The Cost of Clean Water

U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

VOLUME I

SUMMARY REPORT

Publications in "The Cost of Clean Water" Series

Volume I — Summary Report

Volume II — Detailed Analyses

Volume III — Industrial Waste Profiles:

1. Blast Furnaces and Steel Mills
2. Motor Vehicles and Parts
3. Paper Mills except Building
4. Textile Mill Products
5. Petroleum Refining
6. Canned and Frozen Fruits and Vegetables
7. Leather Tanning and Finishing
8. Meat Products
9. Dairies
10. Plastics Materials and Resins

Volume IV — State and Major River Basin Municipal Tables

THE COST OF

CLEAN WATER

Volume I

Summary Report

U. S. Department of the Interior
Federal Water Pollution Control Administration
January 10, 1968

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UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

Dear Mr. President:

This transmits our first report to the Congress on the national requirements and costs of water pollution control. Section 16(a) of the Federal Water Pollution Control Act, as amended, directs the Secretary of the Interior to conduct three studies - one, a study of the cost of carrying out the Federal Water Pollution Control Act, as amended; another, a study of the economic impact on affected units of government of the cost of installing waste treatment facilities; and the third, a study, summarized in the attached report, of the national requirements for and the cost of treating municipal, industrial, and other effluent to attain water quality standards established pursuant to the Act or applicable State law. These studies are required to cover the five-year period beginning July 1, 1968, and to be updated each year thereafter.

Today the Nation is embarked upon a more vigorous effort than ever before to abate water pollution. In enacting the Water Quality Act of 1965 and the Clean Water Restoration Act of 1966, the Congress greatly strengthened the ability of the Federal Government to lead a concerted attack on the pollution problem. Many States have recently strengthened their pollution control programs as well. The water quality standards currently being established are the keystone of this process; they will call for accelerated clean-up of our Nation's waters. The enclosed report, "The Cost of Clean Water," estimates the national requirements and the costs of attaining applicable water quality standards.

This report (Volume I) is a summary of the major findings and conclusions of what, in our view, is the most ambitious cost analysis on this subject yet undertaken. Within the next few weeks we will be transmitting the more detailed reports upon which these findings were based (Volume II, III, and IV).

The cost of water pollution control has been the subject of considerable discussion and controversy; we do not expect this report to settle conclusively this complex and difficult question. On the contrary, the report is only a starting point toward a better understanding; there are still many important gaps in our information. We expect the report to be widely reviewed and discussed, and are hopeful that those discussions will provide useful information for improving and refining next year's version.

As I have indicated, the attached study is one of several related studies mandated by the Congress. The studies of the economic impact on affected units of government and the cost of carrying out the Act will be transmitted to the Congress separately. A study of possible methods for providing pollution control incentives to industry will also be forthcoming. Together, these studies will represent a major step toward improving our understanding of the costs and related economic problems of water pollution control.

Sincerely yours,

Secretary of the Interior

Hon. Hubert H. Humphrey
President of the Senate
Washington, D. C. 20510

Enclosure

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Sincerely yours,

Secretary of the Interior

Hon. John W. McCormack
Speaker of the House of
Representatives
Washington, D. C. 20515

Enclosure

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INTRODUCTION

Section 16(a) of the Federal Water Pollution Control Act, as amended, directs the Secretary of the Interior to conduct a comprehensive analysis of the national requirements for and the cost of treating municipal, industrial, and other effluent to attain water quality standards established under the Act. This first analysis is required to be submitted to the Congress by January 10, 1968, to cover Fiscal Years 1969-1973, inclusive, and to be updated each year thereafter.

This study is extremely important because, although there is widespread agreement that water pollution is a significant and growing problem which must be dealt with, there are no firm estimates as to what the national requirements are or what it will cost to achieve a satisfactory abatement level. Several cost estimate studies of municipal needs have been conducted in the past but they have not been sufficiently comparable in geographical coverage, time phases covered, cost criteria, types of facilities included, or in cost estimate technique to provide a meaningful guide to the national requirements and costs involved. For example, one January 1966 report(1) estimated existing waste disposal needs and projected needs through 1972 at $3.9 billion for the 100 largest cities. A second 1966 report(2) estimated the total municipal treatment backlog at $2.6 billion for treatment plants, interceptors, and outfalls, and estimated the total need through 1972 at an average annual expenditure of $916 million or a total requirement of $6.7 billion for plant construction. A third study(3) provides historical data of construction put in place from 1955 through 1966, and a projection of requirements in 1966 dollars from 1967 through 1980. It estimates that municipal treatment plant construction for the 14-year period would cost $14.4 billion. Of this amount $3.7 billion represents the existing backlog and $10.7 billion is for replacing equipment.

Various other estimates have been made by other sources including some even more varied estimates of industrial waste treatment costs. These studies all contribute useful information, but as yet there has not been a generally acceptable estimate of the national costs of pollution control.

The present study represents the initiation of what will be a continuing evaluation, aimed at estimating water pollution control costs with increasing accuracy. Although it has not been possible to arrive at a completely definitive estimate of required costs, it is believed that the present study provides not only a more comprehensive cost estimate than has previously been developed but also a sound base of information upon which to build future analyses. This estimate is expected to improve in accuracy with each yearly updating.

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(1) Numbers in parentheses refer to references cited on page 39.

This is a summary report (Volume I). Detailed information to support its findings is contained in three appendix volumes, Volumes II through IV. Volume II (Detailed Analyses) contains descriptions and analyses of the various subject areas which formed the basis for the cost estimates in this summary report. Volume III (Industrial Waste Profiles) consists of 10 studies of major water-using industries which describe the costs and effectiveness of alternative methods of reducing industrial wastes. Volume IV (State and Major River Basin Municipal Tables) includes, for the 50 States and the Water Resource Council River Basins, tables showing the breakdown of estimated construction costs, sanitary sewers, and operation and maintenance costs.

SUMMARY AND CONCLUSIONS

This report presents initial estimates of the national requirements for and the cost of treating municipal, industrial, and other effluent during FY 1969-1973 to meet water quality standards established under the Act, and comparable levels for intrastate and coastal waters. Its findings are as follows:

1. The cost of constructing municipal waste treatment plants and interceptor sewers is estimated at $8.0 billion, exclusive of land and associated costs. This total includes $2.7 billion to provide adequate treatment to the urban population whose wastes do not receive any treatment at present; $1.9 billion to upgrade service to secondary treatment for the urban population whose wastes now receive primary treatment (excluding areas where primary treatment is likely to be adequate to meet water quality standards); $2.2 billion for urban population growth; and $1.2 billion for replacing facilities.

2. By 1973 the urban population required to be served will comprise about 75% of the total U. S. population. The estimated costs represent the capital outlays required to provide secondary treatment, or other appropriate treatment levels contained in the water quality standards, to all of this 1973 urban population (162.6 million people.) Currently, only 55% of the urban population is receiving adequate treatment. It is estimated that, to meet water quality standards by 1973, 90% of the urban population will require secondary treatment, and 10% primary treatment.

3. There may be significant opportunity for reducing the costs, as well as for contributing to more effective pollution control, through establishment of intermunicipal sewage treatment and disposal systems and districts. In many cases, however, it will be necessary to overcome existing institutional obstacles to develop effective arrangements for such systems.

4. Operation and maintenance costs for the required treatment works are estimated at $1.4 billion for the five-year period. Unlike annual construction costs, which can be expected to level off after the initial backlog has been eliminated, operation and maintenance costs

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will continue to rise as more sewage treatment plants are placed into operation.

5. There will be substantial additional costs incurred during the 1969-1973 period for the control of overflows from combined sewers. It is anticipated that a variety of control methods will be initiated depending upon individual circumstances and, as a result, the full extent of these costs cannot be estimated at this time.

6. Construction of sanitary collection sewers will require an estimated $6.2 billion over the next five years. These costs will be an integral part of necessary expenditures for waste disposal by the communities involved.

7. Initial estimates indicate that the cost of treating industrial wastes to a level comparable to secondary treatment of municipal wastes will be in the range of $2.6 billion to $4.6 billion. This includes $1.8 to $3.6 billion for new industrial treatment works and $0.8 billion to almost $1.0 billion for replacing equipment. However, these estimates are based upon the minimal levels of control generally considered necessary to comply with water quality standards. Should implementation of the standards involve establishing industrial requirements calling for higher levels of waste reduction, these cost estimates could rise sharply.

8. There are significant opportunities for meeting industrial waste abatement requirements more efficiently through better in-plant controls and process changes, and joint municipal and industrial treatment systems.

9. Estimated costs of operating and maintaining industrial waste treatment facilities will range from $3.0 billion to $3.4 billion over 1969-1973. As in the case of sewage treatment works, these costs will continue to rise with increases in plant in place.

10. Costs for constructing, operating and maintaining heat dissipation equipment will be considerable. However, it is not possible to estimate the costs required to comply with water quality standards because of lack of information on the application of temperature criteria and the effect of heat discharges on existing water temperatures. Some indication of the upper limits of such outlays is the estimate of costs to reduce cooling water after use to its original temperature. Capital outlays in the

1969-1973 period to attain complete temperature restoration would be $1.8 billion. This includes $1.6 billion for new cooling facilities and $0.2 billion for replacing equipment. Operation and maintenance would amount to an additional $0.9 billion over the five-year period. In actual practice, a lesser overall temperature reduction - and a portion of the cost - may well prove adequate.

11. Other effluents will increase in significance as municipal and industrial wastes are brought under control. Additional costs for controlling a wide range of other pollutants, such as sediment, acid mine drainage, and animal feedlot runoff, will be incurred during the five-year period, but these costs cannot be estimated accurately at this time. Over the long run, these sources will require heavy expenditures for pollution control.

NOTE: The above projected costs are expressed in constant dollars. "Constant 1968 dollars" were developed by using July 1967, the beginning of Fiscal Year 1968, as the base. "Current dollars" were developed by multiplying the 1968 "constant dollar" estimates over the FY 1969-1973 time frame by projected cost indexes for each year.

Assuming a continuation of past cost increases, the dollar costs would be proportionally higher. Costs of municipal waste treatment works could rise from $8.0 billion to $8.7 billion; industrial waste treatment facility costs could rise from the $2.6 to $4.6 billion range to the $2.9 to $5.1 billion range. Operation and maintenance costs in current dollars would also rise: municipal waste treatment from $1.4 billion to $1.7 billion and industrial waste treatment from the $3.0 to $3.4 billion range to the $3.2 to $3.6 billion range.

ASSUMPTIONS AND METHODS

Ideally, the costs required to attain water quality standards should be based upon a reasonably accurate knowledge of the treatment requirements of individual municipalities and industrial plants as expressed in the implementation plans which are an integral part of the water quality standards. The national requirement and cost would be the total of the individual costs calculated by this means. However, this initial study was undertaken during the period when most of the standards were being reviewed and changes negotiated with the states. Because of the unavailability of approved water quality standards and data relating to specific municipal and industrial treatment needs, certain assumptions had to be made as to the standards and aggregative techniques had to be used to develop these cost estimates.

In order to estimate the costs of carrying out waste treatment requirements embodied in standards still being negotiated, it was necessary to assume a given level of treatment as generally representative of that contained in the standards. It was assumed that a conventional secondary treatment level (at least 85% effective removal of normal (five-day) biochemical oxygen demand for normal domestic sewage) would prevail for treating municipal wastes with some exceptions which are described later. This is in conformity with the policy reflected in Guideline No. 8 of the Federal Water Pollution Control Administration's May 1966 publication "Guidelines for Establishing WATER QUALITY STANDARDS for Interstate Waters" which reads:

> No standard will be approved which allows any wastes amenable to treatment or control to be discharged into any interstate water without treatment or control regardless of the water quality criteria and water use or uses adopted. Further, no standard will be approved which does not require all wastes, prior to discharge into any interstate water, to receive the best practicable treatment or control unless it can be demonstrated that a lesser degree of treatment or control will provide for water quality enhancement commensurate with proposed present and future water uses.

The validity of this assumption is reflected by the fact that the 10 state standards approved as of December 1, 1967, provided for secondary treatment for all discharges to fresh water. At the same time, however, the basic assumption of secondary treatment of municipal wastes was made in full recognition that there are some states where primary treatment may be adequate or where secondary treatment may be inadequate during the period FY 1969-1973.

Cost estimates presented here have been adjusted to reflect standards and plans currently under review which may reasonably be expected to require less than secondary treatment for certain major municipalities during the FY 1969-1973 period and which, accordingly, lowered cost requirements significantly.

A current inventory of municipal waste treatment facilities does not exist. Accordingly, to estimate required municipal treatment costs it was necessary to update the 1962 municipal waste facilities inventory[4] by taking into account subsequent Federal grants for sewage treatment works. It is estimated that Federal grants were involved in works which accounted for approximately 60% of the total investment in treatment facilities since 1962. This provided a serviceable estimate of the present status of municipal treatment facilities upon which to project needs and costs over the next five years. The aggregated costs of upgrading treatment levels from primary to secondary levels, providing secondary treatment where none now exists, and meeting the additional needs expected by population increases through 1973, were developed by applying actual Federal construction grant project costs for appropriate design populations.

Estimating industrial pollution control costs presented even greater difficulty because of the lack of a current inventory of wasteloadings from industrial sources, the wide range of industrial pollutants and pollutant sources, and the scarcity of data on existing industrial treatment facilities, unmet needs, and industrial treatment costs. For the purposes of this study projected treatment needs and cost estimates to attain the equivalent of secondary treatment were developed by using two methods. One method involved estimating existing treatment facilities by reference to reported treatment application in the 1963 Bureau of the Census' Water Use in Manufacturing[5], and applying established cost factors for conventional waste treatment requirements[6]. The other costing method was based upon economic/engineering studies of specific industrial groups and expert estimates of the prevalence of industrial treatment[7].

A second major assumption made in arriving at the cost estimates is that the required municipal and industrial waste treatment would be provided by the end of FY 1973. This is consistent with implementation plans of most state standards approved or approaching approval.

It was necessary also to set a fixed time period in which to assess costs because cost estimates to attain a given level of water quality will change with the time frame. For example, if the funding period for a construction project were extended from five to ten years, the annual costs would be lower but the total cost would be increased because of accumulated interest charges and probable increased construction costs.

The cost of municipal waste treatment construction works was phased proportionately over the five-year period. This procedure was used to illustrate possible annual increments and to serve as a basis for estimating annual depreciation and annual construction cost increases, although it is recognized that construction would not actually occur at a fixed rate. Where available annual cost estimates are shown in Table 1.

Because of the aggregative analytical techniques used, it was not possible to confine these cost estimates to interstate and coastal waters to which the Act applies; therefore, the cost estimates presented in this report are national in scope. Many states are moving to set standards for intrastate streams, and it appears realistic to assume that these standards will be comparable with standards set for interstate and coastal waters. It, therefore, was both logical and necessary to develop the national estimates presented in this report on the basis of representative treatment levels included in the water quality standards.

Although the estimated costs are expressed primarily in terms of constant dollars, the effects of possible construction costs increases are also shown. It was assumed that the rising cost trend over the last several years would continue during the next five years. Increases in municipal treatment plant construction costs were calculated over the FY 1969-1973 period by projecting increases for each of 20 cities, constructing index figures for each of the states, and using the 1950-1967 period as the historic base for the projections with trends since 1960 given particular emphasis.

Possible rises in industrial treatment plant construction costs were based upon an assumed average annual 3.6% increase over the next five years. Construction costs, reported regularly by ENGINEERING NEWS RECORD in its "Index of Construction Costs", have risen steadily since World War II. This annual rate of increase was presumed to apply over the next five years since this has been the average rate for the decade that began in FY 1958.

These national cost estimates represent the best figures that could be developed with available data. The unavoidable uncertainties in the estimates emphasize the necessity for continuing to seek more accurate inventory data on all sources of wastes. The water quality standards and the improved state program plans being developed under Section 7 of the Act will provide much valuable information for future updating and improvement of these estimates. Further, the accuracy of these initial estimates should be improved after they have been reviewed by the various state and interstate water pollution control agencies. Although much of the data upon which the cost estimates are based were derived from state sources, the states have not as yet participated formally in these evaluations.

TABLE 1. *ESTIMATED CASH OUTLAYS TO MEET PROJECTED WASTE TREATMENT,* SANITARY SEWERS, AND WATER COOLING REQUIREMENTS, FY 1969-1973[1/]

($ Millions)

Requirements	Constant 1968 Dollars					Five-year Total	
	1969	1970	1971	1972	1973	Constant 1968 Dollars	1969-1973 Current Dollars
Capital Requirements:							
Municipal treatment works							
New construction	1400	1400	1400	1400	1400	6800	7400
Replacement	170	210	250	290	330	1200	1300
Sub-total	1500	1600	1600	1600	1700	8000	8700
Sanitary sewer construction	1200	1200	1200	1200	1200	6200	6700
Industrial treatment plants[2/]							
New construction	330- 680	350- 710	370- 730	380- 740	380- 740	1800- 3600	2000- 4000
Replacement	130- 120	140- 160	160- 190	180- 230	200- 270	820- 970	920- 1100
Sub-total	460- 800	500- 860	540- 920	560- 970	580-1000	2600- 4600	2900- 5100
Industrial cooling							
New construction	300	310	320	330	330	1600	1800
Replacement	19	31	43	56	69	220	250
Sub-total	320	340	360	380	400	1800	2000
Total capital outlays	3500-3900	3600-4000	3700-4100	3800-4200	3900-4300	19000-21000	20000-23000
Operation and Maintenance Requirements:							
Municipal treatment works	210	250	280	310	340	1400	1700
Industrial treatment plants[2/]	490- 450	540- 570	610- 680	670- 800	730- 920	3000- 3400	3200- 3600
Industrial cooling plants	79	130	180	230	280	890	950
Total operation & maintenance costs	780- 750	920- 940	1100-1100	1200-1300	1400-1500	5300- 5700	5800- 6200
Total Cash Outlays	4300-4600	4500-4900	4800-5300	5000-5600	5200-5900	24000-26000	26000-29000

1/ Not including possible expenditures for control of storm water or combined sewer overflows.

2/ Industrial treatment plant capital requirements and the associated operation and maintenance requirements are shown in probable ranges of estimated cash outlays.

Note: Detail figures may not add to totals due to rounding.

Source: Detailed analyses supporting the data contained in this Table may be found in Volume II of the Study.

MUNICIPAL POLLUTION

PLANT AND EQUIPMENT INVESTMENT

It is estimated that municipal waste treatment plant and interceptor sewer construction costs to attain water quality standards in the five-year period, FY 1969-1973, will require the expenditure of $8.0 billion. (See Table 2). Increasing costs of construction during the period could expand the total national cost to $8.7 billion.[1] This estimate, which does not include land costs, accommodates costs of upgrading present treatment facilities, constructing new facilities for the presently unserved urban population, providing for population growth and replacing obsolete facilities over the next five years.

The urban population of the United States is estimated at about 146 million persons in FY 1968. Of this total, about 82 million people presently have adequate treatment facilities, almost 32 million have less than adequate facilities, and slightly more than 32 million have no treatment facilities whatsoever. (See Table 3). Eliminating unmet needs will cost an estimated $4.6 billion. This includes $1.9 billion to upgrade presently inadequate treatment facilities and $2.7 billion to provide facilities where none now exists.

The current U. S. urban population is projected to increase by 17 million in the next five years - from about 146 million in FY 1968 to 163 million in FY 1973 with an additional increase of 25 million persons expected by 1978. If this increase follows the same pattern of urbanization that took place in the 1950-1960 decade, and additional capacity in new plant construction is included for population growth to 1978, additional capital outlays of about $2.2 billion will be required by FY 1973.

Replacement of plant and equipment is a continuing capital charge which is estimated at $1.2 billion over the next five years.

Table 2 lists the breakdown of construction costs by state. Federal construction grants, as provided for by Section 8 of the Federal Water Pollution Control Act, as amended, are made to states, municipalities, and interstate agencies. Estimates of state needs provide the most practical initial breakdown in describing where the treatment needs are, what the estimated costs are and, accordingly, the possible extent of Federal expenditures required. The ten states ranking highest in capital outlays required to attain adequate waste treatment by 1973 are, in order: New York - $963.6 million, California - $645.2 million, Michigan - $535.8 million, New Jersey -

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[1] *See second paragraph on page 8.*

TABLE 2. CAPITAL OUTLAYS NEEDED TO OBTAIN ADEQUATE MUNICIPAL WASTE TREATMENT FOR THE U. S. URBAN POPULATION, FY 1969-1973

($ Millions)

State	Total (Current Dollars)	Total (Constant Dollars)	Upgrading of Facilities	Constructing Facilities For Untreated Wastes	Increases In Urban Population 1/	Allowances For Depreciation
U.S.	8,693.1	7,994.0	1,868.7	2,707.4	2,182.5	1,235.4
Ala.	137.0	131.0	33.0	39.0	42.0	17.0
Alaska 2/	14.5	12.8		7.0	5.0	.8
Ariz.	90.0	84.0	4.0	25.5	44.0	10.5
Ark.	48.5	45.5	12.0	4.5	20.0	9.0
Calif 2/	732.2	645.2	2.0	370.5	150.5	122.2
Colo.	103.6	97.6	26.0	18.0	40.5	13.1
Conn.	188.3	175.8	69.5	50.0	36.5	19.8
Del.	31.5	30.1	13.0	4.5	9.5	3.1
D.C 3/	23.0	21.4			8.0	13.4
Fla 2/	369.6	347.0	46.0	191.5	68.0	41.5
Ga.	223.1	209.6	53.5	60.5	69.0	26.6
Hawaii 2/	40.1	35.5		27.5	4.5	3.5
Idaho	24.5	23.0	10.5	2.5	6.5	3.5
Ill.	399.4	367.0	48.0	102.2	136.0	81.0
Ind.	176.1	162.1	39.5	45.5	45.0	32.1
Iowa 2/	36.0	34.7			15.5	19.2
Kans.	52.5	49.6	14.5	.5	22.5	12.1
Ky.	130.0	120.8	39.0	24.5	40.5	16.8
La.	195.0	182.1	21.0	80.5	63.0	17.6
Maine	47.0	43.9	6.0	31.5	3.0	3.4
Md.	136.1	128.4	11.0	45.5	53.0	18.9
Mass 2/	200.0	186.3	64.0	78.5	10.0	33.8
Mich.	592.6	535.8	223.0	144.5	103.5	64.8
Minn.	186.0	172.4	64.5	32.5	49.5	25.9
Miss.	57.0	54.1	3.0	24.0	22.0	5.1
Mo 2/	137.6	126.8	13.0	45.4	50.5	17.9
Mont.	27.0	25.5	16.0		6.0	3.5
Nebr 2/	30.5	29.0	9.9		11.5	7.6
Nev.	19.5	18.1	1.0	.5	13.0	3.6
N.H.	35.0	32.6	7.5	16.0	6.0	3.1
N.J.	561.1	505.0	167.0	161.0	113.5	63.5
N. Mex.	40.5	37.6	1.0	5.5	23.5	7.6
N.Y.	1,070.2	963.6	266.0	390.5	204.0	103.1
N.C.	101.5	95.6	16.0	22.5	36.0	21.1
N. Dak.	13.0	11.3	2.5	4.0	2.5	2.3
Ohio	500.7	461.7	122.0	134.5	131.5	73.7
Okla.	60.5	57.4	10.5	6.0	25.5	15.4
Oreg.	145.3	130.2	29.5	41.5	44.0	15.2
Pa.	331.6	310.9	149.5	27.5	53.5	80.4
R.I.	41.5	38.3	9.5	17.5	5.5	5.8
S.C	100.0	93.9	19.0	35.5	27.0	12.4
S. Dak.	14.0	12.5	5.0		4.0	3.5
Tenn.	154.6	147.8	19.5	68.0	43.5	16.8
Tex.	342.5	323.6	17.0	81.0	155.5	70.1
Utah	136.0	127.4	2.0	88.0	26.0	11.4
Vt.	19.0	17.7	10.0	3.0	2.5	2.2
Va 3/	206.6	194.7	65.0	47.0	59.0	23.7
Wash 2/	173.3	155.3	33.0	84.5	19.0	18.8
W. Va	55.0	50.4	25.0	13.5	5.5	6.4
Wis.	133.3	122.4	47.0	3.5	42.0	29.9
Wyo 2/	9.7	9.0	2.3	.5	4.5	1.7

1/ Includes construction costs for additional capacity for five years of population growth in each State beyond the 1969-1973 period of the cost estimate of needs.

2/ Water quality standards adopted call for primary waste treatment in some urban areas of this State. Standards adopted for other States call for at least secondary waste treatment.

3/ Capital outlays shown for construction of treatment works to serve population in Virginia may actually occur in the District of Columbia with service provided to the Virginia population under contract.

Source: Based on 1962 Inventory of Municipal Waste Treatment, updated; Census of Population, 1960; Bureau of Census Population Estimates, Series P-25.

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TABLE 3. URBAN POPULATION SERVED BY ADEQUATE AND LESS THAN ADEQUATE MUNICIPAL WASTE TREATMENT FACILITIES AND URBAN POPULATION NOT SERVED, BY STATE: FY 1968

(In thousands, except percent)

State	Total Urban Population	Population Served By (Facilities): Adequate	Less than Adequate	None	% of Pop. with less than Adequate or None
U.S 1/	145,602	81,703	31,865	32,293	44.1
Ala.	2,140	819	678	643	61.7
Alaska 2/	121	19		102	84.2
Ariz.	1,411	711	34	666	49.6
Ark.	937	684	156	97	27.0
Calif 2/	17,651	12,766	36	4,849	27.7
Colo.	1,602	854	593	155	46.7
Conn.	2,342	312	1,286	744	86.7
Del.	356	9	267	80	97.5
D.C.	832	832			
Fla 2/	4,860	1,741	864	2,255	64.2
Ga.	2,727	1,081	1,003	643	60.4
Hawaii 2/	591	162		429	72.6
Idaho	349	160	134	55	54.2
Ill.	8,923	7,410	586	927	17.0
Ind.	3,182	2,286	529	367	28.2
Iowa 1/ 2/	1,526 1/	1,590		1/	
Kans 2/	1,475	1,267	192	16	14.1
Ky.	1,539	536	792	211	65.2
La.	2,479	818	515	1,146	67.0
Maine	509	37	60	412	92.7
Md.	2,785	2,119	162	504	23.9
Mass 2/	4,563	1,729	1,173	1,661	62.1
Mich.	6,377	1,340	4,223	814	79.0
Minn.	2,370	769	1,324	277	67.6
Miss.	988	460	23	505	53.4
Mo 2/	3,141	2,522	183	436	19.7
Mont 1/	379 1/	123	263	1/	69.4
Nebr 1/ 2/	846	833	100	1/	11.8
Nev.	376	366	6	4	2.7
N.H.	414	43	102	269	89.6
N.J.	6,444	1,629	3,179	1,636	74.7
N. Mex.	764	671	5	88	12.2
N.Y.	16,003	8,017	3,733	4,253	49.9
N.C.	2,138	1,447	125	566	32.3
N. Dak 1/	254 1/	278	15	1/	5.9
Ohio	7,870	4,591	2,071	1,208	41.7
Okla.	1,694	1,332	199	163	21.4
Oreg.	1,320	552	504	264	58.2
Pa.	8,428	5,325	2,916	187	36.8
R.I.	793	395	190	208	50.2
S.C.	1,134	540	178	416	52.4
S. Dak 1/	287 1/	290	39	1/	13.6
Tenn.	2,214	750	319	1,145	66.1
Tex.	8,874	6,819	130	1,925	23.2
Utah	825	500	19	306	39.4
Vt.	162	9	121	32	94.4
Va.	2,756	1,092	1,328	336	60.4
Wash 2/	2,139	681	444	1,014	68.2
W. Va.	710	149	348	213	79.0
Wis.	2,804	2,049	689	66	26.9
Wyo 1/ 2/	198 1/	189	29	1/	14.6

1/ Population served by treatment facilities exceeds total urban population of these States by 259,000 persons. Thus the detail adds to 259,000 more than the total U. S. urban population.

2/ Water quality standards adopted call for primary waste treatment in some urban areas of this State. Standards adopted for other States call for at least secondary waste treatment.

Source: 1962 Inventory, Municipal Waste Facilities in the United States, updated by FWPCA Construction Grants Awards; urban population estimates based on U. S. Census of Population, 1960; Bureau of Census Population Estimates, Series P-25.

$505.0 million, Ohio - $461.7 million, Illinois - $367.0 million, Florida - $347.0, Texas - $323.6 million, Pennsylvania - $310.9 million, and Georgia - $209.6 million.

Table 4 lists the breakdown of construction costs by Water Resources Council regions. This provides a broader picture than the state-by-state breakdown of required capital expenditures for municipal treatment and relates directly to similar regional estimates of capital expenditures for industrial waste treatment. This breakdown also provides information needed by the Water Resources Council for its report[8] on the adequacy of the Nation's water supplies in the 20 major river basins, as defined by the Council. (Section 102 of the Water Resources Planning Act requires the Council to prepare such a national assessment.) The five Water Resources Council Regions ranking highest in capital outlays required to attain adequate waste treatment by 1973 are, in order: North Atlantic, Great Lakes, South Atlantic Gulf, California, and Ohio.

Table 5 shows the per capita construction costs of primary types and secondary types of sewage treatment plants. Per capita costs fall sharply from the smaller to the larger plants. These data are based on design and cost information for sewage treatment projects constructed in all parts of the Nation with Federal construction grant assistance. Costs of treatment plants and interceptor and outfall sewers are included but land costs, which are not covered by the Federal grant program, have been excluded. The per capita costs are shown in constant dollars, using the FWPCA Sewage Treatment Plant Construction Cost Index.

Per capita costs reflected in Table 5 played an important part in computing the overall cost estimates but there can be considerable variation in such costs. In this study municipal waste treatment plant capital costs were based upon plants using activated sludge systems. Different cost figures would have resulted had capital costs for plants using trickling filters been used instead. In addition, there may be significant differences in construction costs in different parts of the country. For example, some New England states have reported per capita construction costs well in excess of those shown in this table. To the extent that actual per capita costs for a given treatment method or geographical area are significantly different than per capita costs utilized in this study, the costs shown in this study would be proportionately different. Accordingly, as this report is updated, it may be necessary to examine per capita costs for different types of treat- and for different states or regions.

It is evident from these data that it is more economical in terms of cost per person served to construct a large plant rather than a small plant, assuming other things are equal. This conclusion assumes excessive sewering costs are not incurred, the topography is suitable for the extension of sewers, that receiving streams can assimilate adequately the discharges from a large single treatment source, and the economies of scale available by con-

TABLE 4. CAPITAL OUTLAYS NEEDED TO OBTAIN ADEQUATE MUNICIPAL WASTE TREATMENT FOR THE U. S. URBAN POPULATION, BY WATER RESOURCE REGION, FY 1969-1973

($ Millions)

Water Resource Region[1/]	Total (Current Dollars)	Total (Constant Dollars)	Upgrading of Facilities	Constructing Facilities For Untreated Wastes	Increases In Urban Population[1/]	Allowances For Depreciation
United States	8,693.1	7,994.0	1,868.7	2,707.4	2,182.5	1,235.4
Alaska	14.5	12.8		7.0	5.0	.8
Arkansas-White-Red	229.9	216.5	41.9	39.4	92.2	43.0
California	735.2	647.8	2.6	371.3	151.4	122.5
Columbia-North Pacific	349.1	314.4	77.6	127.7	70.7	38.4
Great Basin	130.8	122.4	2.3	79.4	28.9	11.8
Great Lakes	1,164.3	1,059.2	376.3	285.7	246.0	151.2
Hawaii	40.1	35.5		27.5	4.5	3.5
Lower Colorado	108.0	100.8	4.7	29.5	53.3	13.3
Lower Mississippi	232.9	219.1	25.4	97.7	73.7	22.3
Missouri	250.4	234.0	61.5	38.0	91.8	42.7
North Atlantic	2,611.0	2,392.2	746.6	801.6	512.1	331.9
Ohio	728.3	674.6	205.8	172.3	180.7	115.8
Rio Grande	64.7	60.5	2.6	11.9	33.4	12.6
Souris-Red-Rainy	10.2	9.0	2.5	2.6	2.2	1.7
South Atlantic-Gulf	978.6	921.9	172.5	367.7	259.3	122.4
Tennessee	62.9	60.1	8.9	25.5	18.3	7.4
Texas-Gulf	295.7	279.3	14.6	69.5	134.8	60.4
Upper Colorado	14.7	13.8	1.3	6.2	4.6	1.7
Upper Mississippi	671.8	620.1	121.6	146.9	219.6	132.0

1/ Water Resource Regions proposed by Water Resource Council for Type I Comprehensive Surveys. Data was not available to estimate capital outlays needed for the Puerto Rico-Virgin Islands Region.

Source: Based on 1962 Inventory of Municipal Waste Treatment, updated; Census of Population; 1960 Bureau of Census Population Estimates, Series P-25.

TABLE 5. SEWAGE TREATMENT WORKS CONSTRUCTION PER CAPITA COST 1/
(TOTAL PLANT, INTERCEPTORS AND OUTFALLS)

(1968 Dollars)

Design Population	Primary Types of Treatment	Secondary Types of Treatment	
		Activated Sludge	Stabilization Ponds 2/
0 - 999	$148	$175	$85
1,000 - 4, 999	96	117	57
5, 000 - 9, 999. . . .	68	86	29
10, 000 - 24, 999	54	69	14
25, 000 - 49,999	43	56	
50, 000 - 99, 999	35	45	
100, 000 - and up	30	40	

1/ Does not include land costs.
2/ Uniform cost States: North Carolina, South Carolina, Georgia, Alabama, Kansas, Washington.

Source: Based upon the design and actual cost information of sewage treatment projects constructed under P. L. 84-660.

structing a larger or an intermunicipal plant are not offset by other factors.

Total treatment works construction costs in a particular area may be reduced on a per capita basis when it is possible and desirable to serve many communities with a single or a few large treatment works. Economies of scale also may be available when industries and communities jointly construct treatment works to serve their needs. Achieving economies of scale in waste treatment plants can reduce local and national water pollution control costs and this emphasizes the importance of joint community-industry water pollution control participation. In many cases, however, it would be necessary to overcome existing institutional obstacles to develop effective arrangements for such systems.

Sewage treatment plant design normally provides for sufficient capacity to accommodate additional quantities of sewage resulting from population and industrial growth. According to Fair and Geyer[9] many factors are considered before deciding upon a design period for treatment works. Among these factors are obsolescence, depreciation, location, anticipated rate of growth of population and industry, rate of interest that must be paid on bonded indebtedness, future construction costs, and the performance of the works during early years when the plant is operated below capacity. (Today an additional factor is an increased awareness of the need to meet water quality standards.) The authors have estimated that when growth and interest rates are high, the design periods for treatment works may amount to 10 to 15 years. Because of the many variables involved in arriving at average excess treatment plant capacity included in plant designs and the unavailability of current excess capacity data, a plant design period for growth has been estimated as five years. Therefore, construction of waste treatment plants in the period FY 1969-1973 includes the cost of additional capacity for population growth to 1978.

Estimates of construction of waste treatment work costs presented in this report are based on total costs eligible for Federal grants assistance. These are costs incurred in constructing new sewage treatment works or additions to or extensions, alterations, acquisitions and improvements of already existing treatment works; costs for necessary intercepting sewers, outfall sewers, pumping, power, and other equipment; costs for preliminary planning and other actions necessary to construct sewage treatment works such as engineering, legal and fiscal investigations, studies and designs, including the supervision and inspection of construction.

Costs not eligible for FWPCA construction grants assistance include the cost of the site of land on which the sewage treatment works is to be built; the costs for sewage collection systems (intercepting and outfall sewers are not considered to be part of the collection system); and the cost of any work not approved by the Department of the Interior. These ineligible costs, in many cases, present a considerable financial burden to the community, particularly in large metropolitan areas where land costs are high. When it is not possible to isolate treatment works from residential and industrial areas, the cost of the project is increased by the need to landscape, beautify or relocate public and private buildings. New streets, viaducts and costs of rights-of-way add to these ineligible costs. The amount of landscaping, beautification and relocation carried out depends upon each community's financial capability, the aesthetic values involved, and opportunities to shift or delay such costs.

OPERATION AND MAINTENANCE

Costs incurred in operating and maintaining the nation's waste treatment plant to achieve adequate waste treatment for the population by the end of FY 1973 are estimated at $1.4 billion. This estimate could be changed by significant changes in wasteloads from industrial sources.

The estimate is based upon the actual labor and supply costs associated with plant operation and maintenance, but excludes administrative and capital maintenance costs. Although the cost estimate lacks precision, primarily because of differing plant efficiencies, it indicates, nevertheless, that operating costs ultimately could be a greater financial burden upon a local unit of government than the construction cost itself. (Federal grants do not provide for supporting operation and maintenance costs and only a few states either provide such grants now or plan to do so.) This is an important point because with the greater number of plants in place in future years, annual capital costs will level off after the backlog is met while operating costs will continue to rise because of the larger plant treatment facilities in place which will require operation and maintenance.

Many existing waste treatment plants are not being operated effectively and, therefore, are achieving a lesser degree of waste removal than they are capable of attaining. This is a problem area to which continued and intensified research and training efforts should be put.

For example, waste removal efficiency is low in many cases because of inadequate operation by the plant operator or understaffing of treatment plants. The solution rests largely with improving operator capability by providing necessary technical assistance and assuring that present and future requirements for trained treatment plant operators are met. A recent study by the FWPCA[10] indicated that there are major deficiencies in this area, stemming from inadequate training levels, salaries and conditions of employment. These deficiencies must be overcome if a satisfactory level of operational efficiency is to be reached and maintained.

Removal efficiency may be increased by more effective use of currently available treatment methods or by other methods now under study. For example, under an FWPCA research and development grant, a Cleveland, Ohio municipal treatment plant is being used in a pilot study of the possibilities of increasing removal efficiency by using relatively new polyelectrolytes - coagulating chemicals which can increase the effectiveness of sewage purification.

CONTROL OF COMBINED SEWER OVERFLOWS

In addition to construction and operation of municipal waste treatment plants, considerable expenditures will be made to control overflows from combined storm and sanitary sewers during the next five years. The problem arises when the volume of flow, caused by excessive precipitation or snowmelt, exceeds the capacity of the treatment plant and wastewater is allowed to bypass the plant without being treated. This is a more serious problem in many of our older cities where combined storm and sanitary sewers predominate than in the newer cities which are more likely to have separate sewer systems.

Separation of combined sewers has been considered as the principal method of controlling the problem. However, the cost of separating sewers completely would be enormous. It has been estimated at about $49 billion. Moreover, this is not a feasible solution, either from the viewpoint of cost or effectiveness in solving the problem. Sewer separation would involve major and prolonged disruptions to traffic, other street activities, and in utility use because new sewer lines would have to be built in city streets beneath which are electric conduits, water and gas mains, telephone and telegraph conduits, and building service connections for other utilities. Further, studies have shown that urban stormwater itself, even when separated, is a serious pollution source. It is clear, therefore, that sewer separation in itself would not provide a complete answer to the combined sewer overflow problem.

In the next several years we can expect substantial efforts in the direction of partial separation and other control methods. For example, New York City has announced plans to handle the storm overflow problem by constructing, at an estimated cost of $460 million, 30 small wastewater treatment plants located throughout the city. The purpose of these plants would be to treat the large volumes of water which overload the city's sewer system during overflow periods. This method and several other methods for controlling storm overflows are under study and development. Many of these studies are being supported by research and development grants authorized under Section 6 of the Act.

Unquestionably, large costs will be incurred during the FY 1969-1973 period in controlling combined sewer overflows. However, meaningful estimates of the cost of substantial elimination of the problem cannot be predicted at this time.

COLLECTION SEWERS

A collection sewer is one which collects and transports waterborne wastes through an interceptor sewer to the sewage treatment plant after which the treated effluent is discharged to the receiving waters. Interceptor sewers have been included in the estimate of waste treatment needs but collecting sewers have been excluded. However, in practice the distinction between an interceptor sewer and a trunk collecting sewer must be made on almost a case-by-case basis to determine eligibility for FWPCA grant funds.[2]

The estimated cost for installing new collection sewers is placed at about $6.2 billion. Of this amount, about $3.9 billion would be required for providing sewers to the presently unsewered population and an estimated $2.3 billion would be spent to accommodate urban population growth during the FY 1969-1973 period.

The costs of providing collection sewers for the urban population presently unsewered and the expected increase in urban population are shown for the period FY 1969-1973 in order to put these needs in the same time frame as municipal waste treatment needs. These capital costs have been included in this study because of their fundamental relationship to the water pollution control problem.

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[2] *The inclusion of collection sewers in some studies of municipal treatment costs has resulted in some incompatibility in cost estimates of water pollution control costs.*

INDUSTRIAL POLLUTION

Manufacturing is the principal source of controllable waterborne wastes. In terms of the generally quoted measurements of strength and volume, wastes of manufacturing establishments are about three times as great as those of the Nation's sewered population. Moreover, the volume of industrial production, which gives rise to industrial wastes, is increasing at about 4.5% a year or three times as fast as the population.

Table 6 shows reported quantities of industrial wastewater discharged in 1963 and FWPCA estimates of the quantities of standard biochemical oxygen demand (BOD_5) and settleable and suspended solids contained in the wastewater. The wasteload estimates, based upon an estimate of the "average" quantity of pollutant per product unit, indicate that the chemical, paper, and food and kindred industries generated about 90% of the BOD_5 in industrial wastewater before treatment.

Many industrial wastes differ markedly in chemical composition and toxicity from wastes found in normal domestic sewage. Thus, the BOD_5 or solids content often is not an adequate indicator of the quality of industrial effluents. For example, industrial wastes frequently contain persistent organics which resist secondary treatment procedures applied normally to domestic sewage. In addition, some industrial effluents require that specific organic compounds be stabilized or that trace elements be removed as part of the treatment process.

PLANT AND EQUIPMENT INVESTMENT

The minimum investment required to attain water quality standards by FY 1973 for major water-using industrial establishments is estimated to be in the $2.6 billion to $4.6 billion range (Table 7).[3] Increasing costs of construction during the five-year period could expand the $2.6 to $4.6 billion range to the $2.9 to $5.1 billion range. These estimates are based upon the assumption that industries generally will have to provide a level of treatment of industrial wastes equivalent to secondary treatment of municipal wastes.

For analytical purposes, the equivalent of secondary treatment of municipal wastes for industrial wastes was assumed to involve 85% removal of BOD_5 and

[3] *The range of costs presented in this section derives from the lower cost estimates based upon expert estimates in the Industrial Waste Profiles, (Volume III) and the higher cost estimates which are based upon analysis of the Bureau of the Census' 1963 publication, Water Use in Manufacturing.*

TABLE 6. ESTIMATED VOLUME OF INDUSTRIAL WASTES BEFORE TREATMENT, 1963

Industry	Wastewater, billion gallons	Standard Biochemical Oxygen Demand, million pounds	Settleable and Suspended Solids, million pounds
Food and Kindred Products	690	4, 300	6, 600
Textile Mill Products	140	890	not available
Paper and Allied Products	1, 900	5, 900	3, 000
Chemical and Allied Products	3, 700	9, 700	1, 900
Petroleum and Coal	1, 300	500	460
Rubber and Plastics	160	40	50
Primary Metals	4, 300	480	4, 700
Machinery	150	60	50
Electrical Machinery	91	70	20
Transportation Equipment	240	120	not available
All Other Manufacturing	450	390	930
All Manufacturing	13, 100	22, 000	18, 000
For comparison: sewered population of U. S.	5, 300 1/	7, 300 2/	8, 800 3/

1/ 120, 000, 000 persons x 120 gallons x 365 days
2/ 120, 000, 000 persons x 1/6 pounds x 365 days
3/ 120, 000, 000 persons x 0. 2 pounds x 365 days

of settleable and suspended solids. It must be recognized that this value has no application to any specific situation - a substantially greater or lesser efficiency may be required in many cases. At the same time it is believed that this will be the minimal average national treatment level which will be in accordance with water quality standard implementation plans.

The outlay (constant dollars) ranging from $2.6 billion to $4.6 billion to attain this specified industrial treatment level by 1973 includes three components - the estimated costs of meeting current unmet needs ($1.1 to $2.6 billion), accommodating industrial growth through FY 1973 ($0.7 to $1.0 billion), and replacing equipment ($0.8 to $1.0 billion). (See Table 7.)

Investment required to meet current unmet industrial treatment needs ranges from $1.1 to $2.6 billion in constant dollars. In effect, this is the estimated existing backlog which must be overcome. Current requirements broken down by industry are reflected in Table 8. Primary metal industries, for example, require the largest investment to attain the prescribed treatment level. Table 9 shows the breakdown, by Water Resource Council region, of the estimated $1.1 to $2.6 billion capital investment required to eliminate current needs. The North Atlantic Region, for example, requires the largest estimated capital expenditure - $210 to $530 million - to attain the equivalent of secondary waste treatment, as defined, of its industrial wastes.

As indicated earlier, many industrial wastes are characterized by pollutants more difficult to treat than municipal wastes and, as a result, are not treated adequately by conventional secondary treatment procedures applied to domestic sewage. The required treatments, and associated costs, cannot be fully evaluated because of the limited state of current information on treatment requirements for specific industry wastewaters. For the purposes of making these estimates, 85% removal of BOD_5 and of settleable and suspended solids has been selected recognizing that this treatment level may not be adequate in many cases. It is known that the costs of treatment rise sharply when applied at higher levels of waste removal. Some general idea of the major nature of potential increases in total capital investment requirements (constant dollars) with higher levels of pollutant removal can be gained from some illustrative figures.

It was calculated that a total investment of $4.0 to $5.0 billion in industrial waste treatment facilities would have had to be made by FY 1968 to attain at least 85% removal of BOD_5 and settleable and suspended solids (Table 8). Much of these facilities ($2.9 billion by expert estimate and $2.4 billion based upon census projection) already exist and the remaining investment would represent the present backlog. The following table provides some idea of the total capital investment which would have had to be made by FY 1968 to attain higher levels of BOD_5 removal:

TABLE 7. CASH OUTLAYS NEEDED TO MEET CURRENT AND PROJECTED INDUSTRIAL WASTE TREATMENT REQUIREMENTS, FY 1969-1973 1/

($ Billions)

Item	Capital Outlay (Constant Dollars)	
	By Expert 2/ Estimate	By Census 3/ Projection
Meeting Current Unmet Need	1.1	2.6
New Treatment Facilities, FY 1969-1973	0.7	1.0
Replacing Obsolete Equipment	.8	1.0
Total Capital Outlays	2.6	4.6

1/ Assuming at least 85% reduction of BOD_5 and of settleable and suspended solids.

2/ Based upon Industrial Waste Profiles in Volume III of this report.

3/ Based upon Census of Manufactures data and established treatment cost factors.

TABLE 8. TOTAL CURRENT VALUE OF WASTE TREATMENT REQUIREMENTS OF MAJOR INDUSTRIAL ESTABLISHMENTS[1/]

($ Millions)

Industry	Constant Dollars[2/]	
	By Expert[3/] Estimate	By Census[4/] Projection
Food and Kindred Products	740	670
Textile Mill Products	170	170
Paper and Allied Products	320	920
Chemical and Allied Products	380	1,000
Petroleum and Coal	380	270
Rubber and Plastics	41	59
Primary Metals	1,500	1,400
Machinery	39	56
Electrical Machinery	36	51
Transportation Equipment	220	160
All Other Manufacturing	200	290
Total Capital Requirement	4,000	5,000
Plant Currently Provided:		
By industry	2,200	1,800
Through municipal facilities	730	640
Current Backlog	1,100	2,600

1/ Assuming at least 85% reduction of BOD_5 and of settleable and suspended solids.
2/ All values rounded to two significant figures.
3/ Based upon Industrial Waste Profiles in Volume III of this report.
4/ Based upon Census of Manufactures data and established treatment cost factors.

TABLE 9. ESTIMATED REGIONAL INVESTMENT REQUIRED TO ELIMINATE INDUSTRIAL WASTE TREATMENT DEFICIENCIES ACCUMULATED THROUGH 1968, BY WATER RESOURCE REGION1/

($ Millions)

Water Resource Regions3/	Constant Dollars2/ Industrial Waste Treatment
North Atlantic	210-530
South Atlantic - Gulf	70-180
Great Lakes	190-480
Ohio	130-340
Tennessee	34- 85
Upper Mississippi	57-140
Lower Mississippi	87-220
Missouri	24- 61
Arkansas-White-Red	17- 42
Texas-Gulf/Rio Grande	120-310
Great Basin/Upper Colorado/Lower Colorado	9- 24
Columbia-North Pacific/Alaska	48-120
California/Hawaii	39- 98
Total	1, 100-2, 600

1/ Based upon the reduction of at least 85% of BOD_5 and of settleable and suspended solids.
2/ All values rounded to two significant figures.
3/ Puerto Rico-Virgin Islands not included.

Assumed BOD_5 Removal	Estimated FY 1968 Total Industrial Waste Treatment Investment To Attain Specified BOD_5 Removal Levels, Billions of 1968 Dollars	
	Lower Estimate	Higher Estimate
35%	2.3	2.9
85%	4.0	5.0
90%	6.0	7.5
95%	10.6	13.3
98%	13.4	16.8

These illustrative costs show how rapidly industrial waste treatment costs could escalate with higher waste removal. For example, waste treatment equipment valued at from \$6.0 to \$7.5 billion would be required in FY 1968 for 90% BOD_5 removal and 95% removal would require equipment valued at \$10.6 to \$13.3 billion.

No attempt was made to project for higher than 85% pollutant removal either total capital investment for the FY 1969-1973 period or additional capital requirements (total capital investment required less capital value of industrial treatment facilities in place.) From this example, however, it is clear that total capital outlays required over the next five years would rise sharply if water quality standards require significantly higher national pollutant removal levels than the 85% BOD_5 and solids removal levels assumed for this study.

OPERATION AND MAINTENANCE

While capital requirements are large, the most significant impact of waste controlling requirements on the financial and cost structures of industry will occur in the form of rising operation and maintenance costs. Such costs will rise steeply as treatment installations are constructed, approaching by FY 1973 the amount of the capital outlays required by new construction and depreciation. From an estimated \$490 million cost in FY 1969, operating costs will rise within a range of \$730 to \$920 million by FY 1973 if complete secondary treatment of industrial wastes is to be achieved. (These estimates are in terms of constant dollars.) This amounts to total projected operation and maintenance expenditures over the FY 1969-1973 period ranging from \$3.0 billion to \$3.4 billion compared with total capital outlays of \$2.6 billion to \$4.6 billion over the same period.

WASTE REDUCTION METHODS

Industrial waste treatment costs are affected significantly by the methods industry employs to reduce its wastes. In general, waste reduction may be accomplished through treatment by sewering wastes for treatment by municipal facilities, by on-site treatment, through process changes which lessen the amount or strength of wastes generated, by ground disposal, or by combinations of these alternatives.

MUNICIPAL PLANT TREATMENT OF INDUSTRIAL WASTES

Use of municipal facilities is preferred by a majority of industries, and accounts for the largest number of establishments whose wastes are treated. Table 8 indicates that about three-fourths of the current industrial treatment plant is provided by industry and one-fourth is provided by municipalities.

Although only 7.5% of the wastewaters of major industrial establishments were disposed of to municipal sewers in 1964, sewering provided the principal waste handling method for seven of the 11 industrial sectors shown in Tables 6 and 8. The seven industries include food processing, textiles, rubber and plastics, machinery, electrical machinery, transportation equipment, and miscellaneous manufacturing. The wastes of these seven industries are more amenable to treatment at municipal treatment plants than the wastes of the four other industries; paper and allied products, chemicals, petroleum and coal, and primary metals.

The one percent decrease in volume of industrial wastes going to municipal sewers between 1959 and 1964[5] is probably more a reflection of the greater water discharge by industries whose wastes are not amenable to treatment at municipal plants than it is indicative of a trend against the use of municipal treatment facilities by industries. As a matter of fact, there are indications that the situation is shifting toward increased numbers of cooperative municipal-industrial waste treatment plants that are scaled to handle the organic wastes of the pulp and paper, chemical, and other large water using industries. For example, in Bound Brook, New Jersey, a chemical plant treats municipal wastes, reversing the usual relationship between factory and community. In Kalamazoo, Michigan, three good-sized paper mills and one chemical plant use a modern municipal sewage treatment plant. Both Chicago and Seattle have adopted ambitious programs to provide high level treatment of liquid wastes - whether of domestic, commercial, or industrial origin - within their areas of jurisdiction. It would appear that technology has overcome the lag that excluded large industrial waste sources from municipal treatment plants in the past, and that modern engineering competence extends to the construction of efficient and large treatment plants designed to handle wastes from a variety of sources. Since this trend, if there is one, is of very recent origin, it is not reflected in the 1963 Census of Manufactures data. Accordingly, its nature and effect on financial requirements of municipalities and industries probably cannot be evaluated prior to the appearance of the 1968 Bureau of Census' Water Use in Manufacturing unless an inventory of industrial wastes and waste treatment is compiled earlier.

In connection with the trend toward increased use of municipal facilities by many industries, it is important to note the rapid increase in municipal treatment capabilities since World War II. Both the number of treatment plants and the average level of treatment have risen steadily, the growth being most marked since the institution of Federal grants for construction of waste treatment plants. As recently as 1949, almost 40% of the Nation's sewered communities did not have waste treatment provided to them. By 1962, less than 20% of the total number of sewered communities were without waste treatment. Moreover, well over half of the sewered communities had secondary waste treatment facilities. Thus, municipal facilities have an increasing potential capacity for handling many industrial wastes.

Joint systems for handling both municipal and industrial wastes in many cases are likely to provide the means of attaining adequate water pollution control most effectively and least expensively. The extent to which joint handling systems will increase over the next five years will depend largely upon the managerial ability of municipal and industrial officials and their willingness to enter into such cooperative arrangements. This, in turn, will depend upon the costs which industrial establishments are required to pay to use municipally-operated facilities. To the extent that appropriate charges and pretreatment requirements are fixed and that joint treatment facilities are designed and operated effectively, increased use of such facilities by industry may well lower overall pollution control costs significantly over the next five years.

Successful use of such joint plant systems depends upon effective implementation of mutual agreements between the industrial plant and the municipality because the industrial plant, in effect, is paying the municipality for taking on the legal and physical responsibility for treating the plant's wastes. It is important, for example, that the plant carry out required pretreatment measures before disposing of its wastes to municipal sewers, and equally important for the municipality to maintain continuing surveillance of raw wasteloads to be sure that such pretreatment measures have been taken.

PROCESS CHANGES

Reduction of many industrial wastes is often accomplished most efficiently and economically by process modifications. While the rate and effects of technological change are difficult to evaluate, quanitities of water used per unit of production have been decreasing in most industries while recycling to make more efficient use of water is increasing. Moreover, modern operational practices and engineering design increasingly stress waste control.

Review of the waste-to-product ratios of developing technologies in 10 industrial groups(7) indicates that in most instances advanced processing methods result in reduction of wastes. Although there are important exceptions to this, it seems clear that in-plant process changes offer an economic, advantageous means to reduce water pollution from industrial sources and that such changes are likely to increase in importance as industry, in considering waste reduction as a processing goal, puts increasing emphasis on the reduction of water pollution by process modification or change.[4]

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[4] *Material for making future estimates of such trends is contained in the 10 industrial waste profiles which comprise Volume III of this report(7).*

THERMAL POLLUTION

Thermal pollution refers generally to the degrading of streams by the addition of heat. The changes in water temperatures which result may affect aquatic life either directly through the harmful effect of the warmer water upon organisms which cannot tolerate such temperature increases or indirectly by lowering the dissolved oxygen concentrations. (Dissolved oxygen saturation levels in water decrease with temperature increases.)

There are several major sources of water temperature increases. Temperature changes can be induced by reservoir impoundment, by depletion of a stream through diversion, by the warming of irrigation return waters in fields, or by industrial process or thermal electric power generation. This section is concerned with thermal pollution resulting from power generation and industrial process, primarily because these are the significant sources of thermal pollution which can best be evaluated in terms of remedial cost requirements.

Thermal electric power generation is a far greater source of thermal pollution (in effect, heat wasted to cooling water) than is industrial processing. Electric power production in this country has doubled every 10 years during this century, and most of the increase has been achieved through use of thermal-generating methods. The number of new plants has increased the total production of waste heat at a rate far in excess of that with which growing generating efficiency has reduced unit heat loss. In addition, the discharge of heated cooling water at discharge locations has increased as power plants have grown in size. Accordingly, thermal pollution has become an increasingly serious water pollution problem. The seriousness of the problem is expected to intensify further with the planned construction of nuclear-fueled plants, with their attendant higher unit heat loss, to supply about half of the new generating capacity between now and 1975.

Industry, other than the power-generating industry, also faces a considerable expenditure in reducing the temperature of its heated wastewater discharges. Water for cooling purposes represented 70% of all water used by major water-using establishments in 1964.[5]

All of the water quality standards include, or will include, standards for permissible changes in the temperature of water used for cooling purposes. However, the temperature control requirements in the standards vary to some extent and it is not yet possible to make a generalized assumption regarding such standards as was done for treatment levels for municipal and industrial wastes. In some cases, the standards will permit continued heat discharges without the use of specific controls; in other instances, cooling towers or other cooling devices are already in operation. In still other situations, standards will require the construction of additional cooling towers, cooling ponds, or other devices designed to cool heated water. In addition, release of cooler water from reservoirs provides another alternative method for cooling heated water.

If it is assumed that all heated discharges are returned to their original temperatures before use, the required investment in conventional cooling equipment can be estimated after provision is made for existing cooling equipment. Accordingly, an estimate of the cost of providing cooling facilities to all thermal generating plants was developed, based upon recorded net heat rates and the use of mechanical draft cooling towers. The average reported temperature increase in cooling water of 13° F for plants accounting for 90% of thermal generating capacity in 1965[11] was used as the cooling standard to which conventional cost relationships were applied. A more tentative estimate was made of cooling cost for manufacturing establishments, necessarily more tentative because cooling problems tend to be more complex for manufacturing establishments than for the electric-generating industry.

PLANT AND EQUIPMENT INVESTMENT

A total estimated investment of $1.8 billion (constant dollars) in cooling equipment would be required over the next five years to return water to its temperature before use, or $2.0 billion based upon projected construction costs during the period. The $1.8 billion estimate is based upon a current backlog of about $1.0 billion, an estimated $600 million to accommodate growth and $220 million for replacement over the FY 1969-1973 period. (Table 10.) Of this $1.8 billion outlay, an estimated $1.3 billion would be required of the thermal power industry and about $500 million would be incurred by major manufacturing establishments.

The $1.8 billion estimate overstates estimated required capital outlays to the extent that it is based upon the return of cooling water temperature to its original temperature and, as already indicated, water quality standards permit, or will permit, some increase in the temperature of water used for cooling where no harmful effects will occur. In actual practice, adequate heat dissipation probably will be attained with some portion of the $1.8 billion estimate.

In many cases significant improvements in thermal efficiency may be achieved. However, such increased efficiency must at least offset the effect of the trend toward nuclear-fueled generating plants with their lower thermal efficiency.

OPERATION AND MAINTENANCE

Any increase in installed cooling equipment will be accompanied by increased operation and maintenance costs. It is difficult to estimate operation and

TABLE 10. ESTIMATED CAPITAL INVESTMENT REQUIRED TO PROVIDE COMPLETE COOLING FOR POWER-GENERATION AND PROCESSING INDUSTRIES, FY 1969-1973[1/]

($ Millions)

	Constant Dollars[2/]		
	Manufacturing	Thermal Power	Total
Projected Value of Fiscal Year 1968 Cooling Requirement	350	870	1200
Projected Value of Facilities Available	52	130	180
Indicated Deficiency	300	740	1000
Total Investment Required in FY 1969-1973	500	1300	1800

1/ Complete cooling refers to the return of heated water to its temperature before use.
2/ All values rounded to two significant figures.

maintenance costs because of the extreme difficulty of estimating capital outlays over the next five years. However, based upon the assumption of $1.8 billion projected additional capital, it is estimated that operation and maintenance costs for water cooling would rise steadily during the next five years - from about $79 million in FY 1969 to approximately $280 million in FY 1973.

OTHER EFFLUENTS

Thus far, this report has dealt with the national requirements and costs of treating "conventional" wastes such as domestic sewage or pollutants generated by industrial processes. As these wastes come under control, the more diffuse sources will increase in relative significance. Water quality deterioration resulting from such sources as acid mine drainage, wastes from boats and vessels, animal feedlot runoff, sediment and other products of erosion and agricultural runoff, and salinity increases through irrigation will become more noticeable. Over the long run, these sources will require a large portion of expenditures for water pollution control. It is these non-point sources which are referred to as "other effluents".

There necessarily will be wide variations among "other effluents" in the time and manner in which their control will be required by the water quality standards within the next five years. In contrast to conventional forms of pollution for which standards require specific remedial actions within specified time periods (generally over the next five years) standards are less specific with regard to these non-point sources. Some control measures and associated costs to control such pollution can be expected but the content and timing of these control measures cannot be set forth in as definite, specific a manner at this time as control plans for treating municipal and industrial pollution.

The fundamental difficulty in developing water quality standards to cover "other effluents" is that there has been little effort to quantify the pollutional effects, remedies, and control costs associated with such problems. For these reasons, general cost estimates can be made only for a few sources to attain a "good practice" degree of control. Here again, there is no expectation that all of these remedial costs will be incurred before the end of FY 1973.

Some idea both of the difficulty of assessing the magnitude of "other effluents" and the large remedial costs involved are apparent from the following illustrative cases.

WASTES FROM WATERCRAFT

Watercraft discharges contain several significant polluting agents including sanitary wastes with an estimated population equivalent of a city of 500,000 persons. Other discharges such as oil, bilge, and ballast waters may contaminate waterbodies, destroy aquatic life, and discolor vessels, piers, docks and other structures. Bilge and ballast waters also may transfer disease-bearing organisms from a foreign country to the United States.

A recent report to Congress(12) provides a tentative estimate of the size of the problem and its remedial costs. The report estimates that in any given year 110,000 commercial and fishing vessels, about 1,500 Federally owned vessels, and about 8,000,000 recreational watercraft use the navigable waters of the United States. In addition, approximately 40,000 foreign ship entrances in U. S. waters are recorded each year.

The study pointed out the particular difficulty involved in estimating the costs of controlling pollution from watercraft, and cited the lack of treatment and discharge standards and inadequately defined costs of treatment equipment. It reported that the installed cost of onboard equipment for properly handling watercraft wastes could vary from $40 to $100,000 per vessel, depending on size, type, mission, and other factors. It concluded that, based upon the number of vessels of different classes and the wide range of equipment costs, the total cost of bringing all existing American watercraft into compliance with impending regulations will be in the order of $600 million.

OIL POLLUTION

The problem of water pollution from oil spills and its destructive potential was dramatized by the Torrey Canyon disaster last March when that tanker ran aground off the coast of England spilling into the seas the 119,000 tons of crude oil she was carrying. Oil spills, as well as the careless or accidental release of other hazardous materials to streams or near coastal areas, have long been of concern to water pollution authorities. Oil attaches itself and adheres to solid objects. The results can be serious fish kills and harmful effects to other marine and offshore wildlife.

Oil pollution arises from many sources. Major sources include ships and vessels, pipelines, offshore mining and service stations. Coping with these largely accidental pollution incidents requires an extensive surveillance program, alerting system, reaction capability, and contingency fund for cleanup purposes.

Cleaning up an oil-contaminated area is time-consuming, difficult, and costly. The British Government, for example, reportedly is trying to recover $8 million from the owners of the Torrey Canyon for cleanup costs. This does not take into account the cleanup costs to local governments and private agencies. The total direct costs of cleaning up and of preventing our own oil pollution problems have not been estimated, but the Torrey Canyon disaster has emphasized that an oil spill is not only deadly and unanticipated but also is enormously expensive. The indirect damage costs of oil pollution - whether commercial, recreational, or aesthetic - are even more difficult to estimate but they unquestionably are also tremendous.

ANIMAL FEEDLOTS

The recent trend towards raising larger numbers of livestock in concentrated areas has resulted in a growing problem of disposing of tremendous quantities of animal wastes. For example, a feedlot raising 10,000 head of cattle produces about the same sewage disposal problem as a city with a population of 165,000. It has been estimated that, at any given time, there are 11 million cattle on feed in feedlots and the number is expected to increase considerably in the 1970's.

Although installation costs of feedlots vary widely, the few feedlots with recommended treatment lagoons incurred construction costs ranging from one to five dollars per head capacity. Thus, an operator setting up a feedlot with a 20,000 head capacity could spend from $20,000 to $100,000 in construction of waste treatment facilities. Although considerable research is needed in this area, it is known that the potential costs of controlling feedlot pollution are high.

ACID MINE DRAINAGE

Current estimates are that over four million tons of acid-equivalents are discharged annually into streams by active or abandoned mining operations. When the cumulative quantity discharged becomes great enough to exceed the natural neutralizing capacity of the waterbody, damages occur. The severity of the damages depends upon the acidity of the affected waters and their effect upon fish, fish food organisms, and structures and equipment exposed to the acidified water. Costs for pretreatment of water intended for municipal or industrial supplies are also increased. It is estimated that over 4,300 miles of major streams in the U. S. are polluted significantly by acid mine drainage.

An estimated 3.2 million acres of land are producing acid drainage as a result of surface mining activities and erosion. In addition, subsurface mining contributes large acid volumes. The extension of acid drainage is continuing at an estimated 150,000 acres per year, with the rate increasing as a larger population and a larger per-capita output of goods increases demand for materials obtained from mining operations.

Estimates vary widely of the cost of controlling acid mine drainage from both active and abandoned mines. However, there seems little doubt that the eventual cost of cleaning up the problem will involve several billion dollars.

OTHER NON-POINT SOURCES

Although proven methods are available to deal with some "other effluent" problems, and cost assessments may be made on the basis of these methods, many serious sources of pollution still lie outside the boundaries of current knowledge. A prime example is sedimentation - the transport of earth by water that occurs as a result of winds, bank-caving, construction, agricultural practices, and other natural and man-made causes. Silting and discoloring of streams by sediments is a major problem but sedimentation also promotes other pollution by acting as a vehicle to transmit to watercourses such pollutants as pesticides, nutrients, and bacteria as well as decomposable organics and natural toxicants. Solutions to the problem lie in the whole pattern of land use activities required to fix soils in place. The U. S. Department of Agriculture and other agencies currently spend about $200 million a year in programs designed for soil conservation practices; about 80% of these funds are used to combat agricultural sedimentation and the remainder is expended on urban sedimentation problems. USDA officials consider current expenditures sufficient to control only a portion of the problem and are convinced that considerable research efforts should be devoted to quantifying the problem and its remedial costs.

Pesticide control prospects seem to rest largely with stringent regulation of application practices. With accelerated research we may, in time, expect a remedy in the form of degradable toxins that break down readily in water, or in the development of specific pesticides which do not produce harmful effects in man. Costs of control procedures are not assessable, however, at present.

Excessive salinity in fresh water is another difficult non-point source problem. The problem occurs largely in the drier, water-scarce areas which utilize large quantities of water for irrigation. In humid zones, surface water salinity generally is low because soils have been leached by abundant rainfall. In more arid zones, where irrigation is necessary, soils contain larger amounts of salts and surface waters have relatively high salt concentration. Improvement or control of soluble salt concentrations in river water uses requires changes either of the salt sources or the inflow or outflow of salt-free water. Some possible solutions include inter-basin movement of water, increasing precipitation by weather modification, or removal of the salt directly. Accordingly, the Federal Water Pollution Control Administration, the Bureau of Reclamation, and the California Department of Water Resources are conducting a joint pilot study involving the removal of pollutants from irrigation return flows. In addition, FWPCA and the Bureau of Reclamation are making extensive studies of possible salinity control methods in the Colorado River Basin. As in the case of other non-point pollution problems, the eventual remedial costs cannot be estimated now but it is recognized that they will be very high.

Nutrient enrichment, which accelerates growth of aquatic biota, and ultimately modifies the entire ecological system of a lake or other waterbody, is a pollution problem of growing seriousness and prevalence. Lake Erie's degradation is a notable example of changes that occur from nutrient enrichment. The obvious control approach involves limiting the amount of nutrients discharged to the water. Conventional waste treatment methods admittedly are uncertain and inefficient but more advanced methods are rapidly being developed. Other control techniques to be considered include preventing runoff from fertilized fields, replacing phosphate-based detergents, and removing nutrients from waterbodies by such methods as dredging, flushing, and harvesting growths. Considerable private and public research efforts will be needed to solve this problem.

Efforts will be made in these future annual assessments to quantify the extent of these problems and the remedial costs which will be required. At some time, through continued research and development, it is hoped that the capacity will be developed to deal effectively with these difficult, complex and important pollution problems.

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