WATER POLLUTION CONTROL RESEARCH SERIES • 17090 --- 07/70

Cost to the Consumer for Collection and Treatment of Wastewater

U.S. ENVIRONMENTAL PROTECTION AGENCY

COST TO THE CONSUMER FOR COLLECTION AND TREATMENT OF WASTEWATER

by

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Project #17090---

July, 1970

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $1.00

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ABSTRACT

The national average per capita cost for collection and treatment of municipal wastewater is computed based on the 1968 Inventory of Municipal Waste Treatment Facilities in the United States and per capita cost relationships for building and operation collection and treatment facilities. All costs are given per capita served with treatment facilities using the level of treatment existing in 1968. Total cost was computed as $19.80 per capita per year. Of this total, $15.31 represents amortization charges and $4.49 represents current charges. The total cost can also be broken down as $13.34 for collection, $4.38 for treatment and $2.08 for overhead such as customer services, administrative, and general. The cost of collection is, therefore, about three times as expensive as treatment.

Nationally, about 23% of the total cost is paid as sewerage usage charges. This represents about 0.1% of National Personal Consumption Expenditures. Expenditure for water supply averaged $13.42 per capita per year and this is about equal to the amount paid by the consumer in user charges for water supply.

The current status of collection and treatment in the United States is discussed and estimates are made of needed additional expenditure.

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CONCLUSIONS

The cost of collection and treatment of municipal sewage does not represent a large fraction of personal consumption expenditure and the cost of public collection and treatment is significantly lower than the cost of individual disposal units such as septic tanks. From the cost estimates presented it would appear that waste collection and treatment could be placed on a utility basis by increasing the sewerage charges now paid by a factor of about 2.5 provided the homeowner continues to pay for the house connection and municipal sewers as part of the price of the house or as a special assessment. If the entire cost of collection and treatment exclusive of the house connection is to be paid as a user charge, the amount of the charge could exceed the present cost of water supply by about 40%.

RECOMMENDATIONS

In recommending a course of action to conserve the water resources of the Nation it is essential that we understand the economic impact of each alternative plan. For example, the effect on prices paid by the consumer for manufactured goods caused by forcing the industrial pollutor to treat liquid wastes before discharge should be evaluated. The impact on the housing industry caused by regulations demanding adequate collection and treatment of wastewater should be studied. The feasibility of establishing collection and treatment of wastewater as a utility which could charge the user an equitable rate should be studied. The effect on unit treatment cost caused by imposition of effluent standards, especially in smaller plants, should be evaluated to understand the burden this would place on the smaller community.

INTRODUCTION

Over the past year or two in the United States, concern over deterioration of the environment has grown significantly. As a result, the public is showing an increasing tolerance for paying the cost of protecting our air, land, and water resources. It is a truism that the public will ultimately be required to pay the full cost of all forms of pollution control. Thus, the public rather than engineers, economists, or governmental officials must decide the level of expenditure and the corresponding degree of pollution abatement which best matches the life style to which they aspire. The role of engineers and economists is to present the public with the technical and cost related information necessary for rational decision making. Given the present high level of sophistication of the American Public there is little doubt that the public will decide in favor of increased expenditures for pollution abatement. The role of Federal Government is to educate the public and to urge the public to make decisions which are in the best interest of the Nation as a whole. This paper is intended to encourage and facilitate this educational process by attempting to assess in terms of dollars/capita/year the true cost of building and operating collection and treatment facilities for sewage and industrial wastewater. These facilities are required to protect our waterways from the vast pollutional load now being discharged so that our waterways will again be available for public recreational and aesthetic use.

WATER CONTAMINANTS

Contaminant species carried by wastewater which are known to have a detrimental effect on receiving streams can be roughly classified as carbon, nitrogen, and phosphorus. Carbon (organic) compounds serve as the principal food for aquatic microorganisms which if allowed to proliferate will deplete the dissolved oxygen reserves of the stream and create septic and aesthetically objectionable conditions in the stream. The concentration of organic contaminant present in wastewater is measured as Chemical Oxygen Demand (COD) or Total Organic Carbon (TOC) expressed as milligrams/liter. The fraction of the organic contaminant which is readily available as food for microorganisms is expressed as Biochemical Oxygen Demand (BOD) measured as mg/l. This test (BOD) consists of observing the dissolved oxygen depletion which occurs over a 5-day period in a sample of the water under controlled laboratory conditions. There is some disagreement among experts concerning which of the above tests should be used to measure the true capacity of wastewater to deplete dissolved oxygen resources. Unanimous agreement exists, however, on the need to remove organic contaminants from wastewater before discharge to the receiving stream.

Phosphorus and nitrogen discharged to the receiving stream will encourage the growth of nuisance aquatic plants such as blue-green algae. The need for removal of nitrogen and phosphorus from all wastewater is not as well established as the need for removal of organic contaminants. These are specific cases, however, where removal of nutrients is clearly required. Removal of phosphorus is generally believed to be a better investment than removal of nitrogen because of the ability of some aquatic plants to fix nitrogen from the atmosphere.

FACILITIES REQUIRED

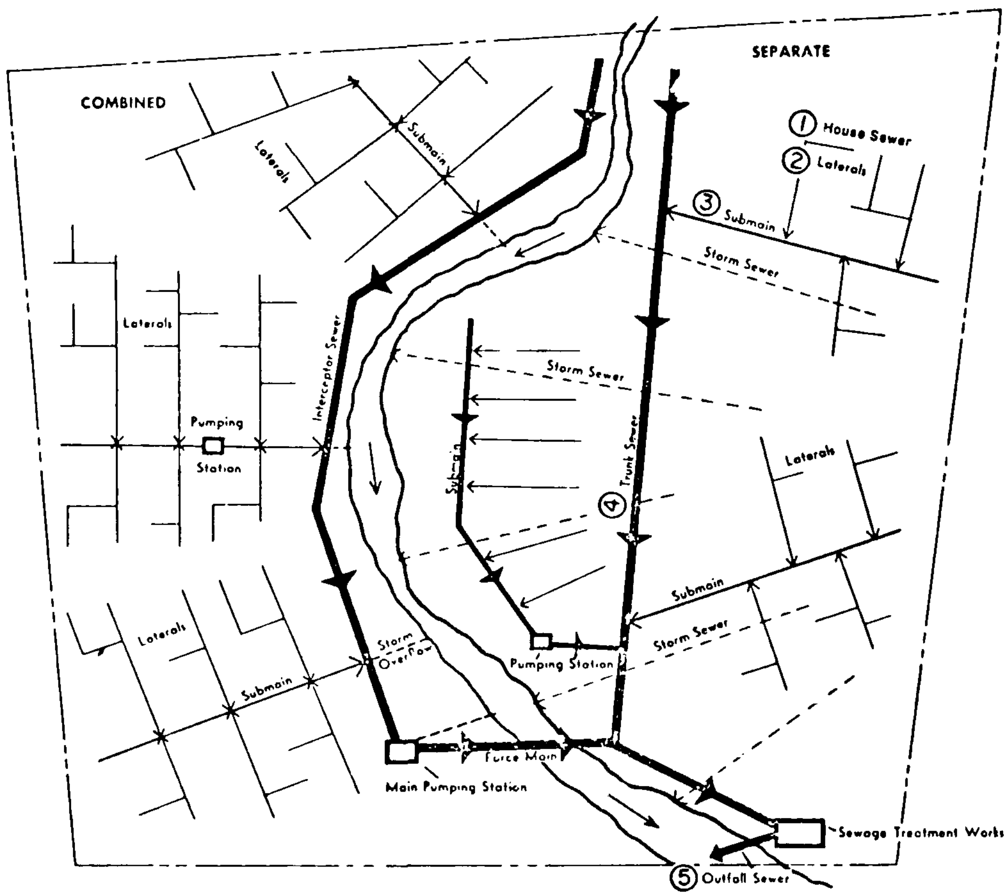
Facilities needed to collect and treat sewage can be enumerated as

1. House connection
2. Municipal sewer system consisting of laterals and trunk sewers
3. Interceptor sewers which collect from the trunks and deliver the sewage to the treatment plant
4. Pumping stations
5. The treatment plant which removes contaminants from the water
6. Outfall sewer which delivers the treated sewage to the receiving stream.

These facilities are illustrated in Figure 1.

In addition to the sanitary sewer, storm sewers are often provided to collect the runoff from the paved areas of the city. Some urban communities collect both sanitary sewage and storm water in a common or combined sewer system. This has the disadvantage of hydraulically overloading the treatment plant when heavy rains occur, flooding basements, and also reducing the velocity of flow in the combined sewers which results in deposition of untreated particulate material in the combined sewer. To avoid hydraulic overload at the treatment plant, sewerage systems using combined sewers normally bypass the plant during high flow periods resulting in high pollutional loads on the receiving stream. This lack of treatment is ameliorated by the fact that the stream is better able to assimilate the increased pollutional load at high flow conditions. The 1968 Inventory of Municipal Waste Treatment Facilities[1] summarized in Table 1 shows that of the 12,911 communities with sewer systems about 1794 or 14% are equipped with combined sewers.

The processes used to treat wastewater are roughly classified as primary, secondary, and tertiary treatment. Primary treatment normally consists of removing particulate contaminants by means of sedimentation. The sludge formed is then reduced in volume by means of anaerobic digestion, dewatered by means of vacuum filtration, centrifugation, or sludge drying beds and finally disposed of by application to the land or incineration. An increased fraction of the particulate matter can be removed by addition of chemicals such as alum, iron salts, or polyelectrolytes. The process modification is often referred to as intermediate treatment.



Typical Sewer Systems

SOURCE: National Association of Counties/Research Foundation, Community Action Program for Water Pollution Control, Library of Congress Card Number 65-29251.

FIGURE 1

MUNICIPAL SEWAGE TREATMENT SUMMARY FOR THE UNITED STATES (1968)

	Number	Percent
Number of communities with sewer systems	12,911	100.0[1]
Discharging raw sewage only	1,416	11.0
Discharging treated sewage only	11,422	88.5
Discharging both raw and treated sewage	73	.5
Type sewers-numbers of communities:		
Separate	10,317	85.2
Combined	1,173	9.7
Both separate and combined	621	.5
Not stated	800	......
1960 Census population of sewered communities	123,843,107	......
Estimated population:		
Connected to sewers	140,226,049	100.0
Discharging raw	9,541,278	6.8
Discharging treated	130,684,771	93.2
Number of facilities-total	14,123	100.0
Discharging raw	1,558	11.0
Discharging treated	12,565	89.0

TREATMENT

	Number	Percent
Treatment plants-total (including 98 unknown degree)	12,565	100.0[1]
Minor	47	.4
Primary	2,384	19.1
Intermediate	75	.6
Secondary	9,951	79.8
Tertiary	10	.1
Estimated population served by		
Minor treatment[2]	1,360,870	1.0
Primary treatment	36,947,397	28.4
Intermediate treatment	5,857,690	4.5
Secondary treatment	85,640,764	65.8
Tertiary treatment	325,530	.3
Total	130,132,251	

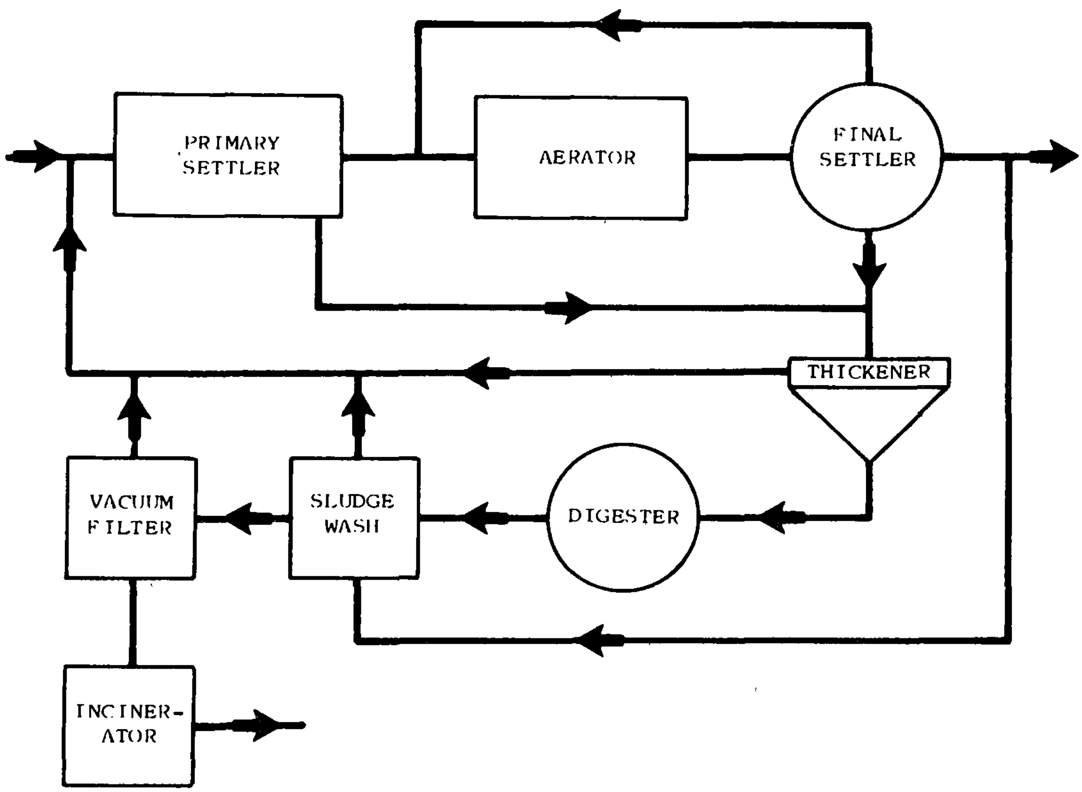
[1] Percentage bases exclude 98 unknown or not stated categories
[2] Less than sedimentation

TABLE 1

By secondary treatment we normally mean some form of biological treatment which converts dissolved organic compounds to microorganisms which can then be settled out and removed in the final clarifier. A process diagram for an activated sludge secondary plant is shown in Figure 2. The activated sludge process consists simply of a stirred tank supplied with atmospheric air in which a dispersed floc composed of organic particulate and active microorganisms is maintained. The floc acts as a support on which new microorganisms grow by using the dissolved contaminants as food. The sludge from the primary and secondary clarifiers or settlers is disposed of in a manner similar to the primary plant. Trickling filters can be used in place of the activated sludge process. A trickling filter consists of a packed column of stones or other media to which a slime of microorganisms clings. The wastewater is trickled over the fixed media and the microorganisms in the slime use the dissolved nutrients to grow more slime. The slime sloughs off periodically and is removed in the final clarifier.

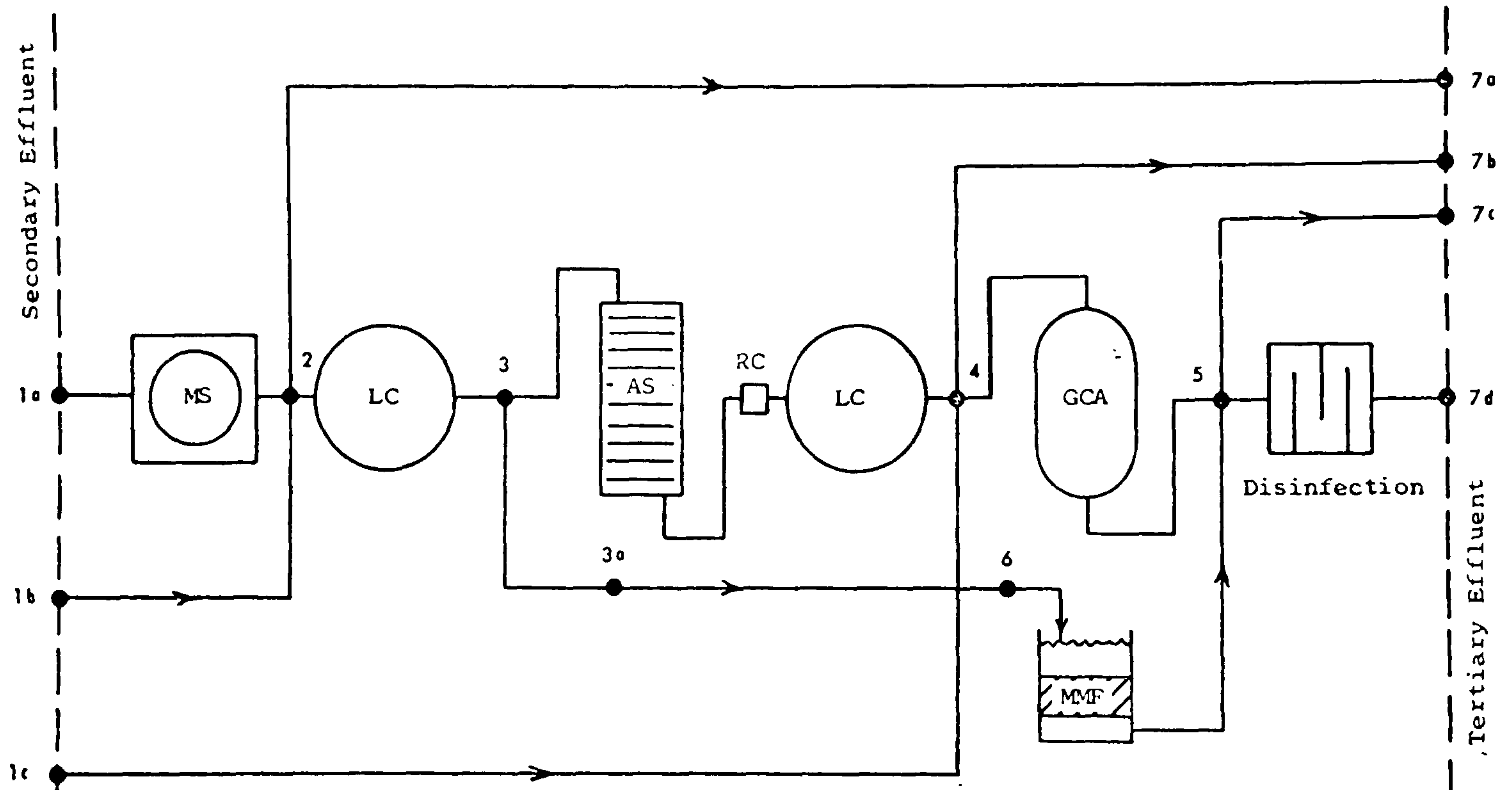
Tertiary treatment consists of processes used downstream of the secondary plant to remove an additional fraction of the contaminants. Microscreening is sometimes used to remove particulate which escapes over the final clarifier weirs. Lime clarification can be used to remove additional particulate and to remove most of the phosphorus. Dual media filtration is used downstream of the lime clarification process to remove the haze of inorganic particulate which often escapes the lime clarification process. To polish an effluent for reuse, granular carbon adsorption can be used to remove the last traces of dissolved and/or particulate organic material. A diagram of tertiary treatment process trains is shown in Figure 3.

Normal raw domestic sewage will measure about 200 mg/l for both 5-day BOD and volatile suspended solids. Removal of 5-day BOD in the primary settler averages about 35% which results in a 5-day BOD of about 130 mg/l for the feed stream to the activated sludge process. The activated sludge process, if operating at peak efficiency, will remove about 90% of the remaining 5-day BOD. A good secondary effluent from the activated sludge process will, therefore, measure about 13 mg/l 5-day BOD. These efficiencies are achieved only under ideal conditions so that the target for performance is often taken as 90% of 5-day BOD across the entire plant or even 85% removal across the plant. The estimated effectiveness of tertiary processes is shown in Table 2.



CONVENTIONAL PROCESSES SYSTEM DIAGRAM

FIGURE 2



MS = Microscreening
LC = Lime Clarification
MMF = Multi-Media Filtration
AS = Ammonia Stripping
GCA = Granular Carbon Adsorption
RC = Recarbonation

WASTEWATER TREATMENT PROCESSES FOR USE DOWNSTREAM OF SECONDARY TREATMENT

FIGURE 3

ESTIMATED WATER CONTAMINANT CONCENTRATIONS IN EFFLUENT STREAM FROM VARIOUS GROUPS OF TERTIARY PROCESSES

		VSS mg/l	BOD_5 mg/l	COD mg/l	TOC mg/l	Nitrogen* mg/l	Phosphorus mg/l as P	Remarks
0.	Secondary Effluent	20	13	60	20	17	10	
1.	Microscreening or Rapid Sand Filtration (1a, 2, 7a)	6	7.5	47	16	17	10	70% Removal of Suspended Solids
2.	Granular Carbon Adsorption (1c, 4, 5, 7c)	2	2	10	3	17	10	90% Removal of Suspended Solids
3.	Lime Clarification (1b, 2, 3, 3a, 4, 7b)	2	6	44	15	17	1	90% Removal of Suspended Solids
4.	Lime Clarification + Multi-Media Filtration (1b, 2, 3, 3a, 6, 5, 7c)	<1	5	42	14	17	1	99% Removal of Suspended Solids
5.	Lime Clarification + Ammonia Stripping (1b, 2, 3, 4, 7b)	2	6	44	15	2	1	90% Removal of Suspended Solids
6.	Lime Clarification + Ammonia Stripping + Granular Carbon Adsorption (1b, 2, 3, 4, 5, 7c)	<1	1	9	3	2	1	99% Removal of Suspended Solids

*Dissolved

TABLE 2

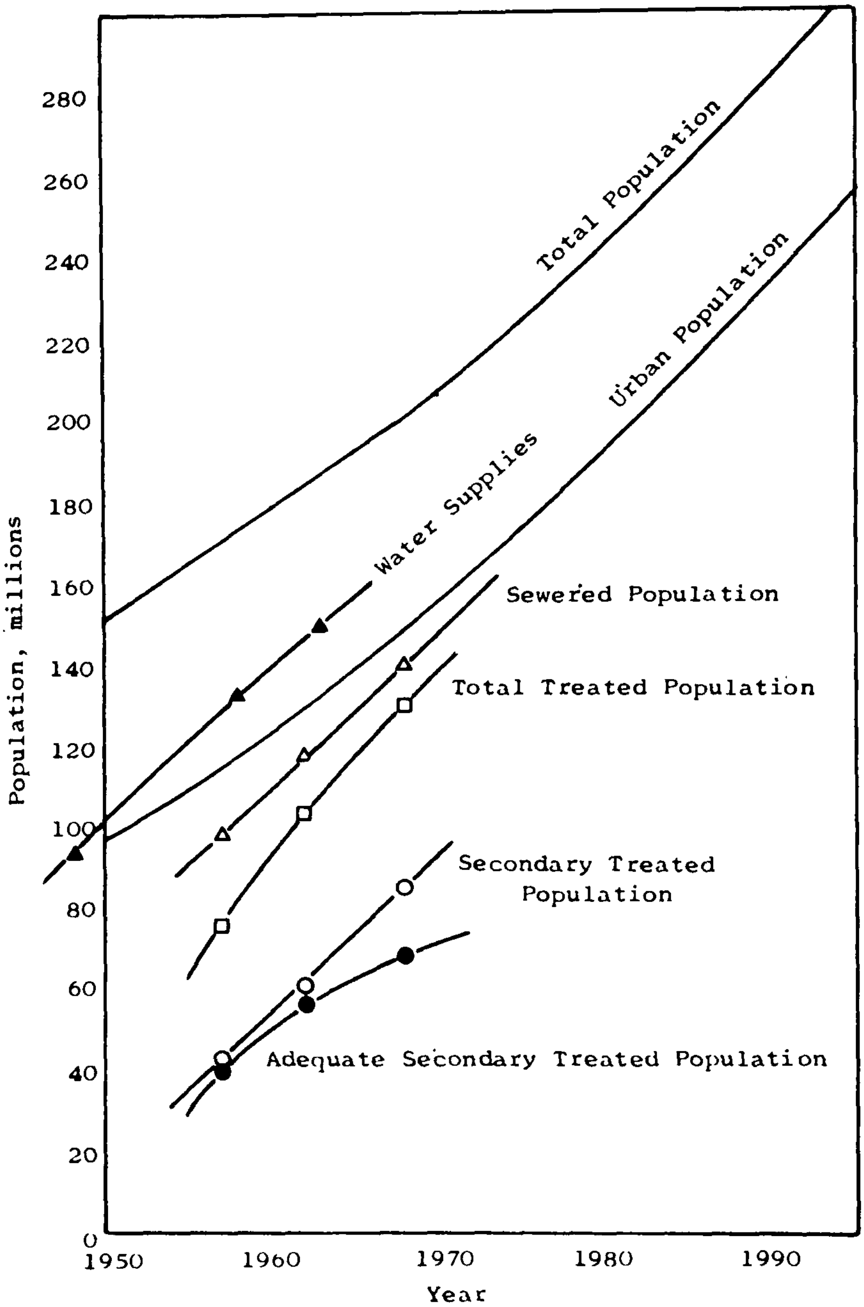
STATUS OF COLLECTION AND TREATMENT IN THE UNITED STATES

The goal of the Federal Water Quality Administration for municipal wastewater treatment was enunciated in the 1968 Cost of Clean Water Report[2] as adequate treatment for the total urban population of the United States by 1973. Adequate treatment was later defined as equivalent to secondary treatment. National effluent standards for discharge to receiving streams have yet to be established. Most States, however, now have effluent standards for BOD removal and disinfection. The range for BOD removal is between 80-90% with 85% the most quoted standard. Twenty-nine States require disinfection of secondary effluent although some require it only seasonally or for discharge to specific streams. The definition of adequate treatment used here will be a treatment train terminated by one of the following processes: activated sludge, extended aeration, or trickling filter.

The definition of urbanized area is the same as that used by the Bureau of Census. The Bureau of Census defines urbanized area as all incorporated area with 100 or more closely settled dwellings and all unincorporated areas with a population density of 1000 or more inhabitants per square mile. Since the average household size in 1968 was 3.23 persons, this last definition of urban area is equivalent to one household per two-acre tract.

The total and urban populations of the United States are shown plotted versus time in Figure 4. Population projections were taken from the work of Resources for the Future reported in Committee Print No. 7[3]. The population served by sewer systems and treatment plants were taken from the 1957, 1962, and 1968 Inventories of Municipal Waste Treatment Facilities[4],[5],[1]. The population served by potable water treatment and distribution facilities were taken from Statistical Summary of Municipal Water Facilities in the United States, January 1, 1963[6].

Figure 4 shows in a rough way the present status of collection and treatment in the United States. The gap or backlog for municipal sewer systems appears to be relatively small although it will be shown later that installation of new sewers is more costly than construction of new plants. Some level of treatment appears to be available for a substantial fraction of the urban population. Secondary treatment and particularly the level of treatment defined above as adequate is available to only about 50% of the urban population. Potable water supply is available to a population which exceeds the urban population.



STATUS OF MUNICIPAL WASTEWATER TREATMENT FACILITIES IN THE UNITED STATES

FIGURE 4

The data presented in Figure 4 show clearly the need for increased expenditures to overcome the backlog of needed construction. The FWQA has proposed overcoming this backlog within a five-year period. The cost associated with meeting the goal of adequate secondary treatment for the total urban population will be assessed, but first the cost of building and operating plants and sewer systems will be developed.

COST RELATIONSHIPS

Cost associated with constructing and operating sewerage systems and treatment facilities are of two basic kinds. The first is the cost of constructing the physical works which is normally paid for by the sale of general obligation municipal bonds. The cost of construction is then repaid in equal yearly payments over the useful life of the structure. Each payment (amortization cost) includes interest on the outstanding debt plus an amount which will insure that the bonds are fully redeemed at the end of the useful life of the structure. To provide for periodic payments, bonds can be sold with graduated maturity dates. The cost of repaying the construction cost and the interest charges is often expressed as level debt service. The life of sewers is normally taken as 50 years and the life of treatment facilities as 25 years. If the bonds have a yield of 5%, the yearly expense for amortizing sewers would be equal to the construction cost multiplied by the factor 0.05478. The corresponding factor for treatment plants would be 0.07095. The interest rate which must be paid by the municipality is related to the credit rating of the community. For example, the yield or effective interest rate for bonds[7] with rating of Aaa and Bbb is shown in Figure 5. Construction cost can be expressed as dollars/capita while amortization cost is expressed as dollars/capita/year. It should be noted that the cost of construction, like all cost, varies with time. The FWQA construction cost indexes for sewers and treatment plants are shown in Figure 6. The level has been adjusted to be 100 at the 1957-59 point used by the Dept. of Commerce.

The second kind of expense (current expense) is associated with operating and maintaining the equipment and structures. Examples of this kind of expense are sewer maintenance charges, operating and maintenance cost for treatment, customer service and accounting, and general and administrative cost. Current expense is related to salaries, fringe benefits, purchases of chemicals and other kinds of supplies. Current expense is expressed as dollars/capita/year. The cost of current expenses also depends on time and can be adjusted by means of the Bureau of Labor Statistics Index for Residential Water and Sewerage Services[8]. This index is shown in Figure 7.

Construction cost relationships for various kinds of plants are shown in Tables 3 and 4. Relationships derived by R. L. Michel of Construction Grants and Engineering Branch of WQO[9] were derived by fitting log-log regression equations to cost data for

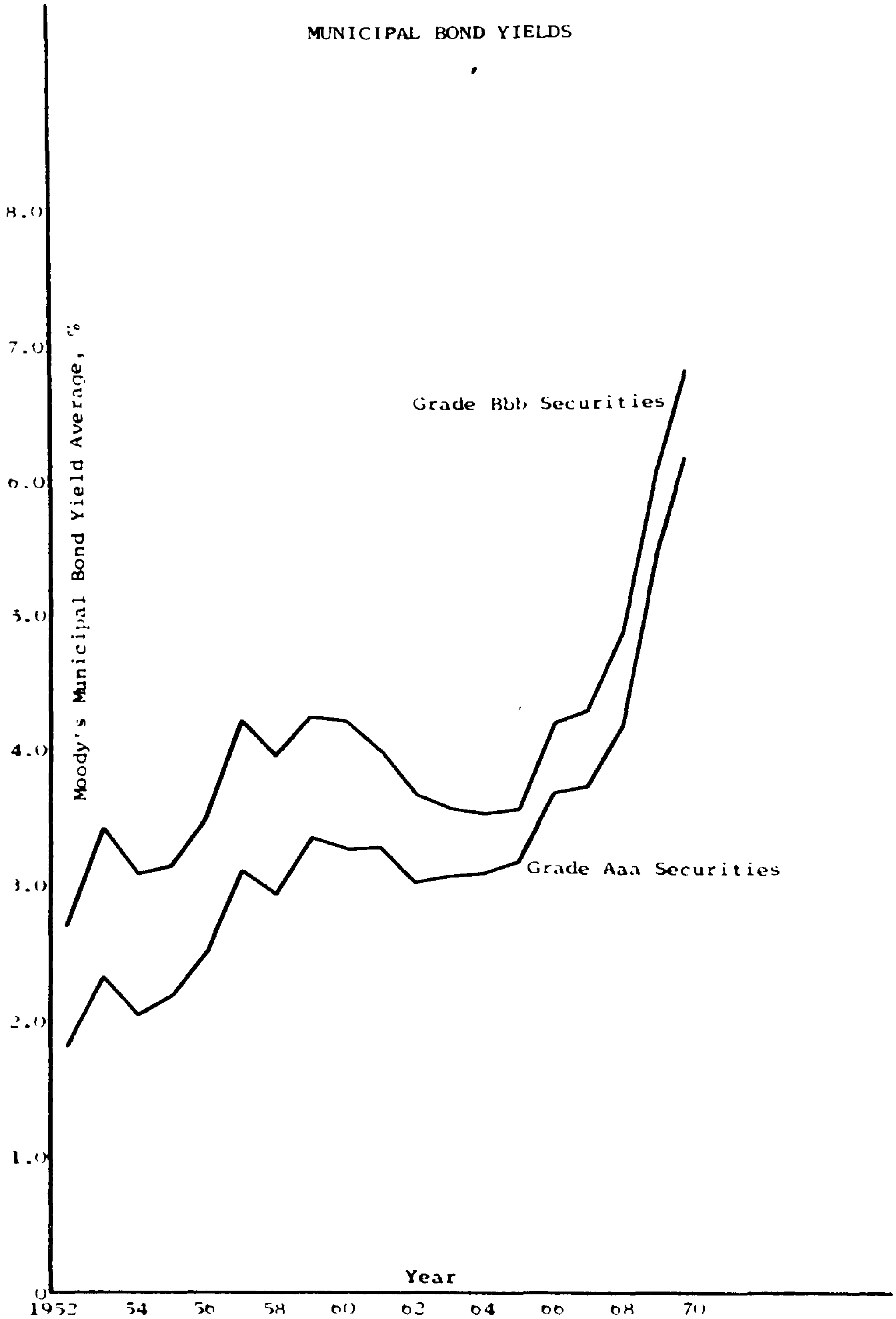
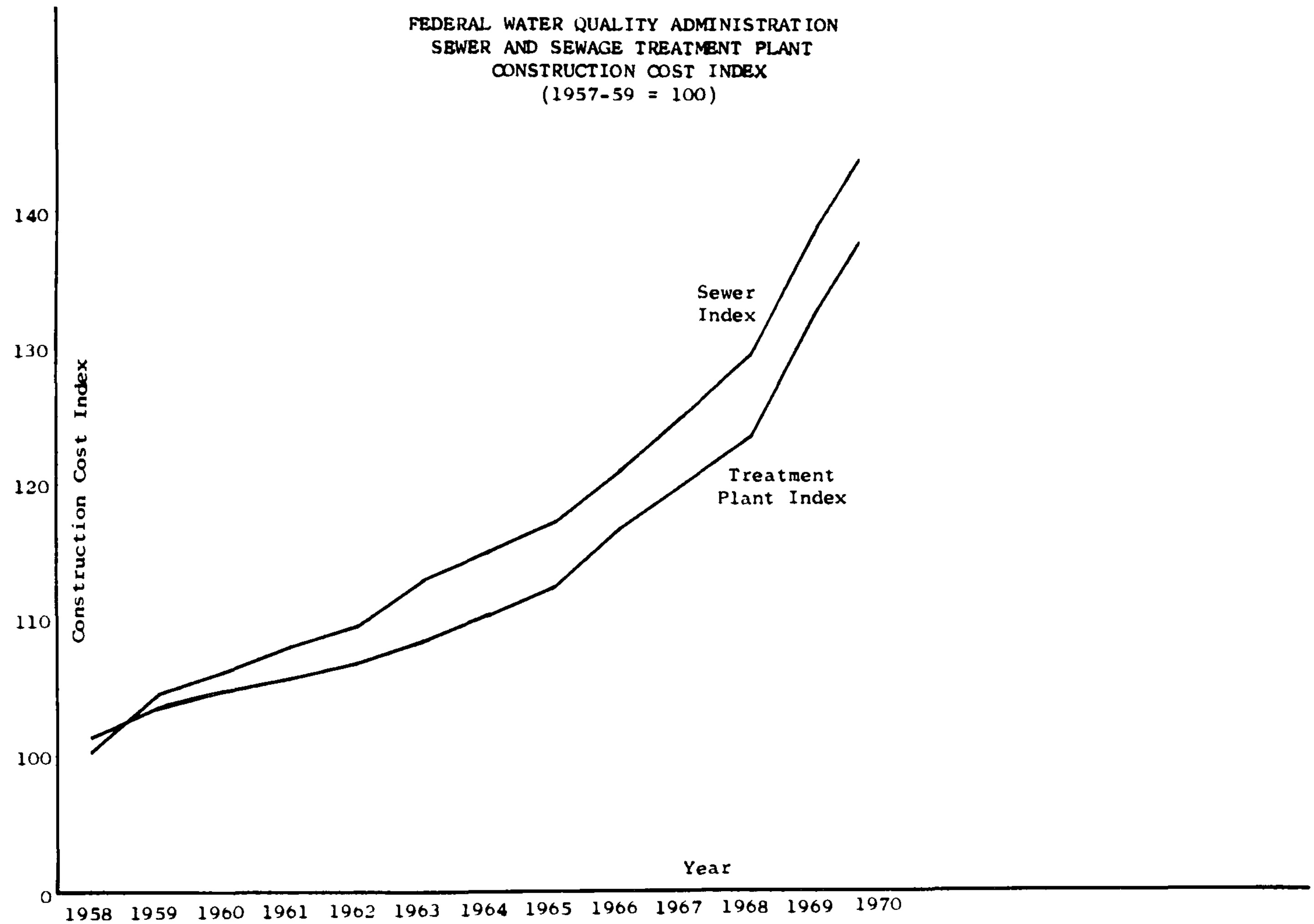

MUNICIPAL BOND YIELDS
Moody's Municipal Bond Yield Average, %
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
Grade Bbb Securities
Grade Aaa Securities
Year
1952
54
56
58
60
62
64
66
68
70

FIGURE 5



FEDERAL WATER QUALITY ADMINISTRATION
SEWER AND SEWAGE TREATMENT PLANT
CONSTRUCTION COST INDEX
(1957-59 = 100)
Construction Cost Index
140
130
120
110
100
0
Sewer Index
Treatment Plant Index
Year
1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970

FIGURE 6

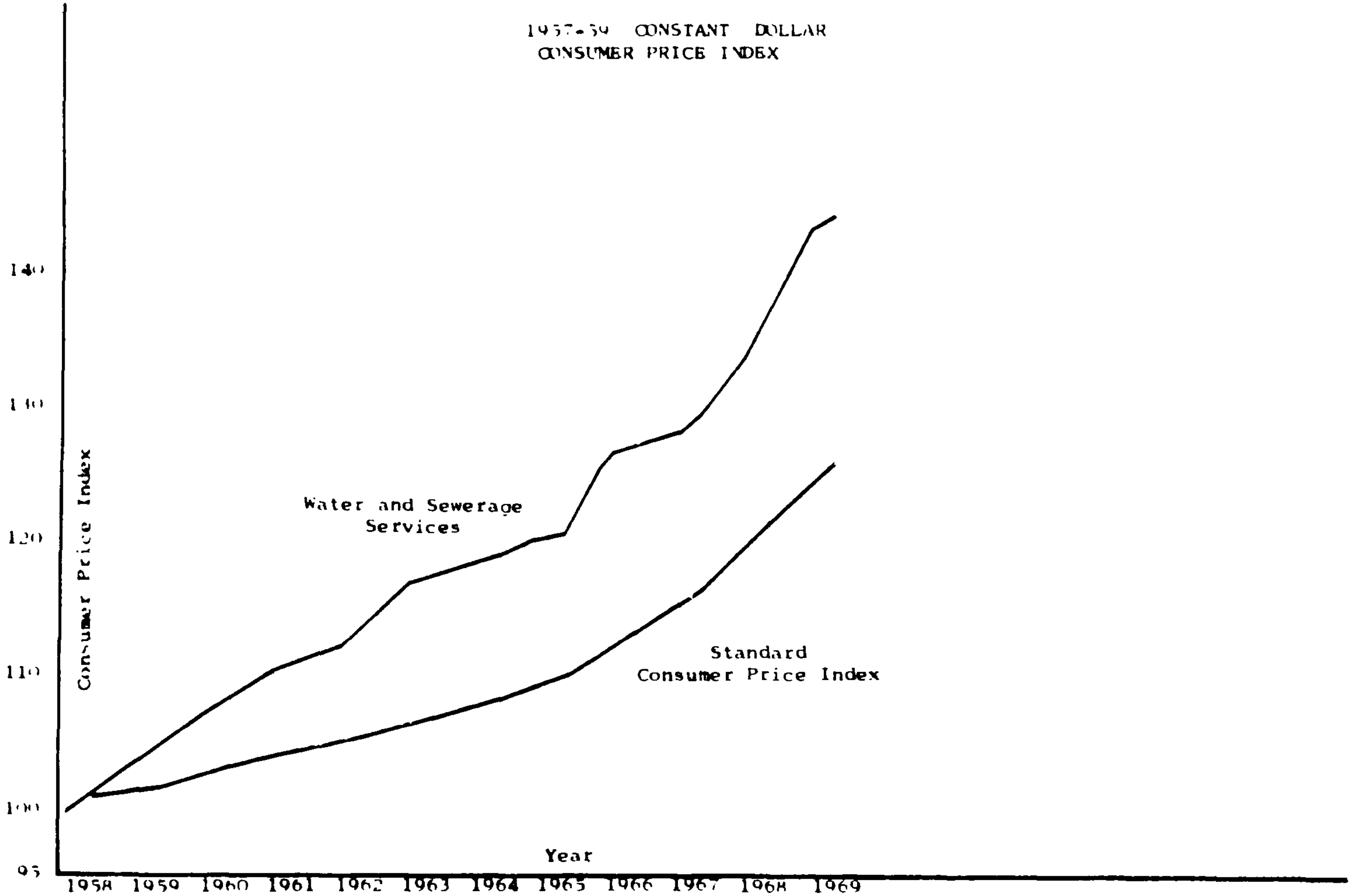

1957-59 CONSTANT DOLLAR
CONSUMER PRICE INDEX
140
130
120
110
100
95
Consumer Price Index
Water and Sewerage Services
Standard Consumer Price Index
Year
1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969

FIGURE 7

CONSTRUCTION COST RELATIONSHIPS

in the form $Y = aX^b$

Type of Treatment Facility	Value for a	Value for b
1. Waste Stabilization Ponds	2863.14	-.6050
2. Primary Sedimentation Plant	675.68	-.3274
3. Activated Sludge Plant	912.73	-.3088
4. Trickling Filter Plant	945.02	-.3105
5. Upgrading Primary to Activated Sludge	1484.03	-.4073
6. Ancillary Works*	86.26	-.0896

where, Y = construction cost, dollars per capita (1968 dollars)
X = design population, number of persons
a & b = constants

Source: R. L. Michel, Construction Grants and Engineering Branch, FWQA

*Ancillary Works Interceptors, Outfalls, and Pumping Stations

TABLE 3

CONSTRUCTION COST RELATIONSHIPS

in the form $Y = aX^b$

Type of Treatment Facility	Value for a	Value for b
1. Primary Sedimentation Plant	514.90	-.2890
2. Activated Sludge Plant	383.75	-.2100
3. Trickling Filter Plant	317.58	-.2000

where,

Y   construction cost, dollars per capita (1968 dollars)
X = design population, number of persons
a & b - constants

Source: Robert Smith, "Cost of Conventional and Advanced Treatment of Wastewaters"

TABLE 4

plants for which FWQA contributed grant-in-aid funds. The relationships attributed to Smith were found by updating and recasting the data from Reference 10. The FWQA construction cost index usedwas the mean for 1968 and equalled 123.55. The sewer index for 1968 was 129.57. Corresponding operating and maintenance cost for various kinds of plants are shown in Tables 5 and 6.

The system of sanitary sewers which collects the wastewater from individual dwellings and delivers it to the sewerage treatment plant is composed of several components (See Figure 1). The first is the house connection which connects the house or business establishment to the street sewer. The average length of the house connection is 60 feet and the size of the pipe is 4-6 inches diameter. The municipal sewer system is made up of concrete sewer pipe ranging in diameter from 6-42 inches diameter. The mean effective diameter for cost estimates is sometimes taken as 10 inches. Manholes are placed at an average interval of 400 feet along the municipal sewer to facilitate changes in direction and grade and also to provide access for cleaning and inspection. Sewer systems are designed for gravity flow, but at times it is necessary to install pumping stations and force mains where gravity flow is not possible.

One of the first attempts to price the sewerage system was made by Isard and Coughlin(11). In this document, a development of 2480 dwellings built on the outskirts of a city of 25,000 population was studied. Three population densities, 1 dwelling per acre, 4 dwellings per acre, and 16 dwellings per acre were studied. These were designated as low, medium, and high density housing. If we assume 3.23 persons per household (1968), the three densities correspond to 3.23 persons per acre, 13.4 persons per acre and 57.7 persons per acre respectively. The cost quoted by Isard and Coughlin applied to 1953. These population densities can be compared to existing cities in 1960 as follows:

Austin, Texas	6.42 persons/acre
Milwaukee, Wis.	12.9 persons/acre
Brooklyn, NY	58.4 persons/acre
Manhattan, NY	117. persons/acre

The average population density for the APWA study(12) of storm and combined sewers was found to be about 8.6 persons/acre.

OPERATING AND MAINTENANCE RELATIONSHIPS

in the form $Y = aX^b$

Type of Treatment Facility	Value for a	Value for b
1. Waste Stabilization Ponds	17.38	-.4172
2. Primary Sedimentation Plant	24.95	-.2634
3. Activated Sludge Plant	30.10	-.2460
4. Trickling Filter Plant	54.99	-.3569

where,

Y operating and maintenance cost, dollars per year/capita (1968 dollars)

X = design population, number of persons

a & b = constants

Source: R. L. Michel, Construction Grants and Engineering Branch, FWQA

TABLE 5

OPERATING AND MAINTENANCE RELATIONSHIPS

in the form $Y = aX^b$

Type of Treatment Facility	Value for a	Value for b
1. Primary Sedimentation Plant	8.44	-.1750
2. Activated Sludge Plant	29.67	-.2400
3. Trickling Filter Plant	52.62	-.3400

where,

Y = operating and maintenance cost, dollars per year/capita (1968 dollars)

X = design population, number of persons

a & b = constants

Source: Robert Smith, "Cost of Conventional and Advanced Treatment of Wastewaters"

TABLE 6

Isard and Coughlin assumed that for the low density housing no municipal sewers would be provided. For the medium density community it was computed that 17.26 miles of sewer would be required. For the high density community 6.91 miles of sewer were needed. The cost was based on an equivalent 10 inch diameter sewer pipe buried 6 feet in the ground. The total investment in terms of 1953 dollars for the medium density community was $482,410. For the high density community the investment was $182,520. Using the FWQA Sewer Construction Index, the equivalent 1968 costs would be $773,786 and $292,762.

Since the number of persons served would be 2480 x 3.23 or 8010, the per capita cost for constructing the sewerage collection system in 1968 would be $96.48 for medium density and $36.42 for the high density community.

Isard and Coughlin also computed the cost of storm sewers for the two communities. The average effective size of pipe was taken as 42 inches. In terms of 1968 dollars the investment for storm sewers in the medium density community was $1,038,510 and $379,956 for the high density community. The per capita construction cost for storm sewers was, therefore, $128.40 per capita for the medium density community and $47.44 per capita for the high density community.

Isard and Coughlin assumed that no sewage pumping would be necessary, and that the life of the sewers would be 50 years.

In a recent unpublished study by American Public Works Association(13) the cost of installing sanitary sewers in two communities, 100,000 and 250,000 population, was studied. The average population density for the smaller city was 8.3 persons per acre while the density in the larger city was 8.9 persons per acre. Sewer miles for the 100,000 population city was 264 miles. For the larger city the sewer miles was 588 miles. An average number of commercial businesses and manufacturing firms was assumed. The cost of individual items for the two cities are given below in terms of dollars per capita.

Population Density	8.3	8.9
House Connections	$81.51	$81.80
Municipal Sewers	$166.99	$148.77
Manholes	$10.46	$9.31
	$258.96	$239.88

Interceptor and outfall sewers, with pumping, are not included in either of the two studies, because these facilities are normally lumped with the treatment plant cost.

If we compare the APWA estimates with Isard and Coughlin estimates, we must use the same basis. Isard and Coughlin did not include house connections. The cost of municipal sewers and manholes from the APWA estimate is $167.45 per capita for the 8.3 persons per acre density and $158.08 per capita for the 8.9 persons per acre density. These estimates are shown plotted with the Isard and Coughlin estimates, in terms of 1968 dollars, in Figure 8.

The equation which relates the cost of municipal sewers to the population density has the following form:

$$\text{Sewer Construction Cost, \$/capita} = \$800\ (\text{persons/acre})^{-0.775}$$

Both the 1960 Census[14] and the APWA Storm and Combined Sewer Study[12] show a relationship between the size of community and population density. The APWA data was used here because it is more recent. The relationship is shown by the dotted line in Figure 9. The relationship has the following form:

$$\text{Population Density, persons/acre} = 0.30\ (\text{community size})^{0.304}$$

The cost of household sewage disposal systems was studied by Thomas, Coulter, Bendixen, and Edwards[15]. This study, which was reported in 1960, attempted to optimize the household system. Optimum costs were estimated for three systems; septic tanks, aerobic treatment units, and cesspools. Poor, average, and good soil conditions were considered. Costs were expressed as present values. For average soil the present value of the septic tank system was given as $1,059. The present value was $1,351 for the aerobic system and $1,348 for the cesspool. Updating these costs to the 1968 level by means of the FWQA Treatment Plant Index gives $1,236 for the septic tank, $1,577 for the aerobic unit and $1,573 for the cesspool. If we assume an interest rate of 6%, the yearly per capita costs computes as $22.93/year/capita for the septic tank, $29.29/capita/year for the aerobic unit and $26.09/capita/year for the cesspool.

Downing[16] reported the cost of a 1050 gallon septic tank with 100 feet of tile in Madison, Wisconsin on February 28, 1967, as $537.50. Downing estimated the life of the tank as 50 years and the life of the tile field as 25 years. Downing assumed that the septic tank system would be inspected and pumped once every two years. The cost of inspection and pumping was estimated as $50.

COST OF SEWERAGE COLLECTION SYSTEMS
WITHOUT
PUMPING STATIONS
VERSUS
POPULATION DENSITY

1968 dollars

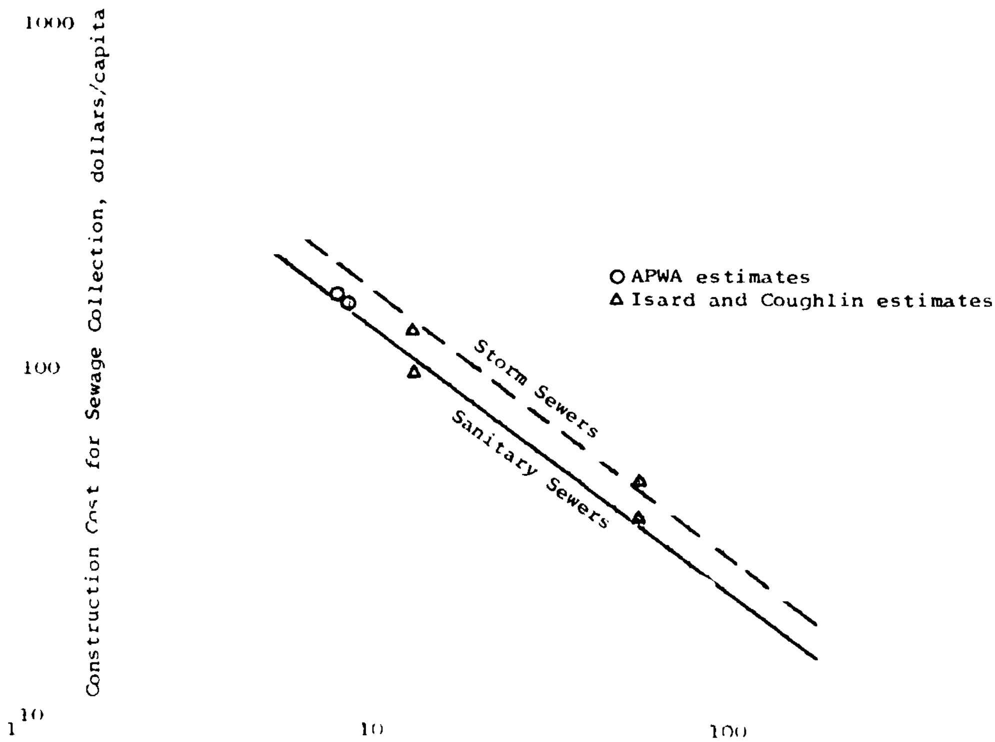


FIGURE 8

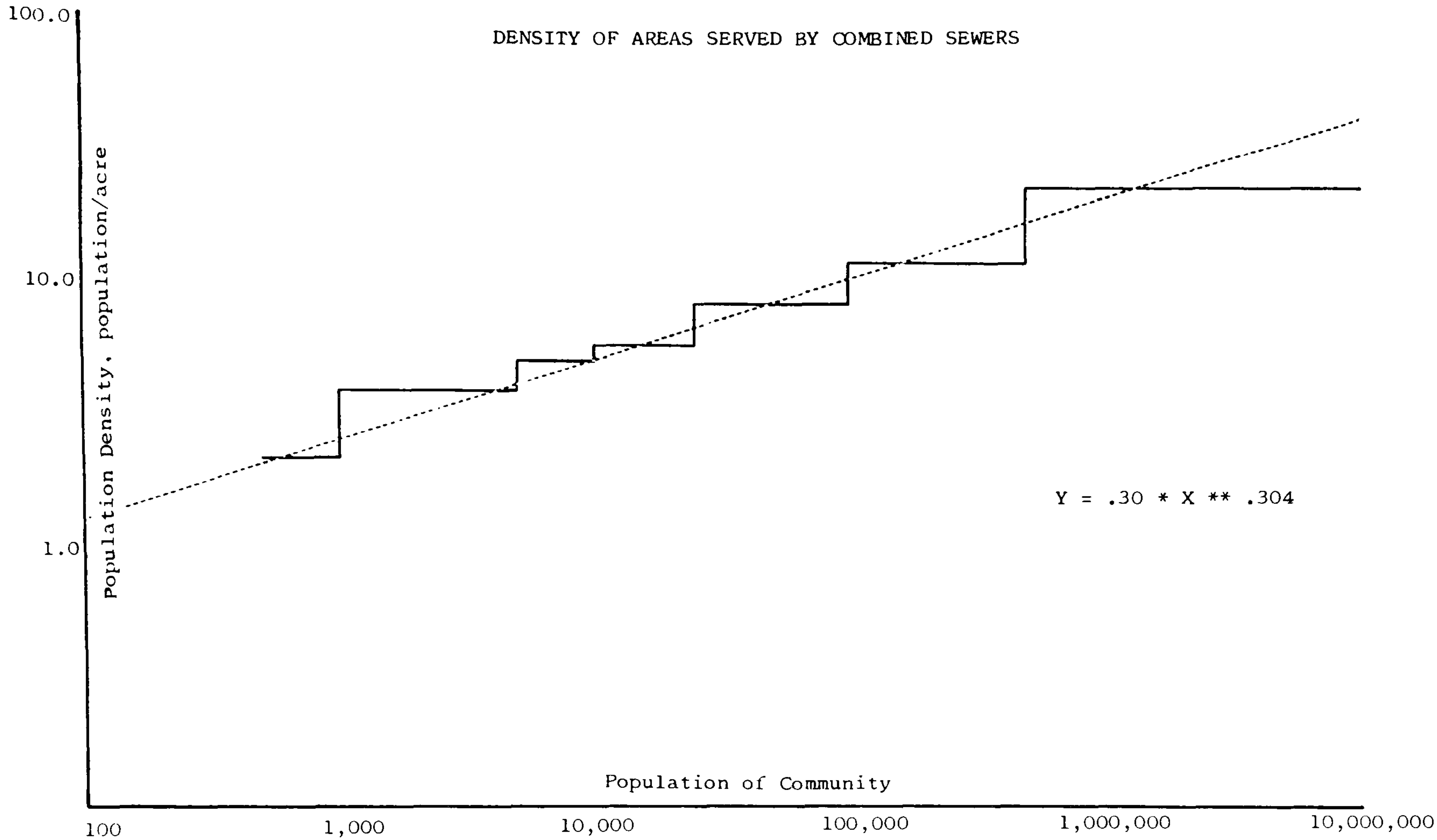

DENSITY OF AREAS SERVED BY COMBINED SEWERS
Population Density, population/acre
100.0
10.0
1.0
Y = .30 * X ** .304
Population of Community
100
1,000
10,000
100,000
1,000,000
10,000,000

FIGURE 9

Recent inquiries in the Cincinnati area revealed that Health Department standards require one 1000 gallon septic tank per household with a minimum of 900 square feet of surface area for the gravel leaching bed. The construction cost of the septic tank installation ranges from $900 to $1000. Inspection and cleaning is required every two years at a cost of between $30 and $35. Amortizing the construction cost over a 35 year average life at 6% interest gives a yearly per capita cost of $20.28. Adding $15 per year for maintenance gives a total per capita cost of $35.28/year.

In a study[17] conducted by the Constructions Grants and Engineering Branch of FWQA, the cost components in 733 federally funded sewer construction projects were analyzed. This study showed that roughly one-half of the construction cost was attributable to lump sum items such as pumping stations, inverted siphons, and flow control devices. It will be assumed here that the cost of pumping stations is included in the cost of ancillary works which was supplied by R. L. Michel of FWQA and shown in Table 3.

The cost of maintaining municipal sewers is conveniently expressed as cents/foot of sewer/year because the principal expense is labor. Bourlon[18] of Midwest City, Oklahoma reported an average cost of 6 cents per foot per year in 1969. Sewer maintenance cost data gleaned from financial reports of a number of cities is shown in Table 7. Averaging the first six values in the table gives an average cost of 6 cents per foot per year. This estimate will be used in this report.

In addition to expenses directly related to owning and operating the facilities two additional types of expenses are incurred. The first is called Customer Service and Accounting, the second General and Administrative. These overhead expenses were gathered from about ten municipal financial reports. Data from an additional ten cities was supplied by Mr. Don Parkhurst of Black and Veatch Engineers, Kansas City, Missouri[19]. These data are shown plotted in Figures 10 and 11. Regression relationships are shown on the plots.

Cost estimates for tertiary processes were reported by Smith and McMichael[20] in the Robert A. Taft Water Research Center Report No. TWRC-9. These estimates which were in terms of construction dollars and operation and maintenance cost in cents/1000 gallons have been converted to dollars per capita and dollars/capita/year by assuming the standard 100 gallons/capita/day. The cost relationships in the new form are shown in Tables 8 and 9.

SEWER MAINTENANCE COST DATA

City	Miles of Sewers	O&M Cost($)	O&M, ¢/ft	Year of Report	Other Things Included in O&M Cost, dollars
Phoenix, Ariz.	1,747.	484,879.00	5.26	'66-'67	
Richmond, Ind.	156.09	37,709.59	4.58	'67	
Knoxville, Tenn.	191.82	100,604.00	9.93	'67	
Walla Walla, Wash.	72.0	12,901.50	3.39	'67	
Alexandria, Va.	11.9	3,806.00	4.91	'68-'69	
South Bend, Ind.	275.	111,735.11	7.70	'67	8 lift stations
Columbus, Ohio	1,678.313	1,038,518.00	11.72	'67	Planning and design section as well as maintenance and construction
Levittown, Pa.	224.4	258,000.00	21.78	'67	24 lift stations
Allegheny County Sanitary Authority	69.	131,162.00	36.00	'60	3 pumping stations 3 ejector stations 1 towboat
East Bay	21.	239,723.00	216.20	'67-'68	12 pumping stations
Philadelphia, Pa.	2,463.	5,860,722.00	45.07	'66	3 treatment plants
Decatur, Ill.	48.	7,511.00	2.96	'67-'68	

TABLE 7

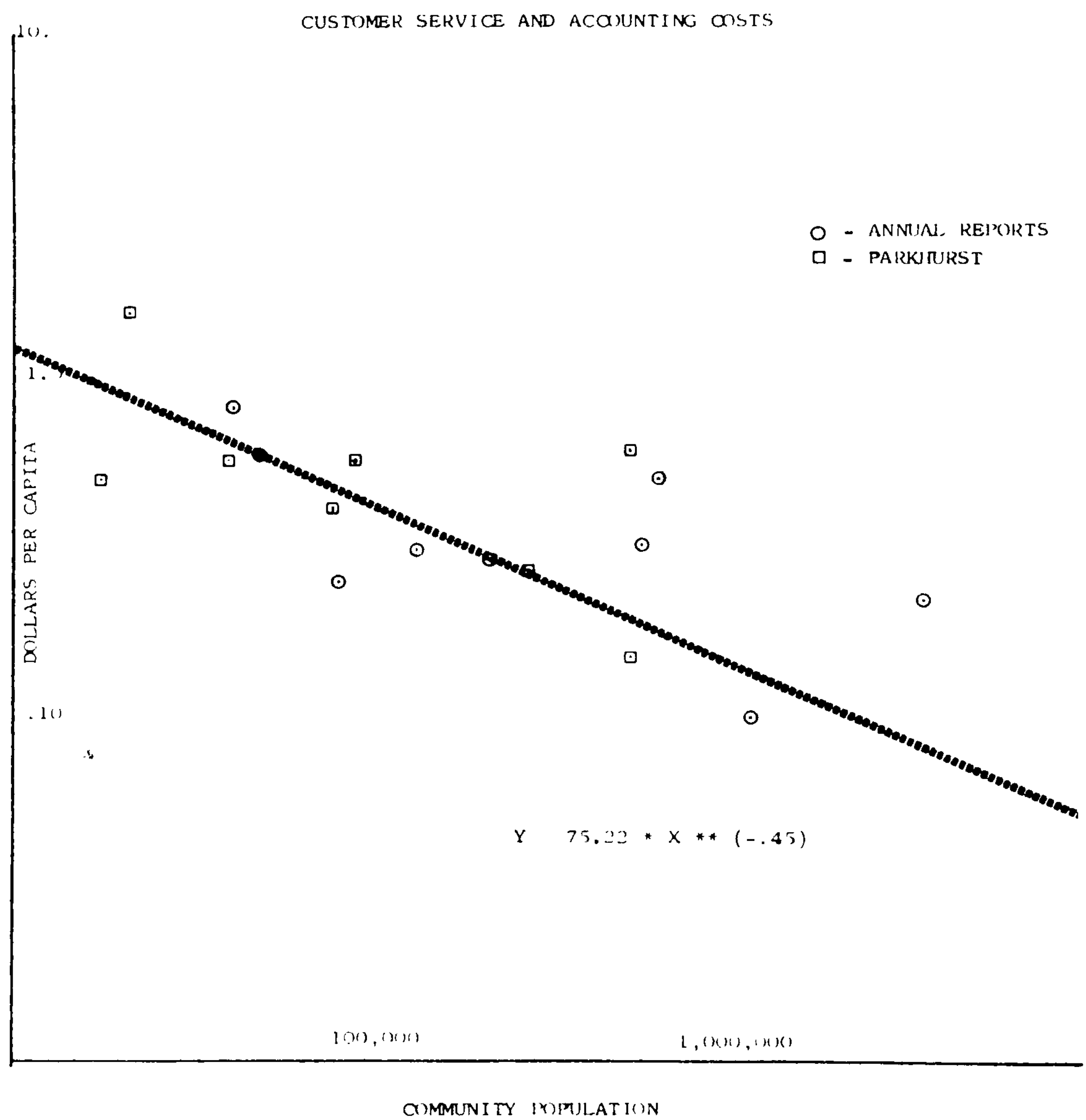
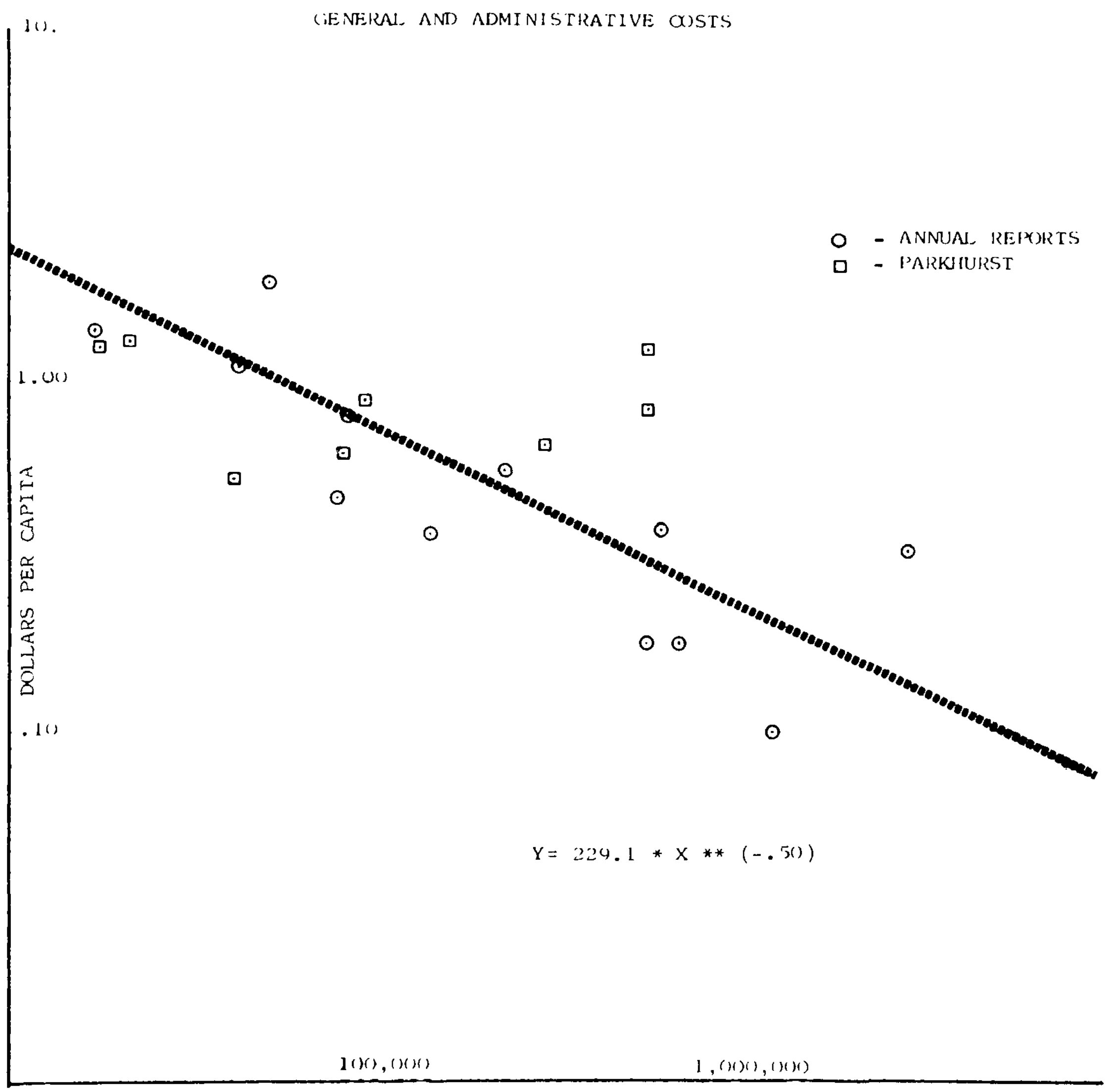

CUSTOMER SERVICE AND ACCOUNTING COSTS
10.
1.
.10
DOLLARS PER CAPITA
O - ANNUAL REPORTS
□ - PARKHURST
Y   75.22 * X ** (-.45)
100,000
1,000,000
COMMUNITY POPULATION

FIGURE 10



COMMUNITY POPULATION

FIGURE 11

CONSTRUCTION COST RELATIONSHIPS

in the form $Y = aX^b$

Type of Treatment	Value for a	Value for b
1. Microscreening	9.37	-.1190
2. Filtration	207.10	-.3400
3. Two-Stage Lime Clarification		
(less than 10 mgd)	140.86	-.2600
(greater than 10 mgd)	50.08	-.1750
4. Lime Recalcination	1903.20	-.5000
5. Ammonia Stripping	22.71	-.1000
6. Carbon Adsorption		
(less than 10 mgd)	1439.59	-.4000
(greater than 10 mgd)	76.01	-.1400

where,

Y = construction cost, dollars per capita (1968 dollars)
X = design population, number of persons
a & b = constants

Source: Robert Smith and Walter F. McMichael, "Cost and Performance Estimates for Tertiary Wastewater Treating Processes"

TABLE 8

OPERATING AND MAINTENANCE RELATIONSHIPS

in the form $Y = aX^b$

Type of Treatment Facility	Value for a	Value for b
1. Microscreening	.30	-.0440
2. Filtration	51.31	-.3800
3. Two-Stage Lime Clarification		
(less than 10 mgd)	148.61	-.4400
(greater than 10 mgd)	12.04	-.2250
4. Lime Recalcination		
(less than 10 mgd)	30.01	-.3000
(greater than 10 mgd)	9.36	-.2080
5. Ammonia Stripping		
(less than 10 mgd)	35.49	-.3330
(greater than 10 mgd)	3.52	-.1330
6. Carbon Adsorption		
(less than 10 mgd)	1418.94	-.5500
(greater than 10 mgd)	23.90	-.2000
7. Two-Stage Lime Clarification With Disposal or Recalcination		
(less than 10 mgd)	33.92	-.2390
(greater than 10 mgd)	26.44	-.2160

where,

Y = operating and maintenance cost, dollars per year/capita (1968 dollars)
X = design population, number of persons
a & b = constants

Source: Robert Smith and Water F. McMichael, "Cost and Performance Estimates for Tertiary Wastewater Treating Processes"

TABLE 9

COST OF MUNICIPAL COLLECTION AND TREATMENT

In order to use the capital cost and operating and maintenance cost relationships to calculate an average cost per capita in the Nation, the distribution of treatment facilities according to size must be used. This kind of data is supplied by the 1968 Inventory of Municipal Waste Treatment Facilities(1). The number of inhabitants and the number of plants in each population size group is shown in Table 10.

Traditionally, treatment plants are not constructed to serve the existing population but to serve the population expected at the end of the design period, normally taken as 20 years. Projecting ahead from 1968 to 1988 and from 1973 to 1993 we obtain, in either case, a ratio of design population to existing population of about 1.50. The design population for use in constructing new plants will, therefore, be the product of the existing population and the excess capacity factor 1.50.

According to a study reported in Volume 1 of the 1969 Cost of Clean Water Report(21), a trend towards constructing plants with larger excess capacity factors has been observed between 1962 and 1968. In 1962, the median capacity of existing municipal waste treatment plants was between 1.2 and 1.4 times that required by the existing population. In 1968 this factor had increased to between 1.4 and 1.6. The excess capacity factor also increases with the size of the plant. For cities in the population range between 50,000 and 500,000 persons, the median capacity in 1968 was 1.6 to 1.8 times the existing population and the modal plant size was 2.0 to 2.5 times the existing population.

The computational scheme (see Appendix) used to find the average construction cost for the Nation as a whole is described as follows: The population served in each population size group was first divided by the number of plants in the group. This number which represents the average number of inhabitants served per plant was then multiplied by the factor 1.5 to find the average design population per plant. Using the design population, the cost per capita was then found from the appropriate construction cost relationship. This per capita cost was then multiplied by the population served to find the construction cost for each population size group. These population group costs were then summed over all groups and the total divided by the actual 1968

POPULATION DISTRIBUTION

FOR SEWAGE TREATMENT IN THE UNITED STATES

1968

Population Size Groups	Total Sewered Population		Stabilization Ponds		Primary Sedimentation	
	Communities	Pop. Served	Plants	Pop. Served	Plants	Pop. Served
Under 500	1791	693,874	896	273,098	156	111,287
500 - 1,000	2259	1,828,753	816	571,600	276	245,841
1,000 - 5,000	5375	12,385,893	1334	2,327,850	832	2,048,489
5,000 - 10,000	1516	9,570,149	179	904,900	269	1,750,960
10,000 - 25,000	1200	15,504,150	131	963,385	237	3,438,355
25,000 - 50,000	422	12,697,700	36	444,280	107	3,001,825
50,000 - 100,000	203	13,421,175	27	319,235	53	3,605,920
100,000 - 250,000	86	14,856,790	16	209,345	56	5,202,805
250,000 - 500,000	37	13,620,080	15	64,335	19	3,472,445
Over 500,000	22	45,648,965	4	13,100	15	13,499,405

Population Size Groups	Activated Sludge		Trickling Filter		Sewered but Untreated Pop.
	Plants	Pop. Served	Plants	Pop. Served	Pop. Served
Under 500	261	90,899	188	74,245	71,915
500 - 1,000	294	225,677	458	353,485	228,925
1,000 - 5,000	752	1,738,430	1641	4,207,595	1,199,535
5,000 - 10,000	242	1,530,225	620	4,101,426	680,098
10,000 - 25,000	205	2,839,385	495	6,227,810	1,070,355
25,000 - 50,000	135	3,229,805	156	4,464,355	639,635
50,000 - 100,000	77	4,401,615	90	3,182,085	747,480
100,000 - 250,000	72	4,322,060	68	2,294,635	1,345,440
250,000 - 500,000	44	4,200,600	58	2,481,290	1,622,125
Over 500,000	27	18,667,965	9	1,025,100	1,977,400

Source: 1968 Inventory of Municipal Waste Facilities in the United States

TABLE 10

population served. This number is then taken as the average construction cost per capita. Average per capita construction cost estimates computed in this way are shown in Tables 11 and 12. Notice that various distributions according to size have been used. Values shown in Tables 11 and 12 must be multiplied by the appropriate excess capacity factor (average value = 1.5) to find the true per capita construction cost. Construction cost relationships from Table 3 were used to compute the values shown in Table 11. Relationships from Table 4 were used to compute average per capita cost shown in Table 12.

A similar procedure, but omitting the 1.5 factor, was used for computing the average operating and maintenance cost in dollars/capita/year. These are shown in Tables 13 and 14.

As pointed out earlier, the per capita construction cost for sewers is a function of the population density as shown in Figure 8. The population density is shown to depend on the size of the community in Figure 9. The procedure for computing the national average per capita sewer construction cost is as follows: For each population size group divide the number of inhabitants served by the number of communities to find the average size community in the population size group. From the average size community find the population density in persons/acre. With this value of population density find the sewer construction cost per capita. Multiply the per capita cost by the total number of inhabitants in the population size group to find the total construction cost for the group. Repeat the procedure for each population size group and sum over all groups. Divide the summed cost by the total number of sewered inhabitants to find the national average per capita sewer construction cost. The details of this computation are shown in Table 15. The average per capita cost using the total sewered population from the 1968 Inventory of Municipal Waste Treatment Facilities[1] was found to be $157.82.

The linear feet of sewer per capita can be shown to depend on the population density in the following way:

$$\text{Feed of Installed Sewer/capita} = 54\ (\text{persons/acre})^{-0.65}$$

Using the total sewered population distribution, a method similar to the one described above was used to find the national average linear feet of sewer per capita. The computed value was 14.28 feet/capita. Details of this computation are shown in Table 16. In a study of waterworks made in 1955, Seidel and Baumann[22] found the average length of water main per 1000 population to be 2.6 miles which corresponds to 13.73 feet per capita.

Population Distribution	Type of Treatment: Activated Sludge	Interceptors and Outfalls	Trickling Filter	Primary Sedimentation	Upgrading From Primary to Activated Sludge	Stabilization Ponds
Total Sewered Population	28.95	29.88	29.46	17.71	17.49	5.23
Activated Sludge and Extended Aeration	25.53	29.49				
Trickling Filter			45.14			
Primary Sedimentation				15.04	15.10	
Stabilization Ponds						21.42

NATIONWIDE AVERAGE CONSTRUCTION COST, DOLLARS PER CAPITA (1968 DOLLARS)

Source: cost data - R. L. Michel, Construction Grants and Engineering Branch, FWQA
population distributions - 1968 Inventory of Municipal Waste Facilities in the U. S.

TABLE 11

Type of Treatment

Population Distribution	Activated Sludge	Trickling Filter	Primary Sedimentation			
Total Sewered Population	34.55	31.87	20.04			
Activated Sludge and Extended Aeration	32.43					
Trickling Filter		44.15				
Primary Sedimentation			18.53			

NATIONWIDE AVERAGE CONSTRUCTION COST, DOLLARS PER CAPITA (1968 DOLLARS)

Source: cost data - Robert Smith, "Cost of Conventional and Advanced Treatment of Wastewaters"
population distributions - 1968 Inventory of Municipal Waste Facilities in the U. S.

TABLE 12

Type of Treatment

Population Distribution	Activated Sludge	Trickling Filter	Primary Sedimentation	Stabilization Ponds		
Total Sewered Poulation	2.03	1.23	1.41	.22		
Activated Sludge and Extended Aeration	1.87					
Trickling Filter		1.94				
Primary Sedimentation			1.32			
Stabilization Ponds				.67		

NATIONWIDE AVERAGE OPERATION AND MAINTENANCE COST, DOLLARS PER YEAR/CAPITA (1968 DOLLARS)

Source: cost data - R. L. Michel, Construction Grants and Engineering Branch, FWQA
population distributions - 1968 Inventory of Municipal Waste Facilities in the U. S.

TABLE 13

Type of Treatment

Population Distribution	Activated Sludge	Trickling Filter	Primary Sedimentation			
Total Sewered Population	2.13	1.39	1.19			
Activated Sludge and Extended Aeration	1.96					
Trickling Filter		2.17				
Primary Sedimentation			1.16			

NATIONWIDE AVERAGE OPERATION AND MAINTENANCE COST, DOLLARS PER YEAR/CAPITA (1968 DOLLARS)

Source: cost data - Robert Smith, "Cost of Conventional and Advanced Treatment of Wastewaters
population distributions - 1968 Inventory of Municipal Waste Facilities in the U. S.

TABLE 14

CONSTRUCTION COST FOR SEWERS   BASED ON 1968 SEWERED POPULATION

NUMBER OF PLANTS	POPULATION SERVED	AVERAGE POPULATION PER PLANT	PER CAPITA COST, $
1791.	693874.	387.	499.51
2259.	1828753.	809.	419.89
5375.	12385893.	2304.	328.17
1516.	9570149.	6312.	258.81
1200.	15504150.	12920.	218.62
422.	12697700.	30089.	179.14
203.	13421175.	66114.	148.81
145.	74125835.	511212.	91.91

TOTAL POPULATION 140227529.

TOTAL CAPITAL COST 22130918624.

AVERAGE PER CAPITA COST 157.82

COST INDEX 1.0000

TABLE 15

PER CAPITA LENGTH OF SEWERS IN THE UNITED STATES

BASED ON 1968 SEWERED POPULATION

Number of Communities	Population Served	Average Population Per Community	Length of Sewer, ft/capita
1,791	693,874	387	36.93
2,259	1,828,753	809	32.10
5,375	12,385,893	2,304	26.32
1,516	9,570,149	6,312	21.73
1,200	15,504,150	12,920	18.96
422	12,697,700	30,089	16.15
203	13,421,175	66,114	13.91
145	74,125,835	511,212	9.43

Total Population	140,227,529
Total Length of Sewers, ft.	2,003,368,843
Average Length of Sewer, ft/capita	14.28

TABLE 16

The yearly charge for Customer Service and Accounting and for General and Administrative Cost were both shown (Figures 10 and 11) to depend on the size of community. A method similar to that described above was used to compute the national average cost of these two services. For Customer Service and Accounting the national average cost was found to be $0.71 per capita per year. For General and Administrative cost the national average was computed as $1.37 per capita per year.

The national average per capita cost for tertiary treatment processes was computed in the same way using the total sewered population size distribution. These computed per capita costs are shown in Table 17. Again an excess capacity multiplier (average = 1.5) must be used to find the true per capita cost for construction.

NATIONWIDE AVERAGE CONSTRUCTION AND OPERATING AND MAINTENANCE COST
FOR TERTIARY WASTEWATER TREATMENT PROCESSES

(based on 1968 dollars and plants of one mgd or larger in the United States)*

	Construction Cost, $/capita	Operating and Maintenance Cost, $/yr/capita
Microscreening	2.07	.17
Filtration	3.20	.58
Two-Stage Lime Clarification	5.97	.97
Lime Recalcination	4.72	.86
Ammonia Stripping	6.37	.79
Carbon Adsorption	14.36	2.95
Two-Stage Lime Clarification with Disposal or Recalcination	-----	1.96
Two-Stage Lime Clarification and Filtration	9.17	1.55
Two-Stage Lime Clarification and Ammonia Stripping	12.34	1.76
Two-Stage Lime Clarification and Ammonia Stripping and Carbon Adsorption	26.70	4.71

* Total Sewered Population from 1968 Inventory of Municipal Waste Treatment Facilities Used. 1.5 Excess Capacity Factor Used for Construction.

TABLE 17

COST OF INDUSTRIAL WASTEWATER TREATMENT

The 1968 Cost of Clean Water[2] report estimated the cost of achieving adequate wastewater treatment in the industrial sector using two separate methods. The first method made use of the 1964 Census of Manufacturers[23] issued by the Bureau of Census. The second method used data presented in the Industrial Waste Profiles reported in the ten sections of Volume III of the 1968 Cost of Clean Water[2] report.

The 1964 Census of Manufacturers listed water use and wastewater production for two classes of manufacturing industry; those using under 20 million gallons per year (smaller users) and those using more than 20 million gallons per year (larger users). The authors of the 1968 Cost of Clean Water[2] report assumed that all of the wastewater from the smaller users would be discharged to public sewers and the cost of treating this industrial waste was lumped with the municipal cost. A small fraction (about 10%) of the water from the larger users was also known to be discharged to municipal sewers. Cost estimates given for industrial treatment refer only to that fraction of the wastewater from larger users which is not discharged to public sewers.

The amount of water discharged to public sewers by the smaller industrial users in 1968 was estimated as 310 billion gallons/yr. The amount of water discharged to the public sewers by the larger users was estimated as 1,029 billion gallons/yr in 1968 and 1,157 billion gallons in 1973. The sewered population in the United States in 1968 was 140.226 million. Estimating the per capita use exclusive of manufacturing as 120 gallons/day/capita the total sewage volume would be 16.83 billion gallons/day or 6,142 billion gallons/yr. On a volume basis the contribution of manufacturing to public sewers is about 22 percent of the total sewered waste which is equivalent to about 26 gallons per day per capita.

Water produced by the larger users (over 20 million gallons/yr) in 1964 was estimated by the Census of Manufacturers as 13,157 billion gallons/yr. Nine-hundred eighty seven billion gallons/yr was discharged to public sewers leaving 12,170 billion gallons/yr to be treated at the plant or discharged without treatment. The largest fraction of this, 9,385 billion gallons/yr, is represented by cooling water which needs either minimal treatment or no treatment.

About 3,703 billion gallons/yr are used as process water. The BOD and suspended solids concentration of process water far exceeds that of normal raw sewage. A comparison of the pollutional load contributed by process water as compared with normal sewage is shown in Table 18. Industrial wastewater is, therefore, greater in volume and pollutional load than municipal sewage.

The first cost estimation method used the 1964 Census of Manufacturers for estimating the quantity of wastewater discharged and used the cost of municipal sewage facilities to represent the cost of industrial wastewater treatment. The assumed removal of contaminants associated with industrial treatment was 85 percent removal of both 5-day BOD and suspended solids. The second method of cost estimation used the Industrial Waste Profiles published in ten sections of Volume III of the 1968 Cost of Clean Water(2) report. This method appears to be the most reliable and also gives the least estimate of the investment expenditures needed. Cost estimates derived using both methods are shown in Table 19, taken from the 1968 Cost of Clean Water report. An annual expenditure between 400 to 600 million dollars was believed to be needed to overcome the deficiency in industrial treatment over the five-year, 1969-73, period. This sum represents about 1½ percent of the approximately $30 billion annual budget for new plant and equipment expenditures in the manufacturing sector.

The same two methods were used in the 1968 Cost of Clean Water(2) report to estimate the annual operating and maintenance cost for industrial wastewater treatment plants. These are shown in Table 20. Over the six-year period the annual operating and maintenance cost averaged about $600 million per year. If we add about $450 million for new plants, the <u>yearly</u> average expenditures for industrial treatment over the five-year period is about 1.05 billion dollars per year. The population of the United States in 1968 was about 200 million and will increase to about 216 million by 1973. Assuming that the entire population pays for industrial wastewater treatment in the form of higher cost for manufactured goods, the average total per capita cost would be about $5.50 per capita/year.

ESTIMATED VOLUME OF INDUSTRIAL WASTES BEFORE TREATMENT, 1964[1/]

Industry	Waste-water Volume (Billion Gallons)	Process Water: Intake (Billion Gallons)	Process Water: BOD$_5$ (Million Pounds)	Process Water: Suspended Solids (Million Pounds)
Food and Kindred Products	690	260	4,300	6,600
Meat Products	99	52	640	640
Dairy Products	58	13	400	230
Canned and Frozen Food	87	51	1,200	600
Sugar Refining	220	110	1,400	5,000
All Other	220	43	670	110
Textile Mill Products	140	110	890	N. E.
Paper and Allied Products	1,900	1,300	5,900	3,000
Chemical and Allied Products	3,700	560	9,700	1,900
Petroleum and Coal	1,300	88	500	460
Rubber and Plastics	160	19	40	50
Primary Metals	4,300	1,000	480	4,700
Blast Furnaces and Steel Mills	3,600	870	160	4,300
All Other	740	130	320	430
Machinery	150	23	60	50
Electrical Machinery	91	28	70	20
Transportation Equipment	240	58	120	N. E.
All Other Manufacturing	450	190	390	930
All Manufacturing	13,100	3,700	22,000	18,000
For comparison: Sewered Population of U. S.	5,300[2/]		7,300[3/]	8,800[4/]

1/ Columns may not add, due to rounding

2/ 120,000,000 persons x 120 gallons x 365 days

3/ 120,000,000 persons x 1/6 pounds x 365 days

4/ 120,000,000 persons x 0.2 pounds x 365 days

TABLE 18

ANNUAL INVESTMENT REQUIRED TO REDUCE THE EXISTING INDUSTRIAL WASTE TREATMENT DEFICIENCY IN FIVE YEARS

(Wastewater Profiles and Estimates)

Industry	Millions of 1968 Dollars: Annual Investment To Reduce Existing Requirement	Total Investment to Reduce Waste Treatment Requirements and Meet Growth Needs: 1969	1970	1971	1972	1973
Food and Kindred Products	43.9	63.2	65.4	69.9	70.0	69.9
Meat Products	7.0	10.1	11.2	11.2	11.7	11.6
Dairy Products	4.6	5.1	5.7	5.5	5.5	5.5
Canned and Frozen Foods	6.7	11.4	12.4	12.6	12.9	13.0
Sugar Refining	13.5	19.3	18.4	22.6	21.4	21.5
All Other	12.1	17.3	17.7	18.0	18.5	18.3
Textile Mill Products	5.3	9.8	10.9	11.1	11.0	11.6
Paper and Allied Products	15.1	19.1	25.5	26.0	26.4	27.0
Chemical and Allied Products	56.0	75.7	76.9	77.7	79.4	77.9
Petroleum and Coal	15.4	15.4	18.1	30.5	31.7	32.1
Rubber and Plastics, n.e.c.	6.2	7.0	7.9	7.1	7.2	7.1
Primary Metals	29.9	83.6	91.3	93.3	96.2	97.8
Blast Furnaces and Steel Mills	19.6	52.4	59.1	60.1	63.0	63.0
All Other	10.3	31.2	32.2	33.2	34.2	34.8
Machinery	5.0	6.9	6.9	7.1	7.1	7.3
Electrical Machinery	1.7	3.6	3.8	3.8	4.0	4.1
Transportation Equipment	8.3	11.7	11.9	12.2	12.1	12.3
All Other Manufacturing	23.5	32.3	32.6	33.0	33.5	33.8
All Manufactures:						
By Wastewater Profiles and Estimates	210.3	328.3	351.2	371.7	378.6	380.9
(By Census-Municipal Projections)	(528.5)	(676.9)	(705.8)	(731.5)	(740.2)	(743.1)

TABLE 19

ANNU/)PERATING AND MAINTENANCE COSTS

1968-1973

Industry	Annual Operating and Maintenance Costs (Millions of 1968 Dollars)					
	1968	1969	1970	1971	1972	1973
Food and Kindred Products	85.4	95.9	107.0	118.7	130.4	142.1
Meat Products	15.3	16.4	17.7	19.0	20.3	21.6
Dairy Products	16.1	17.1	18.3	19.4	20.5	21.6
Canned and Frozen Foods	17.9	19.9	22.0	24.2	26.5	28.7
Sugar Refining	19.1	22.5	25.8	29.8	33.5	37.3
All Other	17.0	20.0	23.2	26.3	29.6	32.9
Textile Mill Products	39.0	41.7	44.8	47.9	51.0	54.3
Paper and Allied Products	33.3	35.9	39.3	42.8	46.4	50.0
Chemical and Allied Products	21.1	37.2	53.5	70.0	86.8	103.3
Petroleum and Coal	60.5	63.5	67.2	73.3	79.6	86.1
Rubber and Plastics, n.e.c.	1.8	3.0	4.4	5.7	7.0	8.2
Primary Metals	137.8	146.5	155.9	165.7	175.7	185.9
Blast Furnaces and Steel Mills	90.1	95.5	101.6	107.9	114.4	121.0
All Other	47.7	51.0	54.3	57.8	61.3	64.9
Machinery	2.5	3.7	4.9	6.2	7.5	8.7
Electrical Machinery	4.8	5.5	6.1	6.8	7.5	8.2
Transportation Equipment	29.4	31.4	33.4	35.5	37.5	39.6
All Other Manufacturing	15.3	21.0	26.8	32.6	38.5	44.5
All Manufacturers:						
By Wastewater Profiles and Estimates	430.9	483.4	543.3	605.2	667.9	730.9
By Census-Municipal Projections	(348.7)	(453.6)	(565.6)	(679.9)	(802.1)	(921.7)

TABLE 20

EVALUATION OF THE TREATMENT BACKLOG

The magnitude of the backlog in construction of treatment facilities is shown in Figure 4. The FWQA target has been to overcome this backlog by 1973. Using 1968 as the base year the cost of constructing the additional needed treatment facilities can be computed by first noting that the projected urban population for 1973 is about 165.2 million persons. Inventories of Municipal Waste Treatment Facilities for 1957, 1962, and 1968[4],[6],[1] are summarized in Table 21. From Table 21 it can be seen that in 1968 a total of 69.979 million persons were served by adequate secondary treatment. It will be assumed that those served by primary sedimentation and intermediate treatment can be adequately served by upgrading the present facilities to activated sludge treatment. This population numbers 36.377 million with primary sedimentation and 5.858 million with intermediate treatment making a total of 42.235 million to be upgraded.

Subtracting these two totals from the 165.2 million estimated 1973 urban population gives a total of 52.986 million for which new activated sludge plants plus interceptors and outfalls will be needed by 1973. The cost of this new construction of activated sludge plants in terms of 1968 dollars is computed as follows: 52.986 million x 1.5 x ($28.95 + $29.88) = $4.676 billion. The cost of upgrading the primary and intermediate plants can be calculated as follows: 42.213 million x 1.5 x $17.49 = $1.107 billion.

An allowance for depreciation of installed treatment facilities must be added to the cost of new construction. The replacement cost of the treatment plants and ancillary works will be taken as the average replacement cost obtained by averaging the replacement value in 1968 with the replacement value in 1973.

The value of installed structures in 1973 will be approximated by the value of activated sludge plants and ancillary works for the total urban population. This can be computed as follows: 165.2 million x 1.5 x ($28.95 + $29.88) = $14.578 billion.

The replacement value of plants and ancillary works in 1968 is computed as shown in Table 22. The total replacement value of treatment works in 1968 is approximately $10.599 billion. The average value of structure over the five-year period will, therefore, be 12.589 billion dollars. The useful life of plants will be taken as 25 years and the useful life of ancillary works as 50 years. Since the cost of activated sludge plants about

SUMMARY OF WASTEWATER COLLECTION AND TREATMENT IN UNITED STATES
1957 - 1968 (Population in Millions)

	1957	1962	1968
TOTAL SEWERED POPULATION	98.361	118.372	140.226
Total Treated	76.443	103.685	130.685
Discharging Raw	21.917	14.687	9.541
TOTAL TREATED	76.443	103.685	130.685
Minor	1.860	2.351	1.361
Primary	25.667	32.733	36.947
Intermediate	5.591	7.409	5.858
Secondary	43.326	61.191	83.640
Tertiary	0.000	0.000	0.326
PRIMARY TREATMENT			
Septic Tanks	0.987	0.681	0.569
Sedimentation	24.680	32.052	36.377
ADEQUATE SECONDARY TREATMENT			
Activated Sludge	24.754	33.287	38.542
Standard Rate Trickling Filter	9.351	11.532	11.979
High Rate Trickling Filter	5.963	11.473	16.433
Extended Aeration	0.000	0.406	2.705
	40.068	56.698	69.659
WASTE STABILIZATION PONDS	0.760	2.195	6.091
INTERMITTENT SAND FILTER			0.332
APPLICATION TO LAND			0.413
OTHERS AND UNKNOWN			9.090
TERTIARY TREATMENT			.326

Source: Inventory of Municipal Waste Facilities in United States

TABLE 21

ROUGH CALCULATION OF INVESTMENT IN SEWAGE TREATMENT FACILITIES AND ANCILLARY WORKS IN THE UNITED STATES IN 1968

		Population Served	Unit Cost per PE*	Capital Cost** Billions of Dollars
1.	Activated Sludge, Extended Aeration and Tertiary Treatment Plants	41.567 mil.	$25.53	$1.592
2.	Primary Sedimentation and Intermediate Treatment Plants	42.805 mil.	$16.04	$1.030
3.	Trickling Filter Plants	28.412 mil.	$45.14	$1.924
4.	Stabilization Ponds	6.091 mil.	$21.42	$.196
	Total	118.875 mil.		$4.742
5.	Interceptor Sewers and Outfalls	130.685 mil.	$29.88	$5.857
				$10.599

* Population Equivalent

** Design population taken as 1.5 times the population served

Total Investment = $11.069 Billion

Average Treatment Plant Cost per PE = $26.59

TABLE 22

equals the cost of ancillary works, the depreciation rates of 4% and 2% will be averaged to give an overall rate of 3%. The cost of depreciation will, therefore, be 377.67 million dollars per year or a total of $1.888 billion for the five-year period.

Summing the cost of new activated sludge plants ($4.676 billion), upgrading primary and intermediate plants ($1,107 billion) and providing for depreciation ($1.888 billion), the total cost of overcoming the backlog is $7.671 billion in terms of 1968 dollars. The 1968 Cost of Clean Water[2] report estimated this cost of overcoming the backlog of municipal construction as $8 billion in 1968 dollars.

The cost of constructing treatment works has been inflating at a rate between 6% and 6.5% over the last two years. Using a 6% inflationary estimate the $7.671 figure must be multiplied by a factor of 1.1274 to give a total of $8.648 billion in current dollars.

The third report of the series known as the Cost of Clean Water Series was issued in March 1970. This report entitled The Economics of Clean Water[24] reported the results of a very detailed study of the investment backlog in municipal treatment works. The backlog as of 1969 was computed as $4.4 billion. The required investment for the 1970-74 period was conservatively estimated as $10 billion in current dollars.

FULL COST OF COLLECTION AND TREATMENT

Expenditures for sewage collection and treatment are of two basic kinds; capital outlay for land, equipment, and structures, and current expenses such as labor, chemicals, and supplies. To compute the total cost of sewage collection and treatment these two kinds of expenses must be equated. This can be done in two ways. All expenses can be expressed either on a continuous cash flow basis or on a present value basis. These concepts are discussed fully in Chapter 5 of Plant Design and Economics for Chemical Engineers by Peters and Timmerhaus[25].

The full cost of sewage collection and treatment will be computed here on a continuous cash flow basis. The treatment plant will be amortized over a 25-year period and the collection system will be amortized over a 50-year period. The cost of borrowing money will be taken as 5 percent. The cost of land for the plant site is not included because of the strong dependency on the area of the country and topographical considerations.

The capital investment in existing treatment plants for the year 1968 is computed in Table 22 based on the 1968 Inventory of Municipal Waste Facilities and the construction cost relationships developed by R. L. Michel of Construction Grants and Engineering Branch of FWQA. Cost estimates for some minor processes are not available, and the specific type of treatment is not known for more than nine million population. The average capital cost per population equivalent for the processes shown in Table 22 is $26.59/capita. Multiplying this by the total treated population of 130.685 million and the factor 1.5 gives the total investment in treatment plants of $5.213 billion. The investment in ancillary works (interceptors and outfalls) is $29.88 x 1.5 x 130.685 or 5.857 billion dollars. The amortization factor of 0.07095 corresponding to 25 years and 5 percent interest was used to compute an amortization charge for the treatment plant of $2.83/capita/year. The amortization charge for ancillary works using an amortization factor of 0.05478 corresponding to 5 percent and 50 years was computed as $2.46/capita/year.

A computation of the average per capita cost for operation and maintenance of treatment plants based on the 1968 Inventory is shown in Table 23. The limits of $1.63 and $1.47 were averaged to give $1.55/capita/year for operation and maintenance plants.

COMPUTATION OF NATIONAL AVERAGE
OPERATION AND MAINTENANCE COST FOR TREATMENT PLANTS
(1968 dollars)

	Population Served, mil.	Annual Cost per capita	Operation and Maintenance Cost/yr.
Activated Sludge and Extended Aeration	41.247	$1.87	$77.132 mil.
Primary Sedimentation and Intermediate	42.235	$1.32	$55.750 mil.
Trickling Filters	28.412	$1.94	$55.119 mil.
Stabilization Ponds	6.091	$0.67	$4.081 mil.
Total	117.985		$192.082 mil.

1. Average Operation and Maintenance Cost = $1.63/capita/yr.

2. Average Operation and Maintenance Cost = $192.082 mil./130.685 mil. = $1.47

Source of Cost Data: R. L. Michel, Construction Grants and Engineering Branch, FWQA

TABLE 23

American Public Works Association estimated the cost of the house connection as $81.51 per house. This corresponds to 60 feet of 6-inch vitrified clay pipe. Amortization cost for the house connection, assuming 3.23 persons per household is $1.38 per capita per year. The cost of constructing municipal sewers has been shown in Table 24 to average $157.82 per capita. Using the amortization factor for 50 years and 5 percent, the yearly amortization cost for municipal sewers was computed as $8.64/capita/year.

The average cost of maintaining municipal sewers was taken as 6 cents per linear foot per year. The average length of sewer was computed to be 14.28 feet/capita. The average yearly cost of sewer maintenance is, therefore, 86 cents/capita/year.

The average charge for customer service and accounting was computed as 71 cents/capita/year. The general and administrative cost was computed as $1.37 per capita per year.

The total cost of collection and treatment based on the treatment level prevailing in 1968 is shown in Table 24.

On a per capita basis the total cost shown in Table 24 would change only slightly if the whole nation was equipped with activated sludge treatment. For example, the amortization cost for the plant would be $3.08/capita/year instead of $2.83 and the operation and maintenance cost for the plant would be $2.03 instead of $1.55. The total increase in cost would, therefore, be 73 cents/capita/year which is only about 3.7 percent of the total cost.

Current expenditures, revenue from user charges, and capital outlay data have been collected by the Bureau of Census for various governmental units in the United States. Data for the Nation as a whole is shown in Table 25. Current expenditures include operating and maintenance for the treatment plant, sewer maintenance, billing and collection, and miscellaneous administration including engineering.

The capital outlay for sewerage works and for water supply facilities is shown in Figure 12. From Table 25 it can be seen that the reported current expenditures for sewage collection and treatment is only about 10 to 15 percent higher than the revenue collected in user charges.

The total population with treatment facilities in 1968 was 130.685 million. If we assume that only the treated population paid user charges, the 534 million dollar figure can be divided by 130.685 to give an average user charge of $4.09. The average expenditure for sewerage services using the same assumption is 625/130.685 = $4.77. The average expenditure is close to the estimate of $4.49/capita/year.

TOTAL COST OF SEWAGE COLLECTION AND TREATMENT IN 1968
ON A CONTINUOUS CASH FLOW BASIS
1968 dollars/capita/year

Amortization Cost		
House Connection	$1.38	
Municipal Sewers	$8.64	
Interceptors and Outfalls	$2.46	
Treatment Plants	$2.83	
Total Amortization Cost	$15.31	
Current Expenses		
Municipal Sewer Maintenance		$0.86
Treatment Operation and Maintenance		$1.55
Customer Service and Accounting		$0.71
General and Administrative		$1.37
Total Current Expenses		$4.49
Total Cost of Municipal Collection and Treatment	$19.80	

TABLE 24

EXPENDITURES FOR SEWERAGE COLLECTION AND TREATMENT
IN THE UNITED STATES
(millions of current dollars)

Year	Sewer Charges	Sewer Current Expenditure	Capital Outlay
1968	534	625	1,107
1967	571	626	1,069
1966	571	505	1,202
1965	519	462	1,107
1964	468	420	1,095
1963	470	407	1,057
1962	386	386	886
1961	330	377	726
1960	318	336	767
1959	266	303	708
1958	226	284	649
1957	219	262	644

TABLE 25

CAPITAL OUTLAY FOR NEW SEWAGE COLLECTION
AND TREATMENT FACILITIES
IN
CURRENT DOLLARS

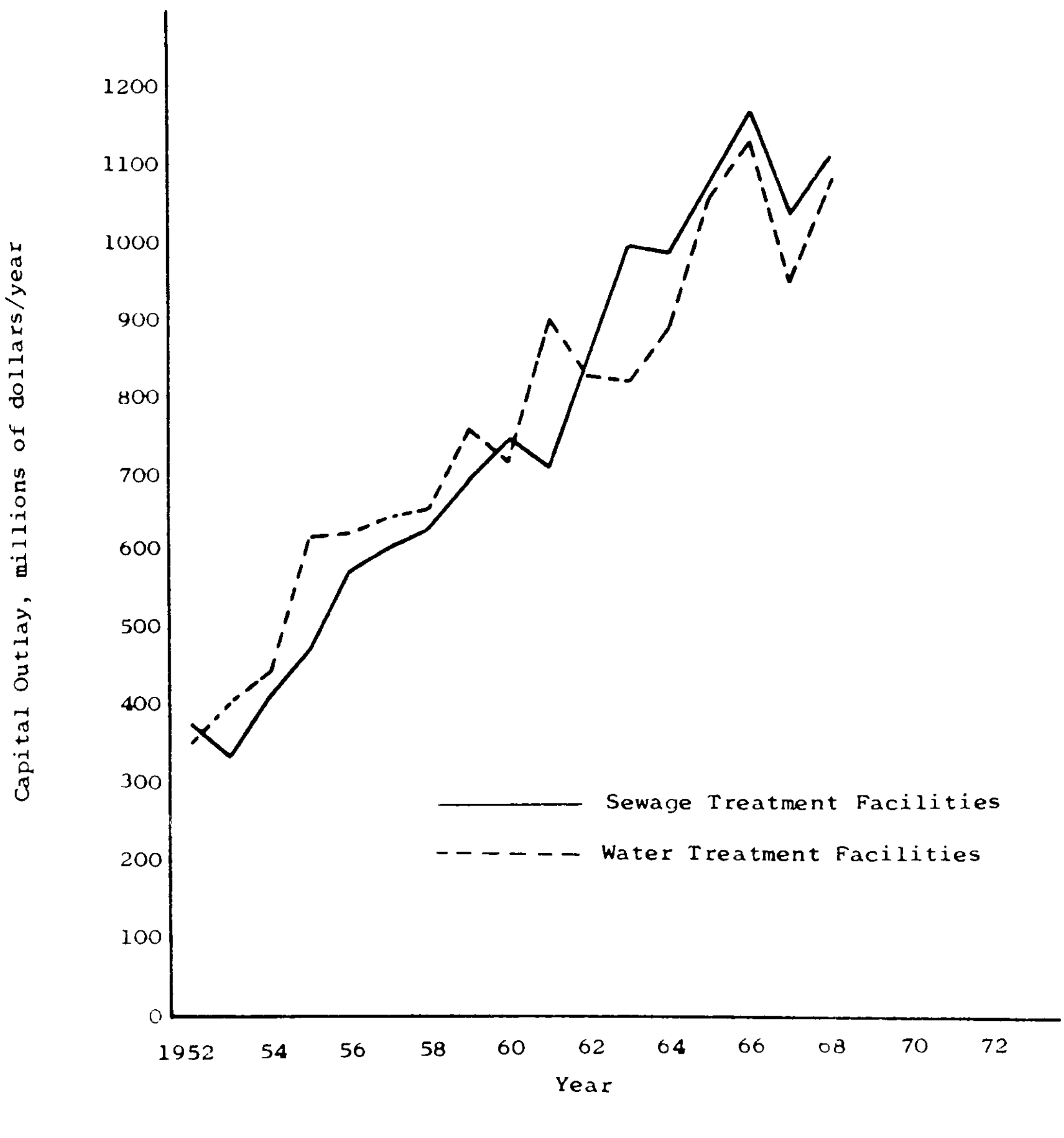


FIGURE 12

Among the conclusions which can be drawn from Table 24 are first, that the current expenses associated with collection and treatment are only about 23 percent of the total cost for domestic sewage collection and treatment and second, that the cost of constructing sewers is about three times the cost of constructing treatment plants. This conclusion does not change appreciably if activated sludge secondary treatment is assumed.

The house connection is normally paid for by the house owner as part of the purchase price for the house. The cost of constructing municipal sewers is paid for either as an assessment or as part of the purchase price for the house. In some instances grants-in-aid are provided by the Federal Government to finance sewerage systems in rural areas. The cost to the rural municipality in this case, would be about $9.78/capita/day of which about 40 percent is paid for in user charges. The remainder is paid for in the form of taxes primarily at the local level.

The cost of tertiary treatment can now be examined using the values shown in Table 17 as a background. Again amortizing the construction cost over 25 years at 5 percent interest, the cost of microscreening for removing particulate organic matter which escapes the final clarifier would amount to about 33 cents/capita/year.

GOVERNMENTAL EXPENDITURE FOR GRANTS-IN-AID

Treatment plants, interceptor sewers, and outfalls are normally financed by selling municipal general obligation bonds which are paid back out of general revenue from taxes. Part of the capital outlay for these facilities is supplied in the form of grants-in-aid from Federal and State Governments. The principal source of grants-in-aid for treatment plants, interceptors and outfalls is the Federal Water Quality Administration. The amount of these grants-in-aid for construction are shown in Table 26. Other Federal governmental agencies supply lesser amounts of grants-in-aid. For example, the Economic Development Administration of the Dept. of Commerce expended $5,307,000 during fiscal year 1969 for sewerage works. For the four-year period, 1966-69, a total of $44,868,000 was expended by EDA for sewage works. The Dept. of Commerce also administers the Appalachian Regional Development Act. Under the terms of this law a total of $7,309,000 was expended for sewerage works grants-in-aid in the six-year period, 1965-70. The Farmer's Home Administration makes grants-in-aid primarily for construction of new sewers. The total expenditure during fiscal year 1970 for water supply and sewers was about $42 million of which about $20 million was used for new sewer construction. The Department of Housing and Urban Development also makes grants-in-aid for sewage works and water supply. Expenditure for sewage collection and treatment facilities totaled $228 million over the four-year period, 1966-69. Of the $228 million, 92.5% was spent on new sewers.

Federal Water Quality Administration is authorized by Congress to contribute up to 30 per cent of the construction cost of treatment plants, interceptor sewers, and outfalls if the State government makes no contribution. FWQA can increase the federal contribution to 55% of the construction cost if the State government will provide at least 25% of the cost.

In 1967 only seven states authorized the expenditure of intergovernmental funds for construction of sewage treatment facilities. The amount of money appropriated or authorized together with the actual expenditure for construction is shown for all seven states in Table 27. The total for authorized funds was $14.5 million but the amount actually expended is not known. The total amount of public construction in 1967 was $1,069 million for sewers and treatment plants. In 1967 grants-in-aid from the federal government amounted to about $154 million. States contributed a maximum of $14.4 million for a total of $168.4 million. This represents about 15.7% of the capital outlay for construction in 1967.

CONSTRUCTION GRANTS FOR CONSTRUCTION OF WASTE TREATMENT WORKS ADMINISTERED BY FWQA

1963	$93,349,000
1964	$66,432,000
1965	$69,755,000
1966	$81,479,000
1967	$84,476,000
1968	$122,107,000
1969	$202,517,660
1970	$514,840,867
Proposed Expenditure	
1971	1 Billion Dollars
1972	1 Billion Dollars
1973	1 Billion Dollars
1974	1 Billion Dollars

TABLE 26

STATE GRANTS-IN-AID FOR SEWERS AND SEWAGE TREATMENT PLANTS

(1967)

	Appropriated or Authorized funds	Capital Outlay For Sewage Facilities
Delaware		$2,695,000
Cities	$263,000	
Maine	$678,000	$679,000
Maryland		$3,691,000
Cities	$304,000	
Counties	$1,435,000	
Special Districts	$79,000	
New Hampshire		$1,194,000
Cities	$997,000	
New Jersey		$12,383,000
Cities and Special Districts	$3,464,000	
New York		$51,755,000
Cities	$414,000	
Counties	$5,600,000	
Towns	$264,000	
Vermont	$851,000	$1,118,000
Total	$14,349,000	$73,515,000

Source: U.S. Bureau of Census, Census of Governments, 1967, Vol. 6, No. 4, State Payments to Local Governments, U.S. Government Printing Office, Washington, D.C., 1968.

TABLE 27

A more recent analysis of the grants-in-aid program was presented in the FWQA report, The Economics of Clean Water[24]. The federal share of all waste-handling cost was placed at 18% which is about the same as the overall level of federal assistance to local governments for all purposes.

COST COMPARISON BETWEEN COLLECTION AND TREATMENT, RELATED SERVICES AND PERSONAL CONSUMPTION EXPENDITURE

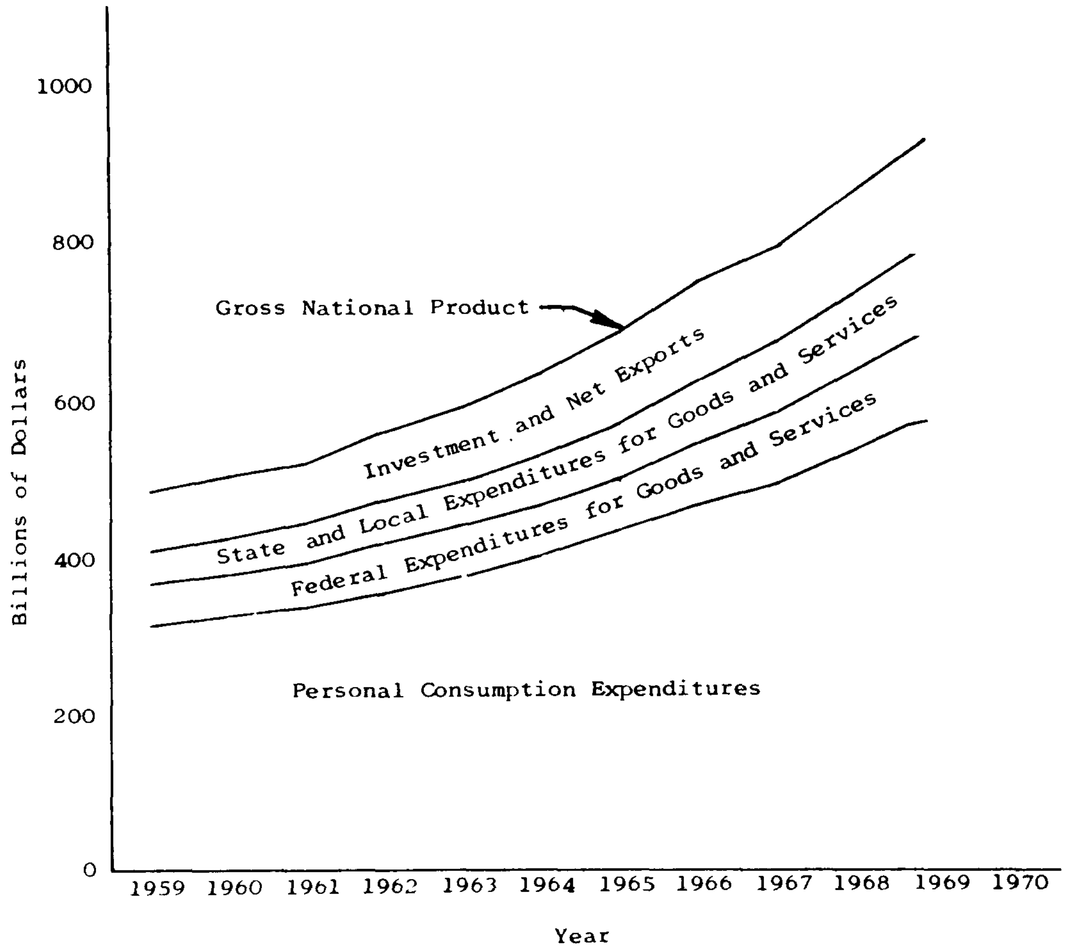
Even though the benefits associated with sewage treatment are difficult to evaluate in terms of dollars, the true cost of owning and operating collection and treatment facilities can be estimated with adequate precision. Expenditure for other personal consumption categories and governmental activities is available from the work of the Bureau of Census[26],[27]. A comparison of the cost of municipal and industrial wastewater collection and treatment with other categories of spending will be made here in an effort to show the general magnitude of the problem.

The national product of the United States is shown in Figure 13 for the years 1959-69. The gross national product is approaching one trillion dollars. About 62% of this potential buying power is spent on personal consumption expenditures. These are itemized for the years 1965-68 in Table 28. Spending for water and sewerage services represents the total paid user charges which, in 1967, was given as 1.97 billion dollars.

Other more detailed cost data gathered by the Bureau of Census and shown in Table 25 and 29 show the total amount paid by consumers for water and sewerage services to be 2.76 billion dollars in 1967. This larger estimate represents about 0.56% of the total personal consumption expenditures.

The amount paid by consumers in 1967 for water supply was 2.187 billion dollars or about 0.44% of total personal consumption expenditures. The amount paid for sewerage services was 0.571 billion dollars, about 0.116% of the total, which is about 1/9 that paid for toilet articles.

The number of persons served by potable water supplies in 1967 was about 163 million. Dividing the total revenue (2187 mil.) by the population gives about $13.42/capita/year paid for water supplies. The total cost of supplying potable water was investigated in 1955 by Seidel and Baumann[22]. The delivery cost per 1000 cu. ft. was found to vary from $3.21 to $2.02 with an overall average of $2.75. This average cost corresponded to plants in the range of 2-6 mgd. Using the consumer price index for water and sewerage services the $2.75 cost corresponds to a 1967 cost of $4.10 per 1000 cu. ft. or 54.7 cents/1000 gallons. The same report by Seidel and Buamann showed that the



DISPOSITION OF NATIONAL PRODUCT IN THE UNITED STATES

Source: U. S. Department of Commerce <u>1969 Business Statistics</u>

FIGURE 13

PERSONAL CONSUMPTION EXPENDITURE BY TYPE OF PRODUCT

(Millions of dollars)

	1965	1966	1967	1968
FOOD AND TOBACCO	107,183	114,621	117,395	124,694
CLOTHING, ACCESSORIES, AND JEWELRY	43,318	48,360	51,054	55,460
PERSONAL CARE	7,578	8,068	8,578	9,110
1. Toilet articles and preparations(n.d.c.)	4,211	4,543	4,877	5,261
2. Barbershops, beauty parlors, and baths(s.)	3,367	3,525	3,701	3,849
HOUSING	63,509	67,506	71,806	77,409
HOUSEHOLD OPERATION	61,789	66,786	70,498	75,919
1. Furniture, including mattresses and bedsprings (d.c.)	6,254	6,826	7,033	7,460
2. Kitchen and other household appliances(d.c.)	6,026	6,766	7,087	7,801
3. China, glassware, tableware, and utensils(d.c.)	2,526	2,776	2,900	3,245
4. Other durable house furnishings(d.c.)	6,119	6,650	6,915	7,839
5. Semidurable house furnishings (n.d.c.)	4,169	4,696	4,970	5,464
6. Cleaning and polishing preparations, and miscellaneous household supplies and paper products(n.d.c.)	4,261	4,560	4,684	4,899
7. Stationary and writing	1,434	1,646	1,769	1,879
8. Household utilities	17,845	18,912	19,900	20,950
a. Electricity(s.)	6,608	7,027	7,493	8,131
b. Gas(s.)	4,075	4,242	4,432	4,588
c. Water and other sanitary services(s.)	1,771	1,873	1,972	2.068
d. Other fuel and ice(n.d.c.)	5,391	5,770	6,003	6,163
9. Telephone and telegraph(s.)	6,423	6,905	7,532	8,140
10. Domestic service (s.)	3,964	4,028	4,444	4,638
11. Other(s.)	2,768	3,021	3,264	3,604
MEDICAL CARE EXPENSES	28,082	31,142	34,647	38,580
PERSONAL BUSINESS	21,879	24,287	26,226	29,593
TRANSPORTATION	58,154	60,489	62,844	72,220

TABLE 28

PERSONAL CONSUMPTION EXPENDITURE BY TYPE OF PRODUCT

(Millions of dollars)

[Continued]

	1965	1966	1967	1968
RECREATION	26,298	28,850	30,903	33,552
1. Books and maps(d.c.)	2,061	2,365	2,670	2,669
2. Magazines, newspapers, and sheet music(n.d.c.)	2,868	3,059	3,217	3,413
3. Nondurable toys and sports supplies(n.d.c.)	3,436	3,743	3,993	4,700
4. Wheel goods, durable toys, sport equipment, boats, and pleasure aircraft(d.c.)	2,933	3,248	3,481	4,012
5. Radio and television receivers, records, and musical instruments(d.c.)	6,013	6,905	7,409	7,852
6. Radio and television repair(s.)	1,032	1,072	1,143	1,227
7. Flowers, seeds, and potted plants(n.d.c.)	983	1,078	1,113	1,234
8. Admissions to specified spectator amusements	1,811	1,923	2,027	2,130
a. Motion picture theaters(s.)	927	964	989	1,045
b. Legitimate theaters and opera, and entertainments of nonprofit institutions (except athletics)(s.)	495	545	605	632
c. Spectator sports(s.)	389	414	433	453
9. Clubs and fraternal organizations except insurance(s.)	879	934	988	1,049
10. Commercial participant amusements(s.)	1,509	1,555	1,610	1,675
11. Pari-mutuel net receipts(s.)	734	765	795	861
12. Other(s.)	2,039	2,203	2,457	2,730
PRIVATE EDUCATION AND RESEARCH	5,927	6,608	7,490	8,398
RELIGIOUS AND WELFARE ACTIVITIES(s.)	5,972	6,421	6,965	7,876
FOREIGN TRAVEL AND OTHER, NET	3,150	3,196	3,859	7,876
TOTAL PERSONAL CONSUMPTION EXPENDITURES	432,839	466,334	492,265	536,647

NOTE - Consumer durable commodities are designated (d.c.), nondurable commodities (n.d.c.), and services(s.) following group titles.

FINANCES OF WATER SUPPLY UTILITIES OPERATED BY LOCAL GOVERNMENTS

1966-67

		Utility expenditure			
	Utility revenue	Total	Current operation	Capital outlay	Interest on utility debt
Water Supply	2,187	2,587	1,231	1,055	300
Municipalities	1,807	1,898	969	713	216
Special Districts	258	498	189	243	66
Townships	60	81	43	32	7
Counties	62	109	31	67	11

TABLE 29

average daily usage per service was 202.73 gallons per day. The average household in 1968 contained 3.23 persons. The average per capita water consumption for domestic use is, therefore, 60.9 gallons. The cost of potable water for the average household in January, 1970 is then computed as 10.8 cents per day, or $39.42 per year. The per capita/year cost is $12.20.

Committee Print No. 7[3] reported that the average per capita consumption of potable water for the Nation as a whole is about 150 gallons per day per person. Of this 150 gallons about 41% is domestic use, 18% commercial, 24% industrial and 17% public use. Forty-one percent of 150 gallons is 61.6 which agrees well with Seidel and Baumann.

Committee Print No. 7 also allocated the cost of producing potable water as follows: 19% source development, 22% treatment, and 59% distribution. Orlob and Lindorf[28] made a study of the cost of treating potable water in 1956. The cost for a 5 mgd plant was given as 4.3 cents/1000 gallons for debt service and 3.5 cents/1000 gallons for operation and maintenance for a total of 7.8 cents/1000 gallons. This cost represents only 22% of the total delivered cost. The total cost must be 52.3 cents/1000 gallons in 1967 which agrees with the Seidel and Baumann estimate.

For the production of potable water, therefore, it would appear that the public is paying, on the average, the production cost.

Representative charges for refuse collection were gathered by Lennox L. Moak[29] in a study of municipalities made in January, 1961. These charges ranged from $1.00 to $2.00 per month per household for one pickup per week. The 1967 Census of Governments[26] reported a total revenue for collection and disposal of garbage and other wastes of 172 million dollars for the Nation as a whole. The corresponding expenditure was given as $888 million. Only $71 million was spent on capital outlay, the remainder on current expenditure. If we assume that the population served by refuse pickup is about equivalent to the population served by water supplies (163 million) the average expenditure for current expenditure is $5.02 per capita/yr or about $1.35 per household per month. Current expenditure for refuse collection is, therefore, approximately equal to the current expenditure for municipal sewage collection and treatment. The revenue received in user charges, on the other hand, was only about $1.06 per capita per year or about 20% of expenditures.

The distribution of general expenditure according to function for municipalities is shown in Table 30.

PERCENT DISTRIBUTION OF GENERAL EXPENDITURE OF MUNICIPALITIES BY FUNCTION 1967

1.	Education	16.6%
2.	Highways	10.5%
3.	Public Welfare	6.6%
4.	Hospitals and Health	6.8%
5.	Police Protection	10.6%
6.	Fire Protection	6.8%
7.	Sewerage	5.8%
8.	Sanitation Other than Sewerage	4.1%
9.	Parks and Recreation	4.7%
10.	Housing and Urban Renewal	4.2%
11.	Terminal Facilities	2.0%
12.	Libraries	1.6%
13.	Financial Administration	1.7%
14.	General Control	2.8%
15.	General Public Buildings	1.7%
16.	Interest on General Debt	3.9%
17.	Other and Unallocable	9.6%
	TOTAL	100.0%

Source: 1967 Census of Governments, "Finances of Municipalities and Township Governments"

TABLE 30

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APPENDIX

The total cost of constructing wastewater treatment plants is a function of the design capacity of the plant. If the design capacity is expressed as millions of gallons per day, Q, the construction cost, C, in dollars can be calculated from the following expression where C_o and a are constants.

$$C = C_o(Q)^a \tag{1}$$

If it is assumed that, on the average, each person contributes 100 gallons of wastewater per day, the per capita construction cost, C_p, can be expressed in terms of the design population, D, as follows where C_{op} and b are constants.

$$C_p = C_{op}(D)^b \tag{2}$$

In equation (2), b equals (a - 1) and C_{op} equals $C_o/(10{,}000)^a$

When a treatment plant is designed, the design capacity is made larger than the existing population to allow for population growth. The ratio between design population and existing population will depend on the projected population growth for the community. If the design period is taken as twenty years, the ratio of design population to existing population averages about 1.5.

Using this excess capacity factor, the total cost of constructing plants for the whole nation where the size of communities are distributed according to the 1968 Inventory of Municipal Waste Facilities, can be expressed as follows.

$$\text{Total Cost, dollars} = 1.5\, C_{op} \sum_{i=1}^{i=n} P_i(1.5P_i/N_i)^b \tag{3}$$

P_i = number of persons in i'th population group

N_i = number of plants in i'th population group

To calculate the national average per capita cost this total cost must be divided by some population. If the population existing at the beginning of the design period is used, the per capita cost will be a maximum. If the population selected corresponds to that existing at the end of the design period, the per capita cost will be minimized. On the other hand, a population corresponding to the mean might be used. The values given in Tables XI, XII, and XVII are computed using the population at the end of the design period and are therefore, minimum values. If these per capita costs are multiplied by the factor 1.5, they will correspond to the beginning of the design period or approximately to current observed costs.

This problem is further complicated by the fact that the excess capacity factor used to convert existing population to design population has been increasing in recent years. There is no completely satisfactory way of computing the national average per capita construction cost.

1 Accession Number	2 Subject Field & Group	
W	06C	**SELECTED WATER RESOURCES ABSTRACTS** **INPUT TRANSACTION FORM**

5 Organization

Advanced Waste Treatment Laboratory, Cincinnati, Ohio

6 Title

Cost to the Consumer for Collection and Treatment of Wastewater

10 Author(s)

Robert Smith

Richard G. Eilers

16 Project Designation

17090---07/70

21 Note

22 Citation

23 Descriptors (Starred First)

*Sewage Treatment, *Sewers, *Tertiary Treatment, *Construction Costs, *Annual Costs, Cost Comparisons, Allocation (Cost), Income Analysis, Comparative Costs, Maintenance Costs, Operating Costs, Unit Costs, Water Costs, Cost Trends, Economies of Scale, Efficiencies, Interest Rate, Prices, Salaries, Water Rates

25 Identifiers (Starred First)

27 Abstract

The national average per capita cost for collection and treatment of municipal wastewater is computed based on the 1968 Inventory of Municipal Waste Treatment Facilities in the United States and per capita cost relationships for building and operating collection and treatment facilities. All costs are given per capita served with treatment facilities using the level of treatment existing in 1968. Total cost was computed as $19.80 per capita per year. Of this total, $15.31 represents amortization charges and $4.49 represents current charges. The total cost can also be broken down as $13.34 for collection, $4.38 for treatment and $2.08 for overhead such as customer services, administrative, and general. The cost of collection is, therefore, about three times as expensive as treatment.

Nationally, about 23% of the total cost is paid as sewerage usage charges. This represents about 0.1% of National Personal Consumption Expenditures. Expenditure for water supply averaged $13.42 per capita per year and this is about equal to the amount paid by the consumer in user charges for water supply.

The current status of collection and treatment in the United States is discussed and estimates are made of needed additional expenditure.

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WR:102 (REV. JULY 1969)
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