A-4 describes the conversion from WPA capital *expenditures* to WPA capital *costs* for the private sector for both the with-CWA and without-CWA scenarios. The with-CWA expenditures are taken from Table A-3. In accordance with the analysis described in Section 6, the without-CWA estimates assume that capital expenditures would have been 0.3 percent of total capital expenditures after 1971. Assuming a 20-year productive life of private capital, the expenditures are converted to gross WPA capital estimates for 1992 through 1997 for both scenarios. The gross capital stock estimates are then annualized (in this case, using a 3 percent discount rate), and the resulting capital cost estimates for the two scenarios are reported in the fourth and seventh columns.

Tables A-5 and A-6 indicate the data and calculations used to estimate private WPA O&M expenditures for the without-CWA scenario. The primary assumption is that, without the CWA, WPA O&M expenditures would have grown at the same rate as the total industrial capital

Table A-2. Real Private Water Pollution Abatement Expenditures, 1972–1997 (1997 $millions)

Year	Capital Expenditures[a]	Operation and Maintenance Expenditures[b]
1972	5,011.0	2,634.0
1973	4,962.2	3,072.1
1974	5,120.2	3,446.3
1975	5,685.9	3,734.9
1976	6,528.9	4,322.6
1977	6,651.4	4,856.2
1978	5,883.3	5,168.4
1979	5,804.8	5,633.1
1980	5,168.0	5,519.3
1981	4,813.7	5,425.5
1982	4,669.2	5,510.1
1983	3,693.6	5,723.4
1984	4,011.9	5,954.7
1985	3,793.4	6,180.2
1986	3,508.5	6,564.3
1987	3,511.2	6,834.4
1988	3,344.5	7,032.4
1989	3,974.3	7,171.5
1990	5,278.2	7,735.1
1991	5,349.2	7,134.2
1992	5,056.4	7,276.6
1993	4,712.2	7,079.7
1994	5,011.0	7,492.1
1995	*5,081.4*	*7,570.2*
1996	*5,081.4*	*7,649.0*
1997	*5,081.4*	*7,728.6*

[a] Values for 1995 through 1997 are assumed to be equal to the average observed value for 1990 through 1994.
[b] Values for 1995 through 1997 are projected based on the observed trend from 1972 through 1994.

Source: Vogan, Christine R. September 1996. *Survey of Current Business.* "Pollution Abatement and Control Expenditures, 1972-94." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972-94.

Table A-3. Water Pollution Abatement Expenditures Under the With- and Without- CWA Scenarios, 1972–1997

Year	Total Industrial Capital Expenditures[a] (1997 $millions)	With-CWA WPA Capital Expenditures[b]		Without-CWA WPA Capital Expenditures[b] (1997 $millions)	
		1997 $millions	Percent of Total Capital Expenditures	0.3% of Total Capital Expenditures	0.5% of Total Capital Expenditures
1972	420,974	5,011.0	1.19%	*1,262.9*	*2,104.9*
1973	474,093	4,962.2	1.05%	*1,422.3*	*2,370.5*
1974	480,395	5,120.2	1.07%	*1,441.2*	*2,402.0*
1975	447,976	5,685.9	1.27%	*1,343.9*	*2,239.9*
1976	468,819	6,528.9	1.39%	*1,406.5*	*2,344.1*
1977	525,146	6,651.4	1.27%	*1,575.4*	*2,625.7*
1978	596,443	5,883.3	0.99%	*1,789.3*	*2,982.2*
1979	652,609	5,804.8	0.89%	*1,957.8*	*3,263.0*
1980	647,712	5,168.0	0.80%	*1,943.1*	*3,238.6*
1981	685,206	4,813.7	0.70%	*2,055.6*	*3,426.0*
1982	651,646	4,669.2	0.72%	*1,954.9*	*3,258.2*
1983	609,090	3,693.6	0.61%	*1,827.3*	*3,045.5*
1984	688,201	4,011.9	0.58%	*2,064.6*	*3,441.0*
1985	713,206	3,793.4	0.53%	*2,139.6*	*3,566.0*
1986	685,093	3,508.5	0.51%	*2,055.3*	*3,425.5*
1987	665,444	3,511.2	0.53%	*1,996.3*	*3,327.2*
1988	687,561	3,344.5	0.49%	*2,062.7*	*3,437.8*
1989	704,089	3,974.3	0.56%	*2,112.3*	*3,520.4*
1990	686,172	5,278.2	0.77%	*2,058.5*	*3,430.9*
1991	627,437	5,349.2	0.85%	*1,882.3*	*3,137.2*
1992	622,449	5,056.4	0.81%	*1,867.3*	*3,112.2*
1993	656,658	4,712.2	0.72%	*1,970.0*	*3,283.3*
1994	701,333	5,011.0	0.71%	*2,104.0*	*3,506.7*
1995	755,180	4,707.9	0.62%	*2,265.5*	*3,775.9*
1996	802,501	4,620.7	0.58%	*2,407.5*	*4,012.5*
1997	860,700	4,536.6	0.53%	*2,582.1*	*4,303.5*

[a] As estimated by private gross nonresidential fixed investment in NIPA (CEA, 2000).

[b] Vogan, Christine R. September 1996. *Survey of Current Business.* "Pollution Abatement and Control Expenditures, 1972-94." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972-94. 1995 through 1997 are average of 1990 through 1994.

Table A-4. Annualized Private Water Pollution Abatement Capital Costs Under the With-CWA and Without-CWA Scenarios, 1972–1997 (1997 $millions)

	With-CWA			Without-CWA		
Year	WPA Capital Expenditures[a]	Estimated Gross WPA Capital Stock	Annualized WPA Capital Cost	WPA Capital Expenditures[b]	Estimated Gross WPA Capital Stock	Annualized WPA Capital Cost
1972	5,011.0			1,262.9		
1973	4,962.2			1,422.3		
1974	5,120.2			1,441.2		
1975	5,685.9			1,343.9		
1976	6,528.9			1,406.5		
1977	6,651.4			1,575.4		
1978	5,883.3			1,789.3		
1979	5,804.8			1,957.8		
1980	5,168.0			1,943.1		
1981	4,813.7			2,055.6		
1982	4,669.2			1,954.9		
1983	3,693.6			1,827.3		
1984	4,011.9			2,064.6		
1985	3,793.4			2,139.6		
1986	3,508.5			2,055.3		
1987	3,511.2			1,996.3		
1988	3,344.5			2,062.7		
1989	3,974.3			2,112.3		
1990	5,278.2			2,058.5		
1991	5,349.2			1,882.3		
1992	5,056.4	96,763.4	6,504.0	1,867.3	36,352.0	2,443.4
1993	4,712.2	96,808.7	6,507.1	1,970.0	36,956.4	2,484.0
1994	5,011.0	96,558.7	6,490.3	2,104.0	37,504.1	2,520.9
1995	5,081.4	96,449.6	6,482.9	2,265.5	38,166.9	2,565.4
1996	5,081.4	95,845.2	6,442.3	2,407.5	39,088.5	2,627.4
1997	5,081.4	94,397.7	6,345.0	2,582.1	40,089.6	2,694.6

Capital Life: 20 years Discount Rate: 3 percent

[a] 1995 through 1997 expenditures are average of 1990 through 1994 expenditures.

[b] Without-CWA based on 0.3% of total private capital.

Sources: Vogan, Christine R. September 1996. *Survey of Current Business.* "Pollution Abatement and Control Expenditures, 1972-94." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972-94.

U.S. Bureau of Economic Analysis. Summary National Income and Product Time Series, 1929-1997. [Computer file].

Table A-5. Approximated Total Gross Private Capital Stock, 1972–1997 (1997 $millions)

Year	Total Industrial Capital Expenditures[a]	Approximated Gross Industrial Capital Stock[b]	Annual Growth Rate
1952	178,669		
1953	194,059		
1954	189,685		
1955	210,103		
1956	231,570		
1957	238,935		
1958	208,703		
1959	226,057		
1960	235,894		
1961	230,344		
1962	247,101		
1963	257,185		
1964	284,394		
1965	331,356		
1966	366,972		
1967	358,979		
1968	371,765		
1969	396,702		
1970	390,568		
1971	388,841		
1972	420,975	*1,247,400*	
1973	474,093	*1,341,600*	*7.6%*
1974	480,395	*1,456,500*	*8.6%*
1975	447,976	*1,587,400*	*9.0%*
1976	468,819	*1,717,400*	*8.2%*
1977	525,146	*1,860,100*	*8.3%*
1978	596,443	*2,035,800*	*9.4%*
1979	652,610	*2,265,300*	*11.3%*
1980	647,712	*2,541,800*	*12.2%*
1981	685,206	*2,842,900*	*11.8%*
1982	651,646	*3,199,700*	*12.6%*
1983	609,090	*3,556,800*	*11.2%*
1984	688,201	*3,900,600*	*9.7%*
1985	713,207	*4,306,500*	*10.4%*
1986	685,094	*4,734,400*	*9.9%*
1987	665,444	*5,144,800*	*8.7%*
1988	687,561	*5,555,000*	*8.0%*
1989	704,090	*5,993,500*	*7.9%*
1990	686,172	*6,456,800*	*7.7%*
1991	627,438	*6,926,000*	*7.3%*
1992	622,449	*7,361,600*	*6.3%*
1993	656,659	*7,793,400*	*5.9%*
1994	701,334	*8,247,500*	*5.8%*
1995	755,181	*8,742,500*	*6.0%*
1996	802,501	*9,301,200*	*6.4%*
1997	860,700	*9,901,900*	*6.5%*

[a] U.S. Bureau of Economic Analysis. Summary National Income and Product Time Series, 1929-1997. [Computer file].
[b] Assumes 20-year capital life.

Table A-6. Private O&M Expenditures for Water Pollution Abatement Under With-CWA and Without-CWA Scenarios, 1972–1997 (1997 $millions)

Year	With-CWA O&M Expenditures[a,b]	Without-CWA O&M Expenditures
1972	2,634.0	*2,634.0*
1973	3,072.1	*2,749.3*
1974	3,446.3	*2,882.5*
1975	3,734.9	*3,020.7*
1976	4,322.6	*3,133.9*
1977	4,856.2	*3,246.7*
1978	5,168.4	*3,382.8*
1979	5,633.1	*3,567.3*
1980	5,519.3	*3,770.2*
1981	5,425.5	*3,966.0*
1982	5,510.1	*4,182.4*
1983	5,723.4	*4,374.8*
1984	5,954.7	*4,542.2*
1985	6,180.2	*4,734.2*
1986	6,564.3	*4,915.9*
1987	6,834.4	*5,067.2*
1988	7,032.4	*5,212.9*
1989	7,171.5	*5,363.1*
1990	7,735.1	*5,509.3*
1991	7,134.2	*5,649.9*
1992	7,276.6	*5,763.4*
1993	7,079.7	*5,859.3*
1994	7,492.1	*5,946.1*
1995	*7,694.0*	*6,051.2*
1996	*7,852.5*	*6,197.3*
1997	*8,005.2*	*6,356.0*

[a] Vogan, Christine R. September 1996. *Survey of Current Business.* "Pollution Abatement and Control Expenditures, 1972-94." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972-94. 1995 through 1997 estimated with regression on time.

[b] 1995 through 1997 are projected based on the trend from 1972 through 1994.

stock—the indirect assumption is that they would have both been growing at the same rate as the without-CWA WPA capital stock. Data on total industrial capital expenditures from 1952 through 1997 were acquired from BEA and used to estimate the total gross industrial capital stock for 1972 through 1997, assuming a 20-year productive life for private capital. These estimates are reported in Table A-5, as are the annual growth rate estimates for this stock for the period 1973 through 1997. Private WPA O&M expenditures for the without-CWA scenario (1973 through 1997) were estimated by applying these same growth rates to the observed WPA O&M expenditures in 1972. The results are reported in the last column of Table A-6.

A.2 Public Sewerage Capital and O&M Expenditures

Data on public sewerage expenditures were gathered from various sources; however, the primary source was the Census Bureau's *Government Finances* series, which provides both annual sewerage O&M and capital expenditures information for fiscal years (FY) 1958 through 1996. For FY1957, the Census Bureau's *Compendium of Government Finance* series also provides an estimate of total sewerage expenditures (not disaggregated between capital and O&M). In addition, for selected years between 1902 and 1970 (annually from 1952 through 1970), the *Historical Statistics of the United States, Colonial Times to 1970* (BOC, 1975) provides data on total sanitation expenditures, which includes both sewerage and solid waste expenditures. These data are reported in Table A-7.

The data reported in Table A-7 were used to estimate both sewerage capital and O&M expenditures for the period in which data are only available on a more aggregate level (i.e., 1902 through 1958). As a result, there is considerably less certainty associated with the expenditure estimates from these years.[2] As shown in Table A-8, data for 1957 through 1970 show that total sewerage expenditures as a portion of total sanitation expenditures varied between 53 percent and 71 percent, with an average of 62 percent. Therefore, to estimate annual sewerage expenditures for 1902 through 1956, it was assumed that they represented 62 percent of total annual sanitation expenditures during those years. Using these estimates, Table A-8 also shows

[2]Furthermore, based on available information, it is unclear to what extent sewerage pipe construction expenditures are included in these aggregate data.

Table A-7. Public Sewerage and Other Sanitation Expenditures, 1902–1996 Fiscal Years (current $millions)

Fiscal Year	Sewerage			Total Sanitation
	Capital	O&M	Total	
1902				51[e]
1913				97[e]
1922				189[e]
1927				312[e]
1932				223[e]
1934				177[e]
1936				204[e]
1938				226[e]
1940				207[e]
1942				229[e]
1944				245[e]
1946				370[e]
1948				670[e]
1950				834[e]
1952				992[e]
1953				908[e]
1954				1,058[e]
1955				1,142[e]
1956				1,326[e]
1957			906[d]	1,443[e]
1958	649[a]	254[a]	903[a]	1,505[e]
1959	708[a]	273[a]	981[a]	1,609[e]
1960	767[a]	266[a]	1,033[a]	1,727[e]
1961	726[a]	304[a]	1,030[a]	1,774[e]
1962	886[a]	344[a]	1,230[a]	1,958[e]
1963	1,019[a]	204[a]	1,223[a]	1,996[e]
1964	1,095[a]	408[a]	1,503[a]	2,267[e]
1965	1,107[a]	605[a]	1,712[a]	2,360[e]
1966	1,202[a]	614[a]	1,816[a]	2,571[e]
1967	1,069[a]	555[a]	1,624[a]	2,523[e]
1968	1,107[a]	524[a]	1,631[a]	2,707[e]
1969	1,207[a]	510[a]	1,717[a]	2,969[e]
1970	1,385[a]	423[a]	1,808[a]	3,413[e]
1971	1,744[a]	781[a]	2,525[a]	
1972	2,202[a]	962[a]	3,164[a]	

(continued)

Table A-7. Public Sewerage and Other Sanitation Expenditures, 1902–1996 Fiscal Years (current $millions) (continued)

Fiscal Year	Sewerage			Total Sanitation
	Capital	O&M	Total	
1973	2,428[a]	1,176[a]	3,604[a]	
1974	2,640[a]	1,440[a]	4,080[a]	
1975	3,569[b]	1,693[b]	5,262[b]	
1976	3,955[b]	1,982[b]	5,937[b]	
1977	4,208[b]	2,329[b]	6,537[b]	
1978	4,365[b]	2,777[b]	7,142[b]	
1979	5,619[b]	3,176[b]	8,795[b]	
1980	6,271[b]	3,621[b]	9,892[b]	
1981	6,912[b]	4,209[b]	11,121[b]	
1982	5,895[b]	4,902[b]	10,797[b]	
1983	5,806[b]	5,433[b]	11,239[b]	
1984	5,663[b]	5,853[b]	11,516[b]	
1985	5,925[b]	6,260[b]	12,185[b]	
1986	6,461[b]	6,847[b]	13,308[b]	
1987	7,306[b]	7,555[b]	14,861[b]	
1988	8,300[c]	8,029[c]	16,329[c]	
1989	8,343[c]	8,696[c]	17,039[c]	
1990	8,356[c]	9,953[c]	18,309[c]	
1991	9,104[b]	10,571[b]	19,675[b]	
1992	8,926[c]	11,418[c]	20,344[c]	
1993	10,252[c]	12,440[c]	22,692[c]	
1994	7,989[c]	13,635c	21,624[c]	
1995	8,894[c]	14,690[c]	23,583[c]	
1996	9,326[c]	15,339[c]	24,665[c]	

[a] U.S. Bureau of the Census. *Government Finance.* Annual, as reported by Clark, Edwin. Council on Environmental Quality. "Estimating Baseline Pollution Abatement Expenditures." Table 7- Expenditures for Municipal Wastewater Treatment Facilities 1958-1974.

[b] U.S. Bureau of the Census. *Government Finances.*

[c] U.S. Bureau of the Census. State and Local Government Finance Estimates, by State. <http://www.census.gov/govs/www/estimate.html> Last revised April 26, 1999.

[d] Government Finance Data (BOC, Census of Governments, Compendium of Government Finance, Fiscal Years 1957, 1962, 1967. Table 8. Direct General Expenditure by Function, by Type of Government.)

[e] U.S. Department of Commerce, Bureau of the Census. 1975. *Historical Statistics of the United States, Colonial Times to 1970.* Series Y 533-566. Federal, State, and Local Government Expenditure, By Function: 1902 to 1970. Washington, DC: Government Printing Office.

Table A-8. Estimated Public Sewerage Expenditures Before the CWA: FY1902–FY1971

Fiscal Year	Total Sanitation (TS)[a] (current $million)	Total Sewerage (S)[b] (Current $million)	Total Sewerage (S)[b] (As Percentage of TS)	Sewerage Capital[c] (Current $million)	Sewerage Capital[c] (As Percentage of S)	Sewerage O&M[c] (Current $million)
1902	51			23		9
1913	97			43		17
1922	189			84		34
1927	312			138		56
1932	223			99		40
1934	177			78		32
1936	204			90		36
1938	226			100		40
1940	207			92		37
1942	229			101		41
1944	245			109		44
1946	370			164		66
1948	670			297		120
1950	834			370		149
1952	992			440		177
1953	908			402		162
1954	1,058			469		189
1955	1,142			506		204
1956	1,326			588		237
1957	1,443	906	63%	646	71%	260
1958	1,505	903	60%	649	72%	254
1959	1,609	981	61%	708	72%	273
1960	1,727	1,033	60%	767	74%	266
1961	1,774	1,030	58%	726	70%	304
1962	1,958.	1,230	63%	886	72%	344
1963	1,996	1,223	61%	1,019	83%	204
1964	2,267	1,503	66%	1,095	73%	408
1965	2,360	1,712	73%	1,107	65%	605
1966	2,571	1,816	71%	1,202	66%	614
1967	2,523	1,624	64%	1,069	66%	555
1968	2,707	1,631	60%	1,107	68%	524
1969	2,969	1,717	58%	1,207	70%	510
1970	3,413	1,808	53%	1,385	77%	423
1971		2,525		1,744	69%	781

[a] U.S. Department of Commerce, Bureau of the Census. 1975. *Historical Statistics of the United States, Colonial Times to 1970.* Series Y 533-566. Federal, State, and Local Government Expenditure, By Function: 1902 to 1970. Washington, DC: Government Printing Office.

[b] Government Finance Data (BOC, Census of Governments, Compendium of Government Finance, Fiscal Years 1957, 1962, 1967. Table 8. Direct General Expenditure by Function, by Type of Government.)

[c] Estimated for 1902 through 1957 assuming that the ratio of capital to total sewerage expenditures is constant and equal to the average ratio observed in 1958 through 1971 (71 percent). For 1902 through 1956, total sewerage expenditures are assumed to be 62 percent of total sanitation expenditures, based on data for 1957 through 1970.

that, for 1958 through 1970, annual sewerage capital expenditures as a portion of total annual sewerage expenditures varied between 65 percent and 83 percent, with an average of 71 percent. To divide total sewerage expenditures into capital and O&M categories, it was therefore assumed that capital expenditures represented 71 percent of the total for 1902 through 1957. Table A-8 reports the resulting estimates of both sewerage capital and O&M expenditures for selected years between 1902 and 1971.

All annual sewerage capital and O&M expenditures values for 1902 through 1995 were converted from fiscal year to calendar year estimates. This conversion was accomplished by taking the average of fiscal year estimates for the same and following year (e.g., 1970 values were set equal to the average of the FY1970 and FY1971 estimates).

To explore the pre-CWA determinants of sewerage capital expenditures and to use this information to simulate without-CWA capital expenditures after 1971, data on U.S. population and annual housing starts for 1902 through 1997 were acquired from the Census Bureau. These data are reported in Table A-9 along with corresponding estimates of real annual sewerage capital expenditures. Capital expenditure estimates for the last 2 years were projected, based on the observed trend from previous years (see footnote b in Table A-10). The data in Table A-9 for 1902 through 1971 were used in a regression to explain capital expenditures over the same period. The regression results are reported in Section 6 (Eq. [6.1]) of this report. The predictive capacity of this model is illustrated in Figure A-1, which shows a close correspondence between actual capital expenditures and predicted expenditures for 1902-1971. After 1971 the predicted values are equivalent to the simulated without-CWA expenditures. As shown in Figure A-1 and Table A-9, the without-CWA estimates deviate substantially from the observed with-CWA trend, particularly around 1980.

A similar approach was used to simulate without-CWA sewerage O&M expenditures. In this case, actual O&M expenditures during the period 1932-1994 were regressed on estimates of the size and age of the gross sewerage capital stock in corresponding years.[3] The gross capital stock in each year from 1932 to 1994 was estimated as the sum of sewerage capital expenditures

[3]For 1932-1952, O&M expenditure data are only available for even-numbered years.

Table A-9. Comparison of Total U.S. Population, Housing Starts, and Public Sewerage Capital Expenditures (Actual and Projected), 1902–1997

Calendar Year	U.S. Population (millions)[a]	Housing Starts (thousands)[a]	Sewerage Capital Expenditures (1997 $millions)
			Actual Before CWA[b]
1902	79	157	427
1913	97	307	665
1922	110	574	773
1927	119	643	1,123
1932	125	64	1,040
1934	126	49	884
1936	128	211	979
1938	130	262	1,017
1940	132	397	979
1942	135	227	933
1944	138	96	1,021
1946	141	738	1,433
1948	147	977	1,944
1950	152	1,387	2,365
1952	158	1,051	2,358
1953	160	1,019	2,408
1954	163	1,113	2,664
1955	166	1,182	2,946
1956	169	963	3,208
1957	172	854	3,256
1958	175	955	3,332
1959	178	1,076	3,585
1960	181	888	3,579
1961	184	946	3,820
1962	187	1,053	4,458
1963	189	1,149	4,889
1964	192	1,118	5,018
1965	194	1,012	5,163
1966	197	788	4,937
1967	199	903	4,584
1968	201	1,096	4,670
1969	203	1,079	4,996
1970	205	1,018	5,727
1971	208	1,502	6,868

(continued)

Table A-9. Comparison of Total U.S. Population, Housing Starts, and Public Sewerage Capital Expenditures (Actual and Projected,) 1902–1997 (continued)

Calendar Year	US Population (millions)[a]	Housing Starts (thousands)[a]	Sewerage Capital Expenditures (1997 $millions) Actual With CWA[b]	Sewerage Capital Expenditures (1997 $millions) Projected Without CWA[c]
1972	210	1,720	7,728	*6,897*
1973	212	1,495	8,009	*6,695*
1974	214	923	9,006	*5,968*
1975	216	760	9,972	*5,867*
1976	218	1,044	10,222	*6,429*
1977	220	1,377	10,085	*7,076*
1978	223	1,432	10,946	*7,315*
1979	225	1,241	12,012	*7,194*
1980	227	914	12,188	*6,851*
1981	229	760	10,823	*6,771*
1982	232	785	9,301	*6,955*
1983	234	1,351	8,745	*7,945*
1984	236	1,415	8,515	*8,176*
1985	238	1,494	8,799	*8,435*
1986	240	1,546	9,531	*8,662*
1987	242	1,372	10,481	*8,546*
1988	244	1,243	10,783	*8,501*
1989	247	1,128	10,383	*8,484*
1990	249	947	10,402	*8,388*
1991	252	789	10,335	*8,333*
1992	255	932	10,698	*8,738*
1993	258	1,032	9,914	*9,072*
1994	260	1,183	8,962	*9,469*
1995	263	1,106	9,454	*9,520*
			Projected With CWA	**Projected Without CWA**
1996	265	1,211	*9,873*	*9,839*
1997	268	1,221	*9,873*	*10,025*

[a] U.S. Bureau of the Census. Historical Housing Starts. Inside Standard Metropolitan Areas. Received Fax November 8, 1999. 1946 through 1958 based on average share that SMSA housing starts were of all private housing starts from 1902 through 1998.

[b] Values for 1996 through 1997 are an average of values for 1990 through 1994.

[c] Values for 1972 through 1997 estimated based on the estimated historical relationship (1902 through 1971) between capital expenditures, and housing starts (see Eq. [6.1]).

Table A-10. Comparison of Total Public Sewerage Operation and Maintenance Expenditures (Actual and Projected), 1902–1997

Calendar Year	Sewerage O&M Expenditures (1997 $millions)
	Actual Before CWA[a]
1902	172
1913	268
1922	312
1927	453
1932	420
1934	357
1936	395
1938	411
1940	395
1942	377
1944	412
1946	578
1948	784
1950	954
1952	951
1953	972
1954	1,075
1955	1,189
1956	1,295
1957	1,294
1958	1,294
1959	1,310
1960	1,366
1961	1,536
1962	1,282
1963	1,415
1964	2,308
1965	2,726
1966	2,541
1967	2,273
1968	2,087
1969	1,798
1970	2,204
1971	3,034

(continued)

Table A-10. Comparison of Total Public Sewerage Operation and Maintenance Expenditures (Actual and Projected), 1902–1997 (continued)

	Sewerage O&M Expenditures (1997 $millions)	
Calendar Year	Actual With CWA[a]	Projected Without CWA[b]
1972	3,569	*3,705*
1973	4,134	*4,069*
1974	4,544	*4,433*
1975	4,871	*4,796*
1976	5,398	*5,154*
1977	6,007	*5,497*
1978	6,527	*5,866*
1979	6,867	*6,197*
1980	7,239	*6,551*
1981	7,700	*6,848*
1982	8,215	*7,170*
1983	8,606	*7,487*
1984	8,900	*7,834*
1985	9,311	*8,174*
1986	9,970	*8,505*
1987	10,467	*8,828*
1988	10,836	*9,154*
1989	11,595	*9,480*
1990	12,227	*9,791*
1991	12,604	*10,106*
1992	13,309	*10,405*
1993	14,172	*10,669*
1994	15,036	*10,913*
1995	15,582	*11,166*
	Projected With CWA	**Projected Without CWA**
1996	*16,357*	*11,417*
1997	*17,171*	*11,705*

[a] Values for 1996 and 1997 are projected based on the observed time trend between 1972 and 1995.

[b] Values for 1972 through 1997 estimated based on the estimated historical relationship (1932 through 1971) between O&M expenditures and the estimated size and average age of the sewerage capital stock (see Eq. [6.2]).

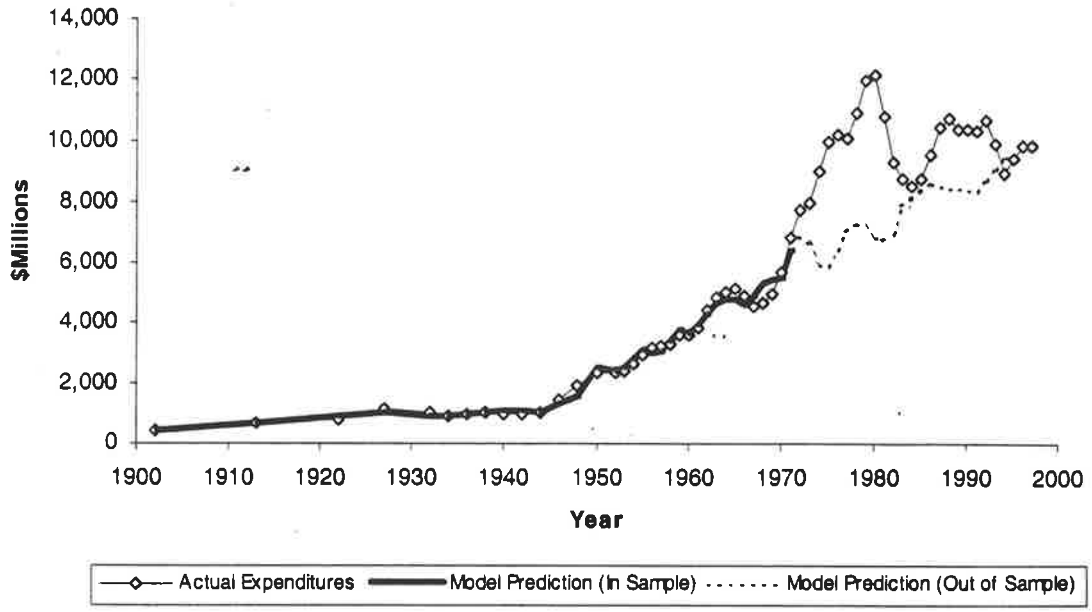

Figure A-1. Public Sewerage Capital Expenditures, Actual vs. Model Predictions, 1902–1997 (1997 $)

in the previous 30 years (Eq. [6.1] was used to predict these values for years without available data). These expenditures were also used to estimate the average age of the gross stock. The data used for this regression are reported in Table A-11, and the regression results are reported in Section 6 (Eq. [6.2]) of this report. Figure A-2 also shows a relatively close correspondence between actual and predicted O&M expenditures for 1932-1994. Both Figure A-2 and Table A-10 also report without-CWA O&M expenditures, which were estimated using Eq. (6.2) and estimates of what the size and age of the gross sewerage capital stock would have been without the CWA (based on the without-CWA capital expenditure estimates reported in Table A-9).

Table A-12 describes the conversion from sewerage capital *expenditures* to sewerage capital *costs* for both the with-CWA and without-CWA scenarios. The conversion requires a long-term (at least 30 years in this case) continuous time series of capital expenditure data. Prior to 1952, the sanitation expenditure data were not available for every year; therefore, the expenditure data are reported only for the period 1952 through 1997. The with-CWA expenditures for this period are taken from Table A-9. For years prior to 1972, capital expenditures without the CWA were assumed to be the same as those with the CWA, and for 1972 through 1997, the without-

Table A-11. Sewerage O&M Expenditures, Capital Expenditures, Gross Capital Stock, and Average Capital Age, 1902-1994

Calendar Year	O&M Expenditures[a]	Capital Expenditures[a] (SEWER_K_EXP)	Estimated Gross Capital Stock[a,b] (KSTOCK)	Estimated Average Age of Capital Stock[c] (KAGE)
1902		427		
1903		423[d]		
1904		456[d]		
1905		524[d]		
1906		537[d]		
1907		540[d]		
1908		555[d]		
1909		594[d]		
1910		601[d]		
1911		619[d]		
1912		644[d]		
1913		665		
1914		685[d]		
1915		704[d]		
1916		721[d]		
1917		680[d]		
1918		645[d]		
1919		715[d]		
1920		724[d]		
1921		810[d]		
1922		773		
1923		980[d]		
1924		1,011[d]		
1925		1,044[d]		
1926		1,034[d]		
1927		1,123		
1928		1,036[d]		
1929		974[d]		
1930		925[d]		
1931		912[d]		
1932	420	1,040	22,084	13.30
1933		879[d]	22,697	13.38
1934	357	884	23,153	13.57
1935		926[d]	23,581	13.74
1936	395	979	23,984	13.85
1937		983[d]	24,426	13.94
1938	411	1,017	24,868	14.04
1939		1,060[d]	25,331	14.13
1940	395	979	25,797	14.18

(continued)

Table A-11. Sewerage O&M Expenditures, Capital Expenditures, Gross Capital Stock, and Average Capital Age, 1902-1994 (continued)

Calendar Year	O&M Expenditures[a]	Capital Expenditures[a] (SEWER_K_EXP)	Estimated Gross Capital Stock[a,b] (KSTOCK)	Estimated Average Age of Capital Stock[c] (KAGE)
1941		1,118[d]	26,175	14.29
1942	377	933	26,674	14.33
1943		1,035[d]	26,964	14.46
1944	412	1,021	27,333	14.53
1945		1,114[d]	27,669	14.61
1946	578	1,433	28,079	14.65
1947		1,426[d]	28,791	14.53
1948	784	1,944	29,536	14.47
1949		1,811[d]	30,835	14.24
1950	954	2,365	31,931	14.08
1951		2,181[d]	33,572	13.74
1952	951	2,358	34,943	13.51
1953	972	2,408	36,528	13.29
1954	1,075	2,664	37,956	13.01
1955	1,189	2,946	39,609	12.70
1956	1,295	3,208	41,510	12.37
1957	1,294	3,256	43,684	12.04
1958	1,294	3,332	45,816	11.74
1959	1,310	3,585	48,113	11.54
1960	1,366	3,579	50,724	11.37
1961	1,536	3,820	53,377	11.28
1962	1,282	4,458	56,286	11.21
1963	1,415	4,889	59,703	11.05
1964	2,308	5,018	63,713	10.94
1965	2,726	5,163	67,846	10.88
1966	2,541	4,937	72,083	10.86
1967	2,273	4,584	76,041	10.91
1968	2,087	4,670	79,643	11.04
1969	1,798	4,996	83,296	11.19
1970	2,204	5,727	87,232	11.32
1971	3,034	6,868	91,980	11.42
1972	3,569	7,728	97,730	11.40
1973	4,134	8,009	104,525	11.39
1974	4,544	9,006	111,499	11.40
1975	4,871	9,972	119,484	11.38
1976	5,398	10,222	128,342	11.34
1977	6,007	10,085	137,131	11.30
1978	6,527	10,946	145,790	11.33
1979	6,867	12,012	154,792	11.30

(continued)

Table A-11. Sewerage O&M Expenditures, Capital Expenditures, Gross Capital Stock, and Average Capital Age, 1902-1994 (continued)

Calendar Year	O&M Expenditures[a]	Capital Expenditures[a] (SEWER_K_EXP)	Estimated Gross Capital Stock[a,b] (KSTOCK)	Estimated Average Age of Capital Stock[c] (KAGE)
1980	7,239	12,188	164,993	11.27
1981	7,700	10,823	174,816	11.23
1982	8,215	9,301	183,458	11.35
1983	8,606	8,745	190,402	11.56
1984	8,900	8,515	196,739	11.82
1985	9,311	8,799	202,589	12.08
1986	9,970	9,531	208,442	12.32
1987	10,467	10,481	214,765	12.51
1988	10,836	10,783	221,990	12.66
1989	11,595	10,383	229,441	12.82
1990	12,227	10,402	236,239	12.99
1991	12,604	10,335	243,061	13.19
1992	13,309	10,698	249,576	13.38
1993	14,172	9,914	255,817	13.53
1994	15,036	8,962	260,842	13.71

[a] In 1997 $millions.

[b] For year = t, $KSTOCK_t = \sum_{i=1}^{30} SEWER\_K\_EXP_{t-i}$.

[c] For year t, $KAGE_t = \sum_{i=1}^{30} \left(\frac{SEWER\_K\_EXP_{t-i}}{KSTOCK_t} \right) \times i$.

[d] Estimated using Eq. (6.1).

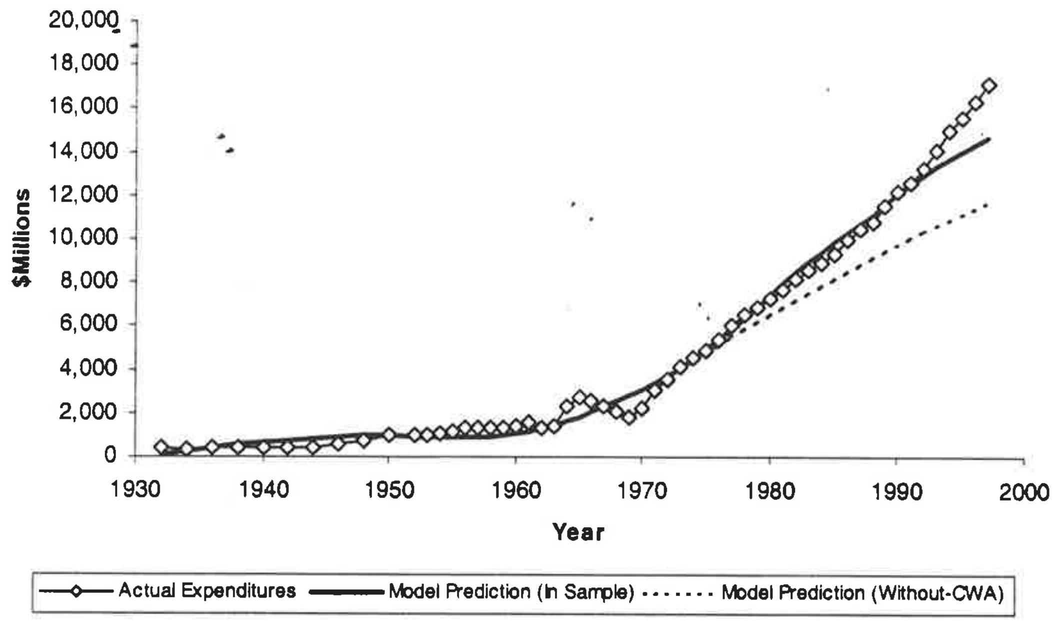

Figure A-2. Public Sewerage O&M Expenditures, Actual vs. Model Predictions, 1932–1997 (1997 $)

CWA estimates are again taken from Table A-9. Assuming a 30-year productive life for sewerage capital, the expenditure estimates for each scenario were converted to gross sewerage capital stock estimates for 1982 through 1997. In Table A-12, the gross capital stock estimates are annualized using a 3 percent discount rate, and the resulting capital cost estimate for the two scenarios are reported in the fourth and seventh columns.

A.3 WPA Capital and O&M Expenditures by Publicly Owned Electric Utilities

Data on capital and O&M expenditures for POEUs were reported as a separate item in the *SCB* report (Vogan, 1996) for 1972 through 1994. These data are included in Table A-13. This table also includes expenditure data converted to 1997 dollars and projected for the period 1994 through 1997 using the average observed value for 1990 through 1994.

Given the difficulties in obtaining historical (i.e., pre-1972) estimates of WPA expenditures or other economic data specific to this sector, we simply used the lowest observed annual WPA capital and O&M expenditures for 1972 through 1994 to characterize without-CWA expenditures. As shown in Table A-14, the lowest real value for O&M expenditures was observed

Table A-12. Public Sewerage Capital Costs Under the With-CWA and Without CWA Scenarios (1997 $millions)

	With CWA			Without CWA		
Year	Capital Expenditures	Estimated Capital Stock[a]	Annualized Capital Costs	Capital Expenditures	Estimated Capital Stock[a]	Annualized Capital Costs
1952	2,358			2,358		
1953	2,408			2,408		
1954	2,664			2,664		
1955	2,946			2,946		
1956	3,208			3,208		
1957	3,256			3,256		
1958	3,332			3,332		
1959	3,585			3,585		
1960	3,579			3,579		
1961	3,820			3,820		
1962	4,458			4,458		
1963	4,889			4,889		
1964	5,018			5,018		
1965	5,163			5,163		
1966	4,937			4,937		
1967	4,584			4,584		
1968	4,670			4,670		
1969	4,996			4,996		
1970	5,727			5,727		
1971	6,868			*6,868*		
1972	7,728			*6,897*		
1973	8,009			*6,695*		
1974	9,006			*5,968*		
1975	9,972			*5,867*		
1976	10,222			*6,429*		
1977	10,085			*7,076*		
1978	10,946			*7,315*		
1979	12,012			*7,194*		
1980	12,188			*6,851*		
1981	10,823			*6,771*		
1982	9,301	*183,458*	*9,360*	*6,955*	*149,530*	*7,629*

(continued)

Table A-12. Public Sewerage Capital Costs Under the With-CWA and Without CWA Scenarios (1997 $millions) (continued)

Year	With CWA			Without CWA		
	Capital Expenditures	Estimated Capital Stock[a]	Annualized Capital Costs	Capital Expenditures	Estimated Capital Stock[a]	Annualized Capital Costs
1983	8,745	190,402	9,714	7,945	154,1.28	7,863
1984	8,515	196,739	10,037	8,176	159,665	8,146
1985	8,799	202,589	10,336	8,435	165,176	8,427
1986	9,531	208,442	10,635	8,662	170,666	8,707
1987	10,481	214,765	10,957	8,546	176,120	8,986
1988	10,783	221,990	11,326	8,501	181,410	9,255
1989	10,383	229,441	11,706	8,484	186,578	9,519
1990	10,402	236,239	12,053	8,388	191,477	9,769
1991	10,335	243,061	12,401	8,333	196,286	10,014
1992	10,698	249,576	12,733	8,738	200,799	10,245
1993	9,914	255,817	13,052	9,072	205,079	10,463
1994	8,962	260,842	13,308	9,469	209,262	10,676
1995	9,454	264,786	13,509	9,520	213,712	10,903
1996	9,873	269,077	13,728	9,839	218,070	11,126
1997	9,873	274,012	13,980	10,025	222,972	11,376

[a] Based on 30-year life of capital and a 3 percent discount rate.

Table A-13. Water Pollution Abatement Capital and O&M Expenditures by Publicly Owned Electric Utilities, 1972–1997

Year	Expenditures (current $millions)[a]		Expenditures (1997 $millions)[b]	
	Capital	O&M	Capital	O&M
1972	29	3	97	10
1973	22	4	70	13
1974	29	5	84	15
1975	32	7	85	19
1976	36	9	90	23
1977	52	10	122	24
1978	63	10	138	22
1979	81	12	164	24
1980	61	13	113	24
1981	57	18	96	30
1982	86	17	137	27
1983	73	19	111	29
1984	54	20	79	29
1985	63	10	90	14
1986	40	10	55	14
1987	37	13	50	17
1988	28	12	36	16
1989	49	11	61	14
1990	77	8	92	10
1991	64	14	73	16
1992	14	10	16	11
1993	11	11	12	12
1994	10	10	11	11
1995			*41*	*12*
1996			*41*	*12*
1997			*41*	*12*

[a] Vogan, Christine R. September 1996. *Survey of Current Business.* "Pollution Abatement and Control Expenditures, 1972-94." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972-94.

[b] Values for 1995 through 1997 are assumed to be equal to the average observed value for 1990 through 1994.

Table A-14. Water Pollution Abatement O&M Expenditures by Publicly Owned Electric Utilities With and Without the CWA, 1972–1997 (1997 $millions)

Year	O&M Expenditures[a]	Without CWA O&M Expenditures[b]
1972	10	*10*
1973	13	*10*
1974	15	*10*
1975	19	*10*
1976	23	*10*
1977	24	*10*
1978	22	*10*
1979	24	*10*
1980	24	*10*
1981	30	*10*
1982	27	*10*
1983	29	*10*
1984	29	*10*
1985	14	*10*
1986	14	*10*
1987	17	*10*
1988	16	*10*
1989	14	*10*
1990	10	*10*
1991	16	*10*
1992	11	*10*
1993	12	*10*
1994	11	*10*
1995	*12*	*10*
1996	*12*	*10*
1997	*12*	*10*

[a] Values for 1995 through 1997 are assumed to be equal to the average observed value for 1990 through 1994.

[b] Assumed to be equal to the minimum observed value for WPA O&M expenditures with the CWA (1972 through 1997).

in 1990 ($10 million), and this was used to simulate without-CWA expenditures. Similarly, Table A-15 shows that the lowest observed value for capital expenditures was $11 million in 1994. This table also shows how the with-CWA and without-CWA capital expenditure estimates for POEUs were converted to annual capital cost estimates for 1992 through 1997, assuming a 20-year life of capital and a 3 percent discount rate.

A.4 Public and Private R&D Expenditures

Data on public and private R&D expenditures for pollution abatement were also included in the *SCB* report for 1972 through 1994. These data, as well as the report's estimates of public R&M and other not-elsewhere-classified expenditures for water pollution abatement, are shown in Table A-16. In Table A-17, the R&D data are converted to 1997 dollars and projected for 1994 through 1997 using the average observed real value from 1990 through 1994. This table also reports Census data on total public and private R&D expenditures for 1972 through 1997 and estimates the percentage of R&D expenditures devoted to WPA technologies in each year. For public R&D, the percentage varied between 0.14 percent (in 1990) and 0.56 percent (in 1973). For private R&D, the percentage varied between 0.08 percent (1993) and 0.55 percent (in 1973). The lowest percentages in each category were used to characterize what R&D expenditures would have been without the CWA, and the resulting estimates are reported in Table A-18.

A.5 Public R&M and Other Expenditures

A similar approach was used for this category of public expenditures. In Table A-19, the R&M and other expenditure data from Table A-15 are converted to 1997 dollars and projected for 1994 through 1997 using the average observed real value from 1990 through 1994. This table also reports Census data on total public consumption expenditures for 1972 through 1997 and estimates the percentage of these expenditures devoted to R&M and other expenditures related to WPA in each year. The percentage varied between 16 percent (in 1982) and 25 percent (in 1992). The lowest percentage was used to characterize the without-CWA estimates, which are reported in Table A-20.

Table A-15. Water Pollution Abatement Capital Expenditures and Costs by Publicly Owned Electric Utilities, With and Without the CWA, 1972–1997 (1997 $millions)

	With-CWA			Without-CWA		
Year	Capital Expenditures[a]	Estimated Gross Capital Stock	Capital Cost	Capital Expenditures[b]	Estimated Gross Capital Stock	Capital Cost
1972	97			*11*		
1973	70			*11*		
1974	84			*11*		
1975	85			*11*		
1976	90			*11*		
1977	122			*11*		
1978	138			*11*		
1979	164			*11*		
1980	113			*11*		
1981	96			*11*		
1982	137			*11*		
1983	111			*11*		
1984	79			*11*		
1985	90			*11*		
1986	55			*11*		
1987	50			*11*		
1988	36			*11*		
1989	61			*11*		
1990	92			*11*		
1991	73			*11*		
1992	16	*1,843*		*11*	*212*	
1993	12	*1,762*		*11*	*212*	
1994	11	*1,704*		*11*	*212*	
1995	*41*	*1,631*		*11*	*212*	
1996	*41*	*1,587*		*11*	*212*	
1997	*41*	*1,537*		*11*	*212*	

[a] Based on a 20-year life of capital and a 3 percent discount rate. Vogan, Christine R. September 1996. *Survey of Current Business.* "Pollution Abatement and Control Expenditures, 1972-94." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972-94. Values for 1995 through 1997 are assumed to be equal to the average observed value for 1990 through 1994.

[b] Assumed to be equal to the minimum observed value for WPA capital expenditures with the CWA (1972 through 1997).

Table A-16. Public and Private R&D, R&M, and Other Not-Elsewhere-Classified Expenditures for Water Pollution Abatement, 1972–1994 (current $millions)

	Public			Private
Year	R&D	R&M	Other	R&D
1972	78	145	171	64
1973	95	190	171	73
1974	96	247	189	57
1975	96	279	210	68
1976	102	328	204	78
1977	108	370	188	91
1978	121	405	218	99
1979	139	425	257	107
1980	118	465	299	110
1981	130	434	286	104
1982	141	416	276	102
1983	153	381	290	93
1984	134	388	337	90
1985	110	464	391	95
1986	126	510	426	104
1987	123	560	452	106
1988	110	580	484	112
1989	108	626	489	125
1990	89	620	514	97
1991	101	761	537	124
1992	123	922	538	55
1993	107	750	575	81
1994	136	622	472	76

Source: Vogan, Christine R. September 1996. *Survey of Current Business.* "Pollution Abatement and Control Expenditures, 1972-94." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972-94.

Table A-17. Comparison of R&D Expenditures for Water Pollution Abatement and Total R&D Expenditures, 1972–1997 (1997 $millions)

	Public			Private		
	Total R&D[a]	WPA R&D		Total R&D[a]	WPA R&D	
Year	1997 $millions	1997 $millions	% of Total	1997 $millions	1997 $millions	% of Total
1972	54,264	260	0.48%	39,109	214	0.55%
1973	53,290	300	0.56%	42,023	231	0.55%
1974	50,789	279	0.55%	43,174	165	0.38%
1975	49,767	254	0.51%	41,937	180	0.43%
1976	51,455	255	0.50%	44,323	195	0.44%
1977	52,640	254	0.48%	46,205	214	0.46%
1978	54,184	265	0.49%	49,246	217	0.44%
1979	55,722	281	0.50%	52,722	216	0.41%
1980	56,143	218	0.39%	57,186	203	0.36%
1981	57,860	220	0.38%	60,778	176	0.29%
1982	59,987	224	0.37%	64,714	162	0.25%
1983	64,060	233	0.36%	69,047	142	0.21%
1984	69,104	197	0.28%	76,745	132	0.17%
1985	75,701	156	0.21%	82,417	135	0.16%
1986	76,734	174	0.23%	84,574	144	0.17%
1987	79,648	165	0.21%	84,176	142	0.17%
1988	79,130	143	0.18%	88,216	145	0.16%
1989	76,534	134	0.18%	93,374	155	0.17%
1990	74,845	106	0.14%	99,338	116	0.12%
1991	71,123	116	0.16%	106,023	142	0.13%
1992	69,398	137	0.20%	107,558	61	0.06%
1993	67,295	116	0.17%	105,113	88	0.08%
1994	66,122	144	0.22%	105,459	81	0.08%
1995	67,265	*124*	*0.18%*	115,191	*98*	*0.08%*
1996	65,743	*124*	*0.19%*	123,402	*98*	*0.08%*
1997	64,566	*124*	*0.19%*	133,308	*98*	*0.07%*

[a] U.S. Bureau of the Census. October 2, 1998. *Statistical Abstract of the United States: 1998.* "No. 988. R&D Expenditures: 1960-1997."

Table A-18. Public and Private R&D Expenditures for Water Pollution Abatement, With and Without the CWA, 1972–1997 (1997 $millions)

Year	Public R&D Expenditures		Private R&D Expenditures	
	With CWA	Without CWA[a]	With CWA	Without CWA[a]
1972	260.4	*76.9*	213.7	*22.3*
1973	300.3	*75.5*	230.7	*24.0*
1974	278.5	*72.0*	165.4	*24.6*
1975	254.4	*70.5*	180.2	*23.9*
1976	255.4	*72.9*	195.3	*25.3*
1977	254.1	*74.6*	214.1	*26.4*
1978	265.4	*76.8*	217.1	*28.1*
1979	280.9	*78.9*	216.2	*30.1*
1980	218.2	*79.5*	203.4	*32.6*
1981	219.7	*82.0*	175.8	*34.7*
1982	224.2	*85.0*	162.2	*36.9*
1983	233.3	*90.8*	141.8	*39.4*
1984	196.9	*97.9*	132.3	*43.8*
1985	156.3	*107.3*	135.0	*47.0*
1986	174.5	*108.7*	144.0	*48.3*
1987	165.2	*112.8*	142.4	*48.0*
1988	142.5	*112.1*	145.1	*50.3*
1989	134.3	*108.4*	155.4	*53.3*
1990	106.0	*106.0*	115.6	*56.7*
1991	115.8	*100.8*	142.2	*60.5*
1992	137.2	*98.3*	61.4	*61.4*
1993	116.3	*95.3*	88.0	*60.0*
1994	144.4	*93.7*	80.7	*60.2*
1995	*124.0*	*95.3*	*98.0*	*65.7*
1996	*124.0*	*93.1*	*98.0*	*70.4*
1997	*124.0*	*91.5*	*98.0*	*76.1*

[a] Values estimated based on observed minimum ratio of public WPA R&D to total public R&D from 1972 through 1994.

Table A-19. Comparison of Public R&M and Other Not-Elsewhere-Classified Expenditures for Water Pollution Abatement and Total Public Consumption Expenditures, 1972–1997 (1997 $millions)

Year	Total Public Consumption Expenditures[a]	Public R&M and Other NEC WPA Expenditures[b]	
	1997 $millions	1997 $millions	% of Total
1972	746,578	1,306	0.17%
1973	756,637	1,561	0.21%
1974	775,167	1,833	0.24%
1975	794,858	2,014	0.25%
1976	804,909	1,976	0.25%
1977	827,059	1,969	0.24%
1978	840,570	2,059	0.24%
1979	852,293	2,079	0.24%
1980	880,917	1,919	0.22%
1981	898,073	1,589	0.18%
1982	918,760	1,479	0.16%
1983	944,334	1,699	0.18%
1984	977,076	1,788	0.18%
1985	1,030,118	2,235	0.22%
1986	1,073,110	2,235	0.21%
1987	1,100,470	2,326	0.21%
1988	1,113,256	2,349	0.21%
1989	1,134,544	2,364	0.21%
1990	1,163,708	2,356	0.20%
1991	1,175,513	2,609	0.22%
1992	1,176,727	2,913	0.25%
1993	1,172,717	2,582	0.22%
1994	1,175,284	2,259	0.19%
1995	1,181,092	*2,615*	*0.22%*
1996	1,197,291	*2,661*	*0.22%*
1997	1,219,200	*2,707*	*0.22%*

[a] Council of Economic Advisers. *Economic Report of the President.* "B-83. Federal and State and Local Government Recepts and Current Expenditures, National Income and Product Accounts, 1959-98." <http://w3.access.gpo.gov/usbudget/fy2000/erp.html> As obtained on December 3, 1999.

[b] Values for 1995 through 1997 are projected based on the observed time trend between 1972 and 1994.

Table A-20. Public Water Pollution Abatement Expenditures for Regulation and Monitoring and Other Expenditures Not Elsewhere Classified, With and Without the CWA, 1972–1997 (1997 $millions)

Year	With CWA R&M and Other Expenditures	Without CWA R&M and Other Expenditures[a]
1972	1,305.5	*1,201.4*
1973	1,561.3	*1,217.6*
1974	1,833.5	*1,247.5*
1975	2,014.3	*1,279.1*
1976	1,976.0	*1,295.3*
1977	1,969.4	*1,331.0*
1978	2,059.2	*1,352.7*
1979	2,079.2	*1,371.6*
1980	1,919.4	*1,417.6*
1981	1,588.9	*1,445.2*
1982	1,478.5	*1,478.5*
1983	1,698.9	*1,519.7*
1984	1,788.4	*1,572.4*
1985	2,234.7	*1,657.7*
1986	2,234.8	*1,726.9*
1987	2,326.4	*1,771.0*
1988	2,349.4	*1,791.5*
1989	2,363.8	*1,825.8*
1990	2,355.5	*1,872.7*
1991	2,609.2	*1,891.7*
1992	2,913.1	*1,893.7*
1993	2,581.5	*1,887.2*
1994	2,259.3	*1,891.4*
1995	*2,614.6*	*1,900.7*
1996	*2,661.0*	*1,926.8*
1997	*2,707.5*	*1,962.0*

[a] Values estimated based on observed minimum ratio of public WPA R&M and other not-elsewhere-classified expenditures to all government consumption expenditures from 1972 through 1994.

A.6 Private Cost Offsets

The last category for which data were collected was the cost offset category. As described in Section 7, we used EPA (1999a) estimates of cost offsets related to water pollution abatement activities for 1972 through 1994. These are reported in Table A-21, which also includes the estimates converted to 1997 dollars and projected for 1995 through 1997 using the average observed real value from the previous 5 years. Section 7 describes how these estimates were used to estimate without-CWA cost offsets (see Table 7-4).

Table A-21. Private Water Pollution Abatement Offsets, 1972–1997 (1997 $millions)

Year	Cost Offsets[a] (current $millions)	Cost Offsets[b] (1997 $millions)
1972	114	381
1973	119	376
1974	161	467
1975	208	551
1976	266	666
1977	290	682
1978	323	708
1979	408	824
1980	531	982
1981	548	926
1982	408	649
1983	438	668
1984	445	654
1985	339	482
1986	382	529
1987	366	492
1988	435	564
1989	374	465
1990	390	465
1991	300	344
1992	340	379
1993	281	305
1994	294	312
1995		*296*
1996		*282*
1997		*268*

[a] U.S. Environmental Protection Agency. 1999a. *1972-1994 Expenditures Data for Air and Water Pollution Abatement and Control and Solid Waste Management.* Draft report. Washington, DC: Office of Policy.

[b] Value for 1995 through 1997 are projected based on the observed trend from previous years.

APPENDIX B
TRENDS IN PUBLIC SEWERAGE CAPITAL EXPENDITURES

This appendix provides a more detailed assessment of observed trends and fluctuations in public sewerage capital expenditures since the mid-1950's. As discussed in Section 5, there was a notable increase in the growth rate of these expenditures in the 1970's, which coincided with the passage of the CWA. From 1956 to 1969, they grew by a total of 56 percent in real terms, whereas from 1970 to 1980 they grew by 113 percent. However, in the early 1980's this trend was reversed, and by the mid-1990's public sewerage capital expenditures were still below their 1980 level. What accounts for these changing trends? To shed light on this issue, we review the primary federal programs supporting wastewater treatment and examine their effects on both federal and state/local spending. We also compare trends in wastewater and nonwastewater public infrastructure expenditures to see in what ways the former were unique after passage of the 1972 CWA.

In 1972 over 40 percent of the U.S. population linked to municipal waste water systems was served by systems with no treatment. Therefore, a principal aim of the CWA was to achieve a minimum level of secondary treatment at all municipal facilities. To achieve this objective, federal funding for the Construction Grants Program (initially created in 1956) increased dramatically and the federal share of the design and construction costs for these plants was increased to 75 percent. As Figure B-1 indicates, the result was a very large increase in annual funds allocated to the program, from less than $1 billion (1997$) in 1972 to as much as $17 billion in the late 1970s. By 1980, only 1 percent of the served population had systems with no treatment, and over 70 percent was served by systems with at least secondary treatment. Thereafter, the Construction Grants Program was gradually phased out. With the passage of the CWA Amendments of 1987, it was replaced by the State Revolving Fund (SRF) Program, which provides states and municipalities with low-cost loans for water quality infrastructure projects. SRF funding levels through 1997 are also shown in Figure B-1.

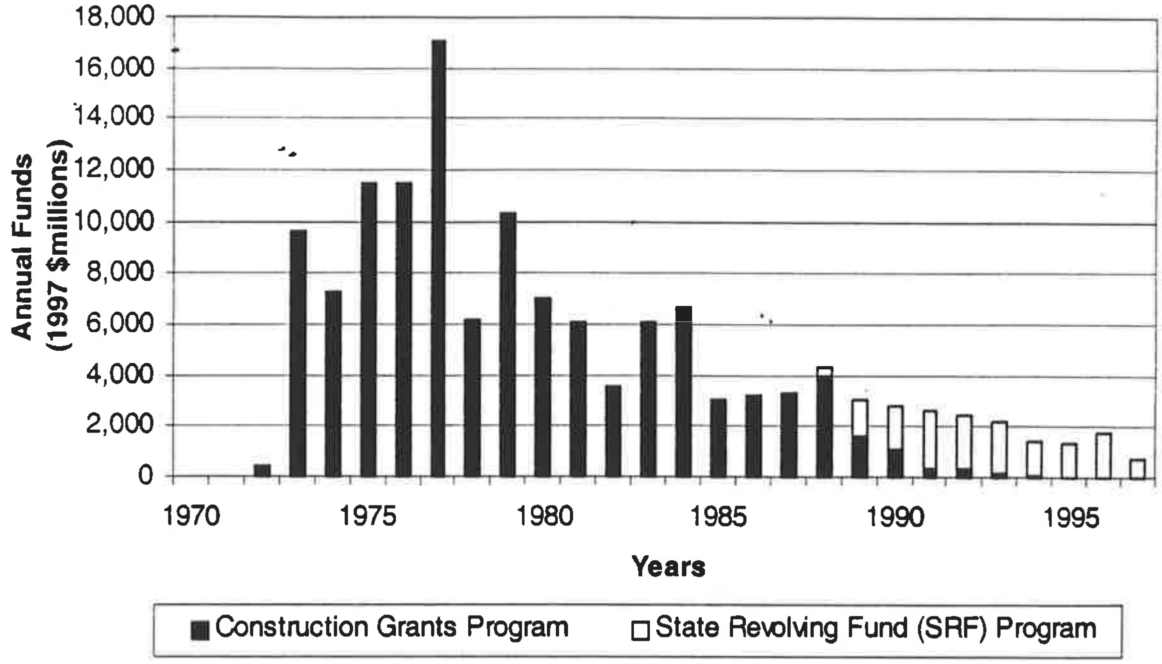

Figure B-1. EPA's Municipal Water Pollution Control Programs Annual Funds: 1970-1999 (1997 $millions)

The Construction Grants Program was clearly a major contributor to the large growth in public sewerage expenditures in the 1970s. As shown in Figure B-2, federal capital expenditures in particular grew dramatically over this period. This growth was only partially offset by the concurrent decline in state and local wastewater capital expenditures. Therefore, although there was some crowding out of state and local expenditures, total wastewater capital expenditures peaked with federal expenditures around 1980 and then declined with federal expenditures into the mid-1980's. After 1985, however, state and local spending resumed its role as the major driver of sewerage capital expenditures. Partially bolstered by the SRF program, state and local spending pushed sewerage capital expenditures to a new peak in the early 1990s.

Although the CWA, primarily through the Construction Grants Program, provided a major boost to wastewater capital expenditures in the 1970s, this trend does not appear to have been sustained after 1980. This conclusion is supported by the evidence in Figure B-3, which

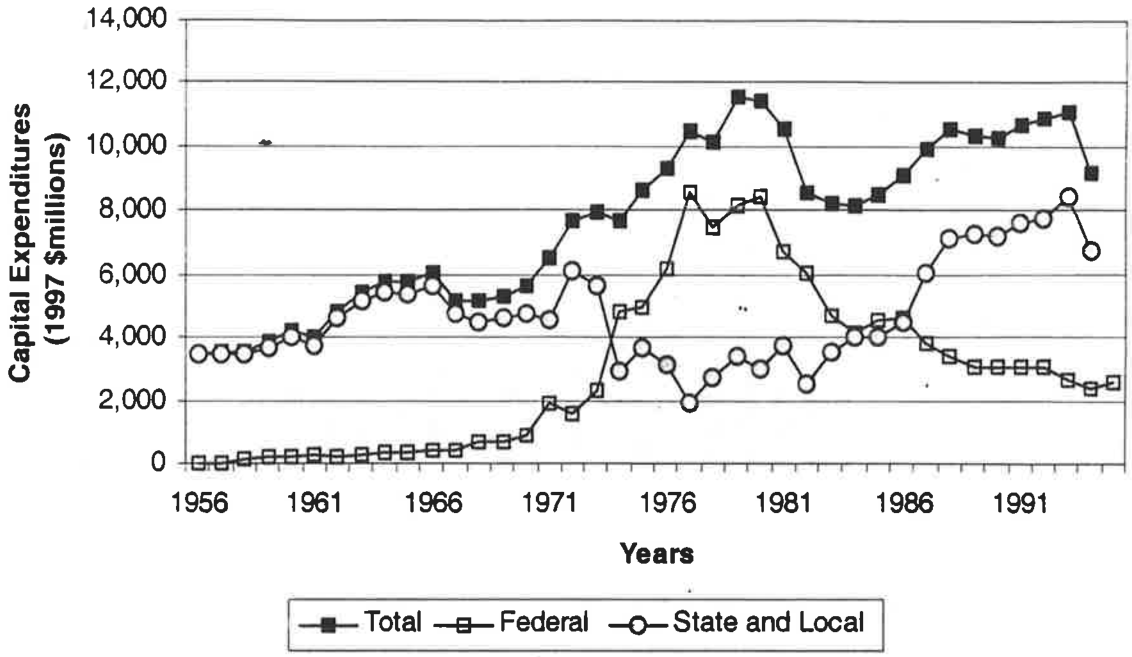

Figure B-2. Public Wastewater Capital Expenditures, 1956-1995 (1997 $millions)

compares trends in wastewater and nonwastewater public infrastructure spending for 1956 to 1995. Spending in both categories generally increased from 1956 to 1969; however, in the following 10 years spending moved in the opposite direction. While other public capital spending declined by over 20 percent in the 1970s, sewerage capital expenditures grew at an unprecedented rate. This is strong evidence of the CWA's stimulative effect on wastewater spending. By contrast, in the 1980s the trends in wastewater and nonwastewater spending began to once again correspond with one another. They both declined in the early 1980s (coinciding with the general recession in the economy) and rose again in the late 1980s. In the first half of the 1990s, there was once again a divergence in these trends; however, during this period nonwastewater infrastructure expenditures increased while wastewater expenditures generally declined.

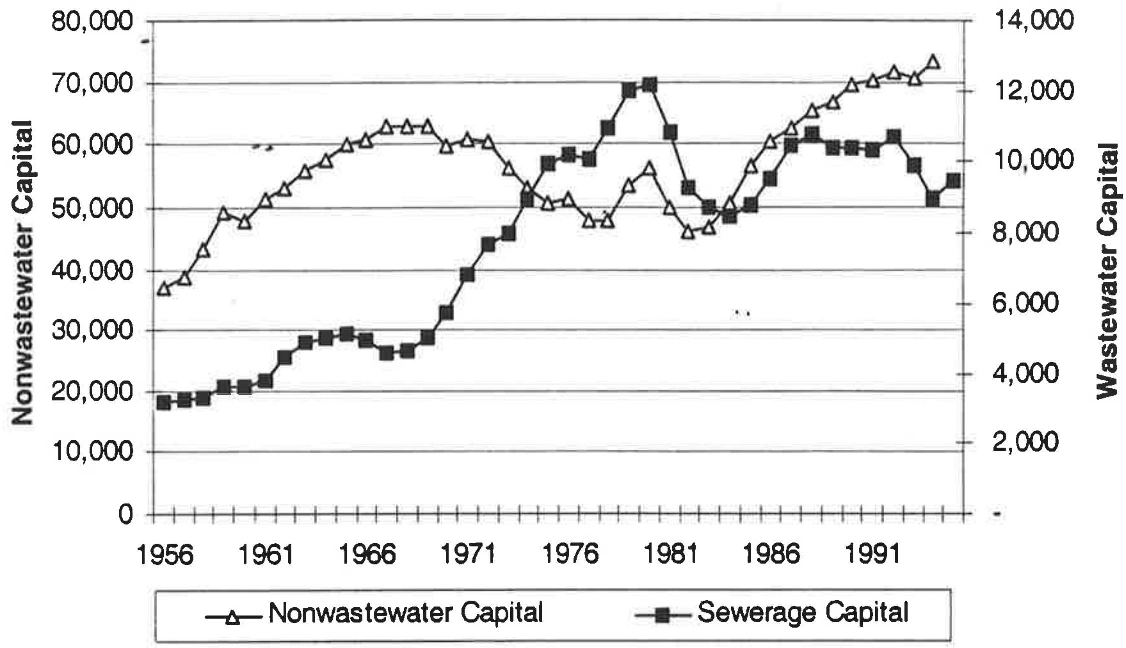

Figure B-3. Public Infrastructure Capital Expenditures, 1956-1995 (1997 $millions)

In summary, the stimulative effect of the CWA on public sewerage expenditures appears to have primarily occurred in the 1970s. Thereafter (up to 1995), public infrastructure capital spending on wastewater projects has generally mirrored or even declined slightly in relation to other public infrastructure projects.

APPENDIX C
INFLATION ADJUSTMENT

All current-dollar estimates used in the analysis were converted to 1997 dollars using the chain-type price index reported in Table C-1. For 1929 through 1997, this index is reported by BEA (see sources in Table C-1). For 1902 through 1927, the chain-type index was estimated using the consumer price index (CPI) (BLS, 1999) for those years (based on the estimated relationship between the CPI and the chain-type index for 1929 through 1997).

Table C-1. Chain-Type Price Index, 1902–1998 (1997=100)

Year	Chain-Type Price Index	Year	Chain-Type Price Index
1902	9.46	1968	24.77
1913	6.80	1969	25.94
1922	11.54	1970	27.32
1927	11.96	1971	28.73
1932	9.01	1972	29.95
1934	9.20	1973	31.64
1936	9.48	1974	34.47
1938	9.64	1975	37.73
1940	9.62	1976	39.93
1942	11.06	1977	42.50
1944	11.98	1978	45.60
1946	13.76	1979	49.49
1948	16.21	1980	54.08
1950	16.37	1981	59.16
1952	17.85	1982	62.90
1953	18.09	1983	65.57
1954	18.29	1984	68.05
1955	18.56	1985	70.39
1956	19.22	1986	72.22
1957	19.88	1987	74.45
1958	20.36	1988	77.17
1959	20.57	1989	80.42
1960	20.86	1990	83.93
1961	21.10	1991	87.23
1962	21.37	1992	89.63
1963	21.62	1993	92.00
1964	21.94	1994	94.19
1965	22.36	1995	96.36
1966	23.00	1996	98.18
1967	23.73	1997	100.00

Sources: U.S. Bureau of Economic Analysis. Summary National Income and Product Time Series, 1929-1997. [Computer file]. <http://www.BEA.DOC.gov/bea/dn1.htm>. Last updated December 18, 1998.
U.S. Bureau of Economic Analysis. "Selected NIPA Tables showing 'preliminary' estimates for the third quarter of 1999." [Computer file]. <http://www.BEA.DOC.gov/bea/dn1.htm>. Last updated November 26, 1999.
Bureau of Labor Statistics. Series Reports. <http://stats.bls.gov> <http://146.142.4.24/cgi-bin/srgate>. Last updated May 27, 1999.

APPENDIX D
SENSITIVITY AND UNCERTAINTY ANALYSIS

As discussed in the main body of this report and in the Appendix A, the analytical procedures used to arrive at our annual CWA cost estimates have required a number of simplifying assumptions. Although the results described in Section 7 represent our best estimates of the incremental costs associated with the CWA, it is important to acknowledge the uncertainty that is inherent in these estimates. Therefore, the purpose of this appendix is to address this uncertainty by examining the sensitivity of our results with respect to certain key assumptions and parameters of the model. First, we examine how alternative assumptions regarding the useful life of capital affect the estimates of annual water pollution abatement capital costs. Second, we conduct alternative simulations of without-CWA expenditures by adjusting certain model parameters and assumptions.

D.1 Sensitivity Analysis with Respect to Useful Life of Capital Assumptions

One of the critical assumptions of the CWA cost analysis is that the useful life of all public sewerage capital is 30 years. In addition, all private water pollution abatement capital has been assumed to last for 20 years. Using a single useful life value for such broad categories of capital is clearly an oversimplification, but one that is required to make the analysis tractable. The 20 year value for private capital is consistent with the productive life assumptions that EPA has used to evaluate the compliance costs of proposed effluent limitations guidelines (e.g., EPA, 1995). A larger value was selected for sewerage capital to reflect the particular durability and long life of many sewerage structures. To explore how these assumptions have affected the analysis, we have rerun the model using alternative useful life assumptions.

As discussed in Section 7, changing the useful life of capital is expected to have two countervailing effects on the resulting estimates of annual capital costs. One the one hand, increasing the assumed useful life of capital implies that the gross capital stock in a given year is composed of more previous years of investment, which increases the stock and its associated costs. At the same time, the costs of each investment is spread over more years, which tends to decrease annual capital costs in later years. The net effect on annual capital costs depends on which of these effects dominates.

For this sensitivity analysis we examine the effect of both increasing and decreasing the useful life assumption for sewerage capital by ten years (to 40 and 20 years respectively). The results are reported in Table D-1, which shows how these alternative assumptions affect the total annual CWA cost estimates (assuming a 3 percent discount rate). Generally speaking the longer life assumption decreases the estimate of total incremental CWA costs, whereas the shorter life assumption has the opposite effect. For 1992–1997, the 40 year assumption decreases costs by between 2.8 percent and 3.3 percent. The 20 year assumption increases the cost estimates for 1992–1996 by between 1.5 percent and 6.6 percent, but it lowers the cost estimate for 1997 by 0.4 percent. The overall effect of changing the useful life assumption for sewerage capital is therefore relatively small, and the sign (positive or negative) of this effect is somewhat ambiguous.[1]

Table D-1. The Effect of Alternative Sewerage Capital Life Assumptions on CWA Cost Estimates

	Total Annual Incremental CWA Cost (1997$ millions)[a]				
Year	20 Year Life[b]		30 Year Life	40 Year Life[b]	
1992	12,689	(+6.6%)	11,899	11,521	(–3.2%)
1993	12,762	(+6.4%)	11,996	11,603	(–3.3%)
1994	13,311	(+5.5%)	12,619	12,219	(–3.2%)
1995	13,753	(+3.6%)	13,274	12,878	(–3.0%)
1996	13,935	(+1.5%)	13,733	13,337	(–2.9%)
1997	14,055	(–0.4%)	14,107	13,711	(–2.8%)

[a] Assuming a 3 percent discount rate.
[b] Number in parentheses is the percentage difference in total estimated cost relative to a 30 year life assumption.

[1] These revised estimates only incorporate changes in sewerage capital costs. They do not address how resulting differences in sewerage capital stock measures might also alter the estimated changes in sewerage O&M expenditures.

The useful life of private WPA capital was also varied to assess the effect of this assumption on model results. Due to the limited time series data available for private WPA capital expenditures, it is not possible to examine the effect of a longer life assumption. Therefore, Table D-2 only reports the results of using a shorter (i.e., 15 year) useful life assumption. For 1992–1997, this leads to a 5–7 percent reduction in the estimated annual costs of the CWA, Again, changing the capital life assumption has a relatively small effect on the model results.

Table D-2. The Effect of Alternative Private WPA Capital Life Assumptions on CWA Cost Estimates

Year	Total Annual Incremental CWA Cost (1997$ millions)[a]	
	15 Year Life[b]	20 Year Life
1992	11,188 (−6.0%)	11,899
1993	11,164 (−6.9%)	11,996
1994	11,728 (−7.1%)	12,619
1995	12,356 (−6.9%)	13,274
1996	12,883 (−6.2%)	13,733
1997	13,414 (−4.9%)	14,107

[a] Assuming a 3 percent discount rate.
[b] Number in parentheses is the percentage difference in total estimated cost (relative to a 20 year life assumption).

D.2 Analysis of Parameter Uncertainty in Models for Simulating Without-CWA Expenditures

Section 4 describes the simulation models used to estimate without-CWA expenditures in the private and public sectors. At the core of these models are parameter estimates which are used to define a relationship between water pollution abatement expenditures and other observable demographic and economic measures. The purpose of this section is to describe how uncertainty regarding these parameter estimates translates to uncertainty in the annual CWA cost estimates described in Section 7. The effect of parameter uncertainty on model results is examined for the three largest categories of cost (i.e., where the effect of parameter uncertainty is expected to be the greatest)—public sewerage capital and O&M costs and private water pollution abatement capital costs.

D.2.1 Public Sewerage Costs

As described in Section 4, the key model parameters used to simulate without-CWA sewerage costs have been econometrically estimated using historical data. These parameter estimates are described in Eq. (6.1) and Eq. (6.2). The degree of parameter uncertainty in these models is expressed in the standard errors and variance-covariance matrix for the estimated coefficients. These error estimates can then be used to calculate plausible upper and lower bound (i.e., confidence interval) estimates for without-CWA sewerage expenditure estimates and for annual CWA costs. Unfortunately, the Durbin-Watson statistics for both of these models are much less than two, which provides strong evidence of serial autocorrelation in both cases. This implies that, although the models have good predictive properties (high R-squared statistics), the estimated standard errors are not reliable.

To examine the effect of autocorrelation on the confidence interval estimates, both equations were rerun using a Cochrane-Orcutt correction. In both cases, the goodness-of-fit declined, and the standard errors increased. Nevertheless, the coefficients of the key variables—population and housing starts in the capital expenditure model and capital stock and age in the O&M expenditure model—continued to be statistically significant at a 0.05 level. Model prediction errors were then compared using the original and the autocorrelation-corrected models. For 1972–1997, the 95 percent confidence intervals for the simulated without-CWA sewerage expenditures were greater by an average factor of 2.3 using the corrected model. For the same period, the confidence intervals for simulated without-CWA O&M expenditures were greater by an average factor of 4.3.

Because of their goodness-of-fit properties, the original models were retained for generating point estimates of without-CWA sewerage expenditures. In other words, the results described in Sections 5, 6, and 7 are not based on the autocorrelation-corrected models. However, the confidence intervals for these expenditure estimates and for the resulting estimates of CWA costs were adjusted using the factors described in the previous paragraph. That is, to more accurately reflect the parameter uncertainty in these models, the confidence intervals based on the original (i.e., uncorrected) models were augmented by factors of 2.3 and 4.3 respectively for without-CWA sewerage capital and O&M expenditures respectively.

Table D-3 shows the results of incorporating parameter uncertainty in the estimation of without-CWA sewerage capital expenditures (Eq. [6.1]). For this table, lower and upper bound estimates of CWA costs for 1992–1997 are calculated using the approximated 95 percent confidence intervals for without-CWA capital expenditures (1972–1997). It must be noted that uncertainty regarding capital expenditures affects total CWA costs in two distinct ways. First, lower (higher) estimates of without-CWA capital expenditure imply higher (lower) estimates of incremental capital costs due to the CWA. Second, lower (higher) estimates of without-CWA capital expenditures imply a lower (higher) accumulated sewerage capital stock which, through Eq. (6.2), implies lower (higher) without-CWA sewerage O&M expenditures and higher (lower) incremental CWA costs. The lower and upper bound CWA cost estimates in Table D-3 incorporate both of these effects. The resulting uncertainty range for incremental annual CWA costs for 1992–1997 generally falls within 25-30 percent of the midrange estimates for that period. Both effects contribute about equally to this uncertainty range.

Table D-3. The Effect of Uncertainty Regarding Without-CWA Sewerage Capital Expenditures

Year	Total Annual Incremental CWA Cost (1997$ millions)[a]				
	Lower Bound[b]		Mid-Range	Upper Bound[b]	
1992	8,744	(–26.5%)	11,899	14,991	(+26.0%)
1993	8,646	(–27.9%)	11,996	15,287	(+27.4%)
1994	9,069	(–28.1%)	12,619	16,116	(+27.7%)
1995	9,518	(–28.3%)	13,274	16,983	(+27.9%)
1996	9,769	(–28.9%)	13,733	17,657	(+28.6%)
1997	9,931	(–29.6%)	14,107	18,251	(+29.4%)

[a] Assuming a 3 percent discount rate.
[b] Based on approximated 95 percent confidence interval for without-CWA capital expenditures.

Table D-4 shows how the CWA cost estimates are affected by incorporating uncertainty regarding the parameters of the O&M expenditure model described in Eq. (6.2). For this table, lower and upper bound estimates of CWA costs for 1992–1997 are calculated using the approximated 95 percent confidence intervals for without-CWA O&M expenditures (1972–1997).

Table D-4. The Effect of Uncertainty Regarding Without-CWA Sewerage O&M Expenditures

Year	Total Annual Incremental CWA Cost (1997$ millions)[a]		
	Lower Bound[b]	Mid-Range	Upper Bound[b]
1992	10,798 (–9.3%)	11,899	13,001 (+9.3%)
1993	10,858 (–9.5%)	11,996	13,134 (+9.5%)
1994	11,456 (–9.2%)	12,619	13,783 (+9.2%)
1995	12,089 (–8.9%)	13,274	14,460 (+8.9%)
1996	12,524 (–8.8%)	13,733	14,942 (+8.8%)
1997	12,866 (–8.8%)	14,107	15,348 (+8.8%)

[a] Assuming a 3 percent discount rate.
[b] Based on approximated 95 percent confidence interval for without-CWA O&M expenditures.

By itself, the effect of this parameter uncertainty on the uncertainty range for total estimated incremental CWA costs is relatively small—plus or minus 9 percent relative to midrange values in 1992–1997.

D.2.2 Private WPA Costs

Due primarily to data limitations, the model used to estimate without-CWA private WPA expenditures is based on a simpler "fixed ratio" approach, which requires much stronger assumptions. One of the fundamental assumptions of this approach is that, if the CWA had not been enacted, annual WPA capital expenditures after 1972 would have constituted a fixed percentage of total annual capital expenditures in the private sector. Therefore, this percentage is the key parameter value to be specified in the model.

Two alternative approaches were considered. The preferred approach, which is discussed in Section 6.2 and included in the main analysis, is to use the observed percentage from years prior to 1972. Unfortunately, only one year of data is available (1965), with a percentage value of 0.3 percent. An alternative but less defensible approach is to assume that this percentage can be approximated by the lowest observed value after 1972 (with the CWA)— 0.5 percent.[2]

What effect would this alternative approach have had on the total CWA cost estimates? The sensitivity of the results to this assumption is shown in Table D-5. Using a 0.5 percent assumption for the portion of total private capital expenditures devoted to WPA reduces the annual total CWA cost estimates for 1992–1997 by 13–14 percent.

Table D-5. The Effect of Alternative Assumptions Regarding Without-CWA Private WPA Capital Expenditures

	Total Annual Incremental CWA Cost (1997$ millions)[a]	
Year	0.5 Percent of Total Capital Expenditure[b]	0.3 Percent of Total Capital Expenditure
1992	10,270 (–13.7%)	11,899
1993	10,340 (–13.8%)	11,996
1994	10,939 (–13.3%)	12,619
1995	11,564 (–12.9%)	13,274
1996	11,981 (–12.8%)	13,733
1997	12,311 (–12.7%)	14,107

[a] Assuming a 3 percent discount rate.
[b] Number in parentheses is the percentage difference in total estimated cost (relative to a 0.3 percent assumption).

[2]This general approach was used to estimate without-CWA R&D, R&M , and POEU expenditures; however, in those cases no information on pre-CWA percentages were available. As discussed in Section 8, this is most likely to have overestimated the incremental costs of the CWA for these cost categories. The overall effect of this overestimation on total CWA costs is likely to be small however, because, as shown in Figure 7-1, these cost categories make up a very small percentage of total CWA costs.

D.3 Analysis of Model Uncertainty for Simulating Without-CWA Sewerage Expenditures

Although a variety of alternative assumptions and models may be specified for simulating without-CWA conditions, we have selected and implemented the approaches which we felt were most defensible given the available data. In some cases, particularly for the larger categories of cost, alternative models may generate significantly different estimates.

For example, an alternative approach to estimating without-CWA sewerage expenditures is to assume they would have represented a fixed proportion of total public infrastructure expenditures after 1972. This "fixed ratio" approach is less rigorous than the model described in Eq. (6.1), but it is also more consistent with the approach used to estimate without-CWA private capital expenditures. Data for 1956–1971 (see Appendix B) indicate that wastewater capital expenditures as a percentage of total infrastructure capital expenditures varied between 7 percent and 10 percent before the passage of the CWA. Assuming that this percentage would have been in the same range (i.e., 9 percent) after 1972 without the CWA, capital expenditures would have actually declined slightly in real terms in the 1970s and rebounded in the 1980s and 1990s. The overall effect of this modeling assumption is shown in Table D-6. Because this approach would generate distinctly lower annual without-CWA expenditures estimates, the costs of the CWA in the 1990s are estimated to be higher. For 1992–1997, using this alternative model would increase the annual CWA cost estimates by 15-24 percent.[3]

The results in Table D-6 illustrate the potential sensitivity of the results to the modeling assumptions; however, it should be emphasized that the alternative model is less defensible for simulating without-CWA conditions. Most importantly, there is insufficient data with which to measure and test (in terms of statistical significance) the relationship between wastewater and other public infrastructure spending prior to 1972. Furthermore, it is not necessarily the case that such a relationship (fixed ratio) would have persisted after 1972. For example, total infrastructure expenditures may have declined in the 1970s primarily due to cutbacks in other areas (e.g., aviation related expenditures) that would not have affected sewerage spending. This would have

[3]The indirect effect of lower capital expenditures and stocks on sewerage O&M expenditures, which would further increase the cost difference, is not included in these illustrative calculatins.

Table D-6. The Effect of Alternative Model for Simulating Without-CWA Sewerage Capital Expenditures

Year	Total Annual Incremental CWA Cost (1997$ millions)[a]	
	Main Results	Alternative Sewerage Capital Model[b]
1992	11,899	14,750 (+24.0%)
1993	11,996	14,688 (+22.4%)
1994	12,619	15,149 (+20.1%)
1995	13,274	15,652 (+18.0%)
1996	13,733	15,951 (+16.2%)
1997	14,107	16,190 (+14.8%)

[a] Assuming a 3 percent discount rate.
[b] Number in parentheses is the percentage difference in total estimated cost (relative to main model results).

resulted in a higher percentage of infrastructure spending devoted to sewerage capital, in which case the fixed ratio model would underestimate without-CWA sewerage expenditures.

D.4 Conclusions

The results summarized in Tables D-1 through D-6 illustrate the sensitivity of the CWA cost estimates to certain key modeling assumptions. For the most part, the variability of results with respect to these assumptions is relatively small (less than 15 percent). More uncertainty is associated with the parameters used in estimating without-CWA sewerage expenditures; however, these parameters have a dual effect—they influence both the sewerage capital and O&M expenditure estimates—which amplifies their effect on model results. Using a fixed-ratio approach to estimate without-CWA sewerage capital expenditures is also shown to have a larger effect on model results, but this approach is expected to generate much less reliable estimates of sewerage expenditures.