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Economic Feasibility of Minimum Industrial Waste Load Discharge Requirements

Office of Research and Monitoring
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ECONOMIC FEASIBILITY OF MINIMUM INDUSTRIAL WASTE LOAD DISCHARGE REQUIREMENTS

By

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ABSTRACT

This study presents order-of-magnitude estimates of the costs of implementing minimum and zero discharge requirements for the manufacturing and electric power industries. The analysis was made, for the most part, at the 2 digit S.I.C. level for the manufacturing industries. The assumed technology was maximum in-plant recirculation and reuse, concentration of the recirculation blowdown by evaporation, and final residual disposal by the applicable least-cost method among incineration, deepwell disposal, solar evaporation, and ocean disposal.

It is concluded that a strict zero discharge requirement would have greatly variable and significant economic consequences, but that less stringent definitions of minimum discharge would be feasible. The limiting factors in applying a strict zero discharge requirement appear to be the availability of physical resources, particularly energy, for purposes of effluent concentration.

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SECTION I

CONCLUSIONS

This study has indicated that the costs of implementing a strict definition of zero discharge of liquid effluents from industrial and electric power plants would be approximately 3.3 times as much as the present costs of attaining ambient water quality standards (stream standards) and would have cost an additional $4.9 billion annually in 1972. The added capital investment in 1972 would have totaled about $17.6 billion. The additional capital investment required would have been about 50 percent of the annual expenditures for new plant and equipment by the manufacturing and electric power industries. The added cost of implementing zero discharge would have been equivalent to a 3 percent rise in wage rates and would probably have reduced after-tax profits by 15 percent in the short run. By 1980 the added costs would increase to approximately $6.8 billion annually in terms of 1972 dollars.

The costs involved vary widely among the various industries. The burden of the paper industry would be the greatest by almost any measure employed. Overall price increases of the order of 3 percent would probably be involved in products and power at the manufacturing level if costs were to be recovered by means of price increases. The steel industry, in particular, would have difficulty passing along such added costs in the face of the availability of lower-cost imports.

A minimum discharge requirement which would minimize effluent volumes and permit the discharge of the residual effluent if treated to meet existing water quality standards would cost only about one-fifth as much as would zero discharge requirements. Such a requirement would have a significant economic impact only on the paper industry.

The limiting factors in implementing zero discharge appear to be the physical resources required, particularly for means to effect effluent volume reductions beyond those attainable by maximum recirculation and reuse of water within a plant. The energy requirements of evaporation, as well as the capacity to produce such equipment, appear to be unrealistically high.

Residual disposal site availability does not appear to offer constraints of a similar magnitude.

It is concluded, at this level of analysis, that implementation of a strict definition of zero discharge of liquid effluents from industrial plants is not feasible in the near future, i.e., utilizing technology that is clearly available.

SECTION II

RECOMMENDATIONS

The present study has defined the order-of-magnitude costs of minimum and zero discharge within several constraints which affect the accuracy of the estimates. The more significant of these are analysis of the manufacturing industries at only the 2-digit S.I.C. level, the assumption of uniform unit costs of recirculation, the assumption of the sole use of evaporation as a concentration method, the assumed need of uniform discharge requirements among all industries, and the assumptions of uniform costs of capital and depreciation periods.

It is recommended that the following additional studies be accomplished utilizing computer methods so that the costs can be developed and segregated at a more disaggregated level and so that the effects of new data and information can be quickly evaluated in the future.

1. Determine the costs of implementing a definition of minimum discharge that would allow the discharge of heat and dissolved solids in recirculated cooling water blowdowns but prohibit process water discharge.

2. Determine the applicability and availability of alternative concentration technologies in various specific industry groups, including the availability of waste heat and the heating values of waste materials for evaporation and incineration, and energy requirements for the optimum methods.

3. Determine in detail the likelihood of changes in production and waste treatment technology due to minimum discharge requirements, including effects on the total environment.

4. Determine the extent to which discharges as in (1) can be minimized in the various industries without the constraint of uniform requirements between industry groups.

5. Determine the extent to which the costs incurred as above would affect each industry, including the probable ability to pass on these costs.

SECTION III

INTRODUCTION

It has been the purpose of this study to determine the economic feasibility of requirements that industrial water effluents be minimized or eliminated. The analysis has, for the most part, been at the 2-digit S.I.C. level in the manufacturing industries and has included the electric power industry.

Various levels of discharge restrictions have been considered as being the basis for definition of minimum discharge. Zero discharge is considered in the strictest sense, i.e., no liquid effluent to a surface body of water. Ultimate disposal of final residuals to the land, air, underground aquifer, and ocean environments have been assumed.

The analysis has been predicated on the use of maximum in-plant recirculation and reuse, concentration of the recirculation system blowdown by evaporation, and final residual disposal by deepwell injection, solar evaporation, incineration, ocean disposal, landfill; the final residual disposal method being the applicable least-cost means. Evaporation for concentration has been considered because it is the only clearly applicable present technology for which reliable cost data are readily available. Treatment for in-plant recirculation and reuse has been assumed equal to the effluent quality requirements for discharge.

All cost data within the body of the report are in 1968 dollars. All necessary reductions of costs to the 1968 basis have been made on the basis of an annual cost inflation of 3.5 percent. The base year was chosen because it is the year of the most recent Census of Manufactures data and the base year for the Cost of Clean Water industry profiles which were used as defining terminal treatment costs. Only in the Conclusions have costs been expressed in current dollars (1972).

Costs are generally expressed in annualized terms. Operating costs are used throughout as excluding capital charges. Annualized capital costs are based upon a 10-year life and an interest rate of 8 percent.

Where references are made to the large water-using industrial plants, this means those plants taking in more than 20 million gallons of water annually and is in accordance with the Census of Manufactures usage. Values added and value of shipments in those plants are as defined in Water Use in Manufacturing, Census of Manufactures and refer only to those plants within an industry.

SECTION IV

INDUSTRIAL WATER UTILIZATION

Any study of minimum industrial water discharges must take into account not only the volumes of water involved, but also the particular uses to which portions of the water used are put. The uses largely determine the maximum degree of re-use and thus the final volumes which must be considered for treatment and/or ultimate disposal beyond effluent quality requirements, i.e., requirements to meet water quality standards.

The data of Table 1 show overall water use practices in the manufacturing industries in plants taking in more than 20 million gallons annually according to the 1967 Census of Manufactures. The numbers in parentheses were calculated by difference for the most part. The quantities of water discharged by use were calculated by the ratios of total discharge to total use times the water intake by purpose. These data are shown graphically in Figure 1. The schematics of Figure 2 through 8 show similar data for each of the 7 major water-using industries, derived in the same way as for Figure 1.

No such data were available for the electric power industry. Water use data for the electric power industry were developed as shown below on the basis of known water uses and projected numbers of plants, capacities, and efficiencies through 1980.

Table 2. Conventional Fossil-Fueled Electric Power Plants

	1957	1967	1968	1969
No. of Plants	1,039	971	979	981
Installed Capacity, mw	99,500	210,237	226,020	241,355
Net Generation, 10^9 kwh	497.2	974.1	1,072.9	1,159.8
Plant Factor, %	57	53	54	55

Scheduled new plants and additions, 1970-1977

No. of plants 67
Capacity, mw 134,300

Federal Power Commission, January, 1971, Steam - Electric Plant Construction Cost and Annual Production Expenses.

Table 1. Water Use Statistics (All Industries - Total) 1968

Parameter	All Establishments	Establishments Recirculating Water	Once-through Water Users
Water Intake, Total	15,467	13,171	(2,296)
Fresh Water Co. Systems	10,862	9,403	(1,459)
Fresh Water Public Systems	1,592	1,317	(275)
Brackish Water	3,013	2,451	(562)
Treated Prior to Use	3,506	3,249	(257)
Water Discharged, Total	14,276	12,063	(2,213)
Treated Prior to Discharge	4,353	3,960	(393)
Water Used, Total	35,701	33,405	(2,296)
Process Uses	(10,245)	9,460	(785)
Air Conditioning	(1,108)	1,069	(39)
Steam Electric Power	(4,361)	4,050	(311)
Cooling and Condensing	(18,312)	17,293	(1,019)
Boiler Feed and Sanitary	(1,675)	1,534	(141)
Water Discharged:			
Public Utility Sewers	1,022	769	(253)
Surface Water Body	9,545	8,163	(1,382)
Tidewater Body	3,316	2,825	(491)
Ground Water	190	144	(46)
To Other Users	203	164	(39)
Water Intake by Purpose:			
Process Uses	4,295	3,510	(785)
Air Conditioning	249	210	(39)
Steam Electric Power	3,009	2,698	(311)
Cooling and Condensing	6,877	5,858	(1,019)
Boiler Feed and Sanitary	1,036	895	(141)
Water Discharged by Use:			
Process Water	(3,972)	(3,215)	(757)
Air Conditioning	(230)	(192)	(38)
Steam Electric Power	(2,771)	(2,471)	(300)
Cooling and Condensing	(6,347)	(5,365)	(982)
Boiler Feed and Sanitary	(956)	(820)	(136)

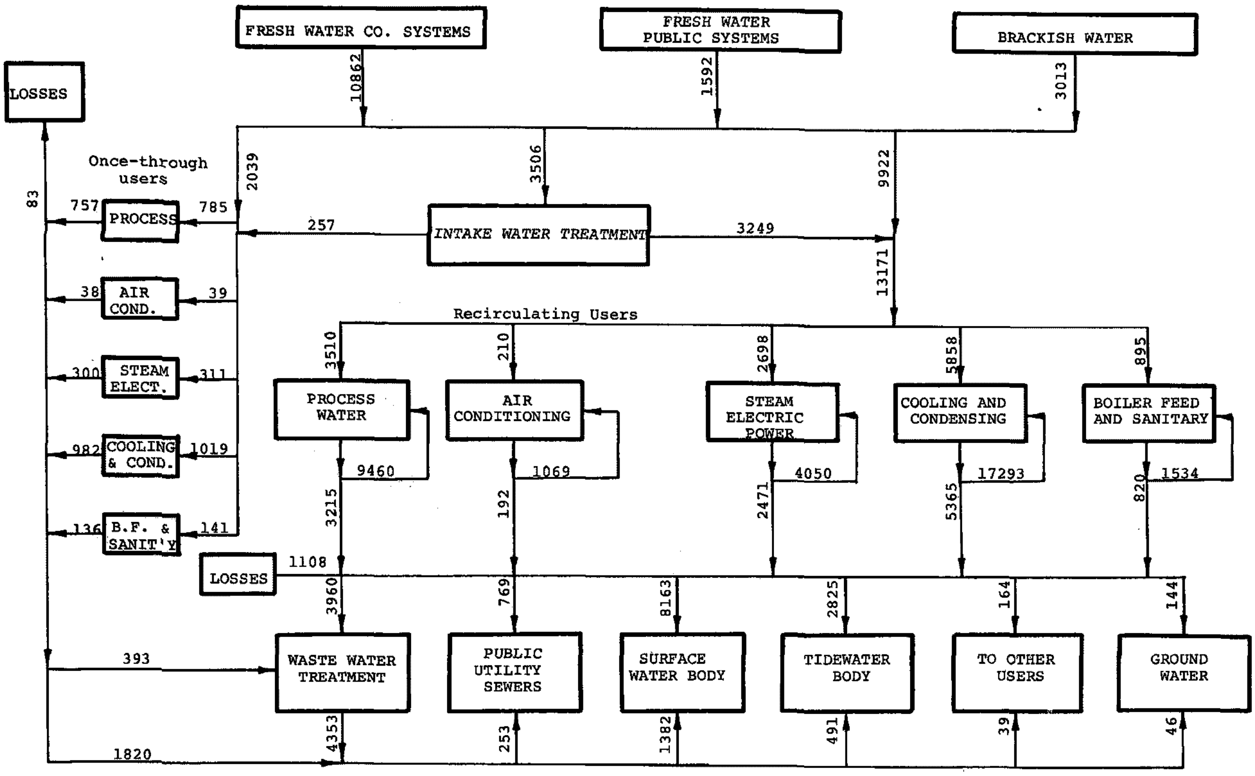

FIGURE 1. SCHEMATIC OF INDUSTRIAL WATER UTILIZATION (ALL INDUSTRIES, TOTAL) - 1968

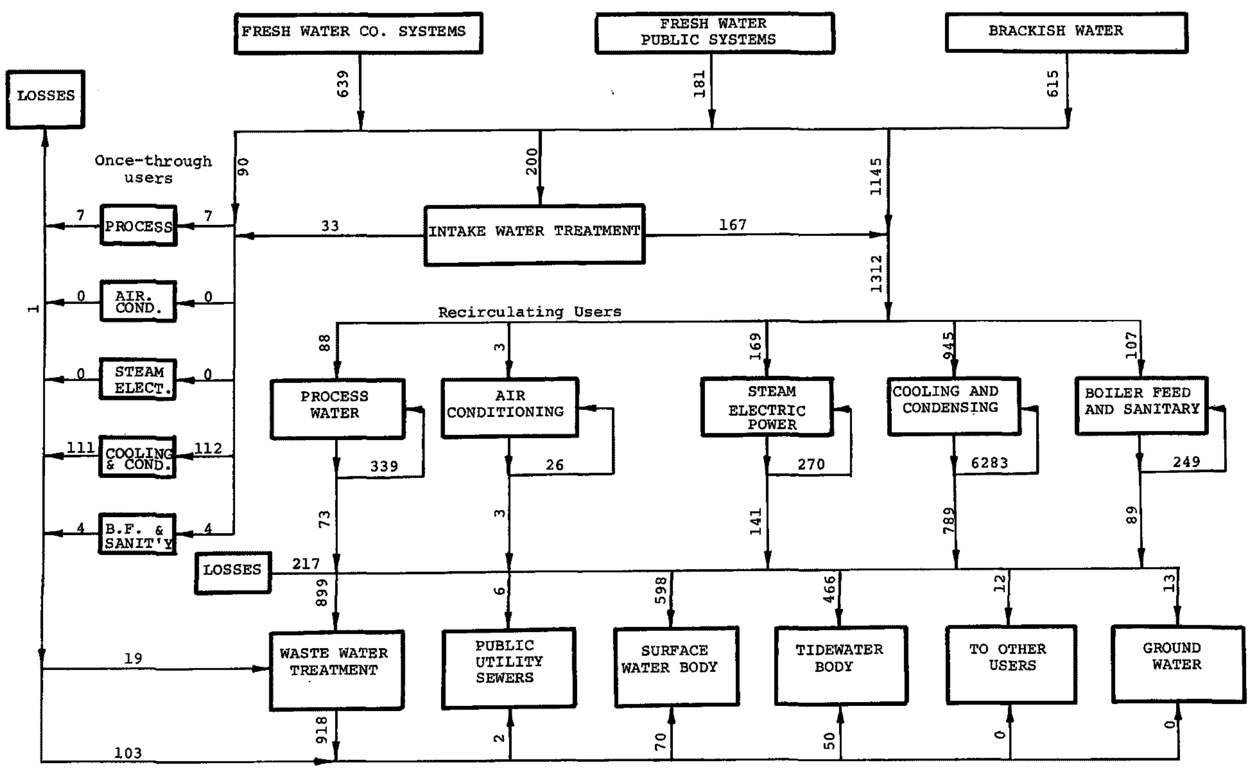

FIGURE 2. SCHEMATIC OF INDUSTRIAL WATER UTILIZATION (PETROLEUM & COAL PRODUCTS 29) 1968

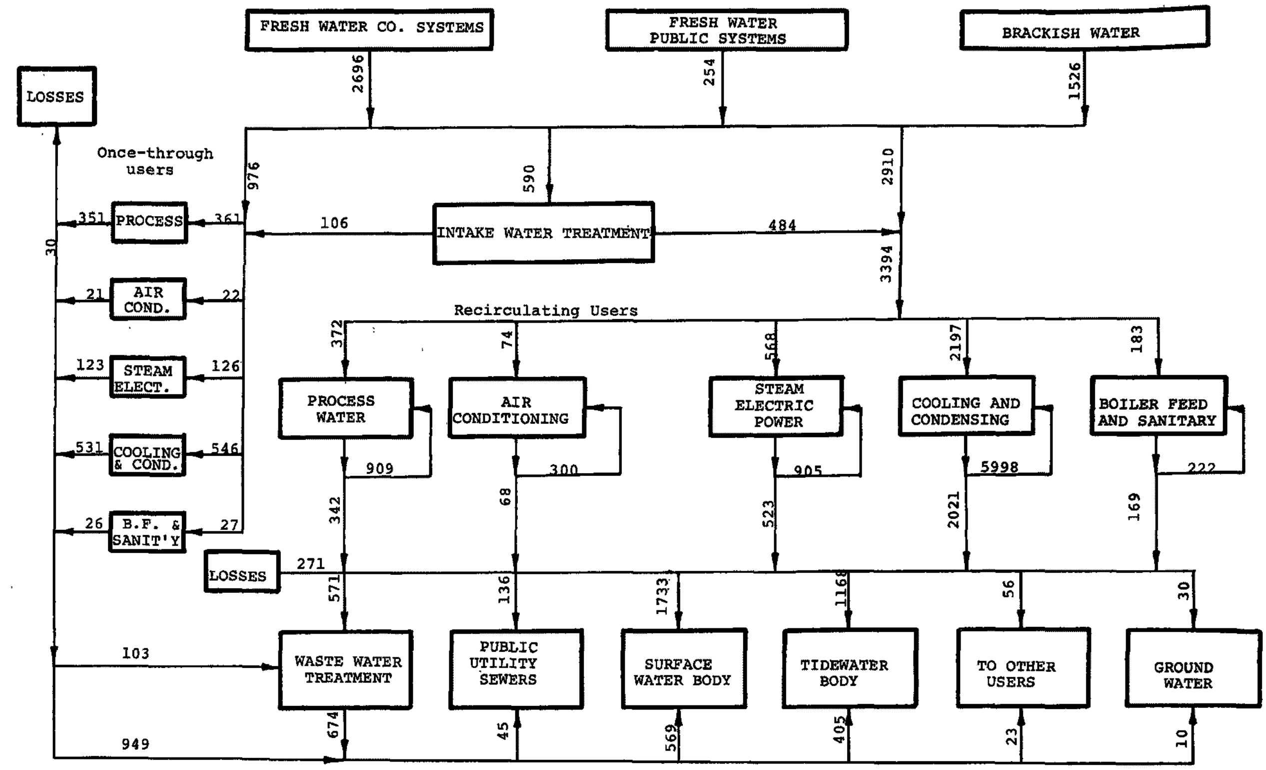

FIGURE 3. SCHEMATIC OF INDUSTRIAL WATER UTILIZATION (CHEMICAL & ALLIED PRODUCTS - 28) 1968

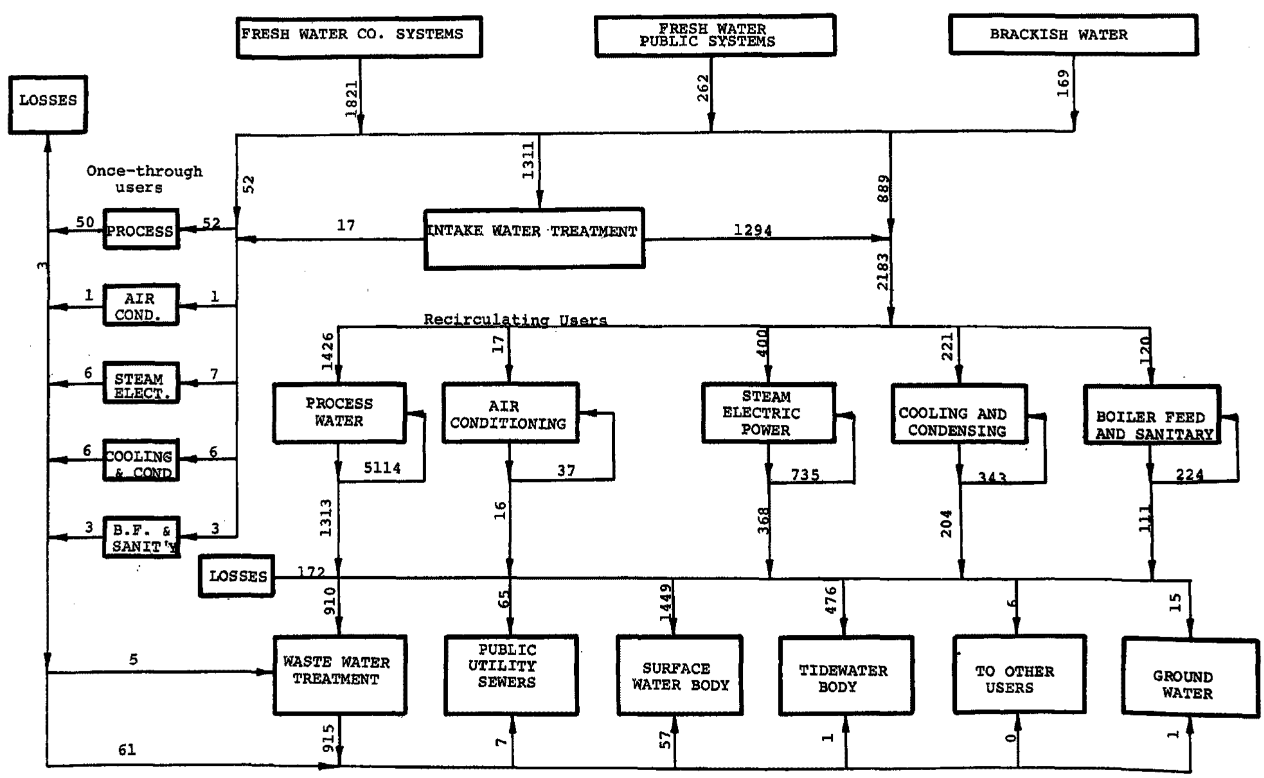

FIGURE 4. SCHEMATIC OF INDUSTRIAL WATER UTILIZATION (PAPER & ALLIED PRODUCTS - 26) 1968

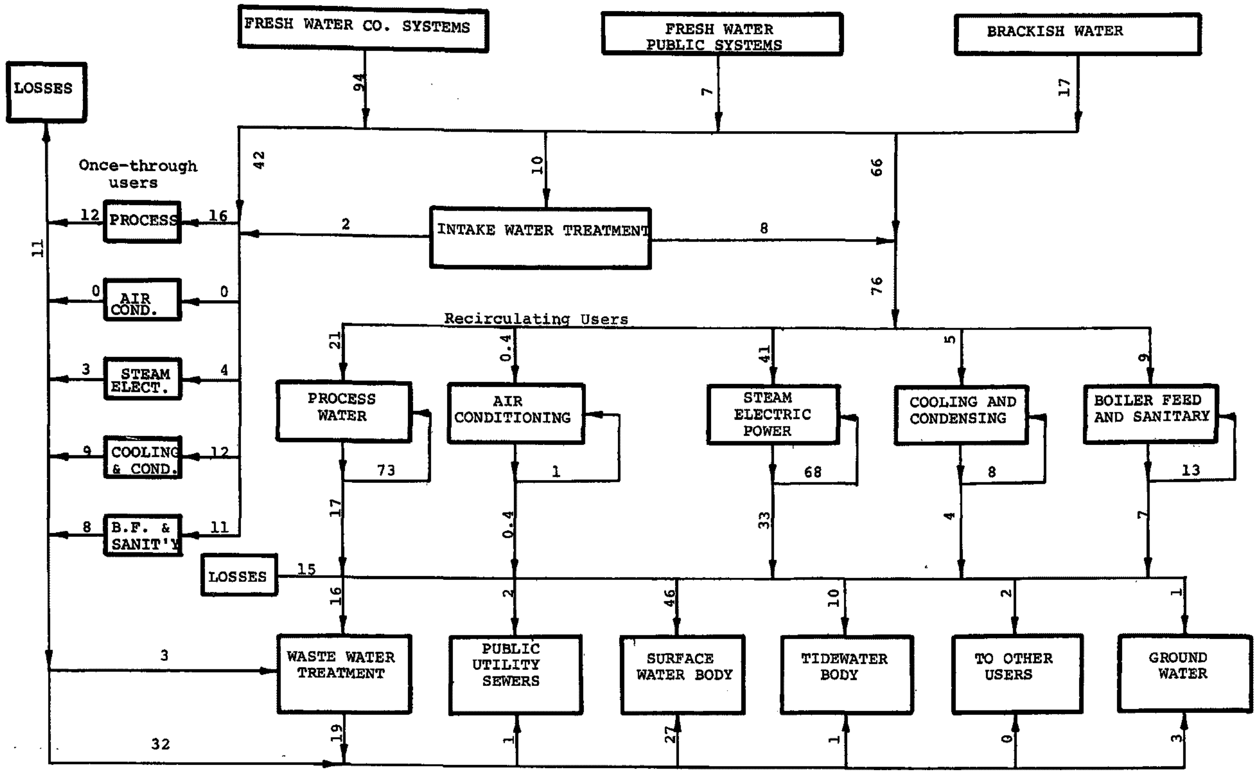

FIGURE 5. SCHEMATIC OF INDUSTRIAL WATER UTILIZATION (LUMBER & WOOD PRODUCTS 24) 1968

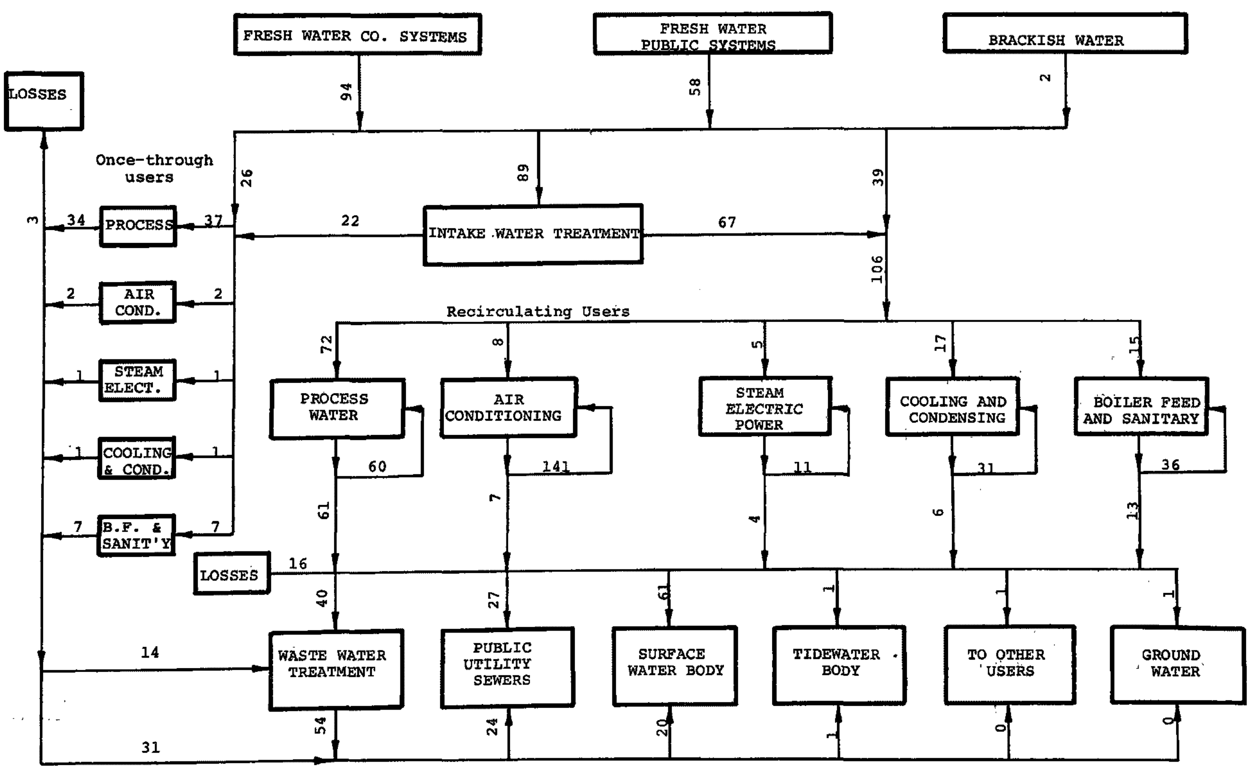

FIGURE 6. SCHEMATIC OF INDUSTRIAL WATER UTILIZATION (TEXTILE MILL PRODUCTS - 22) 1968

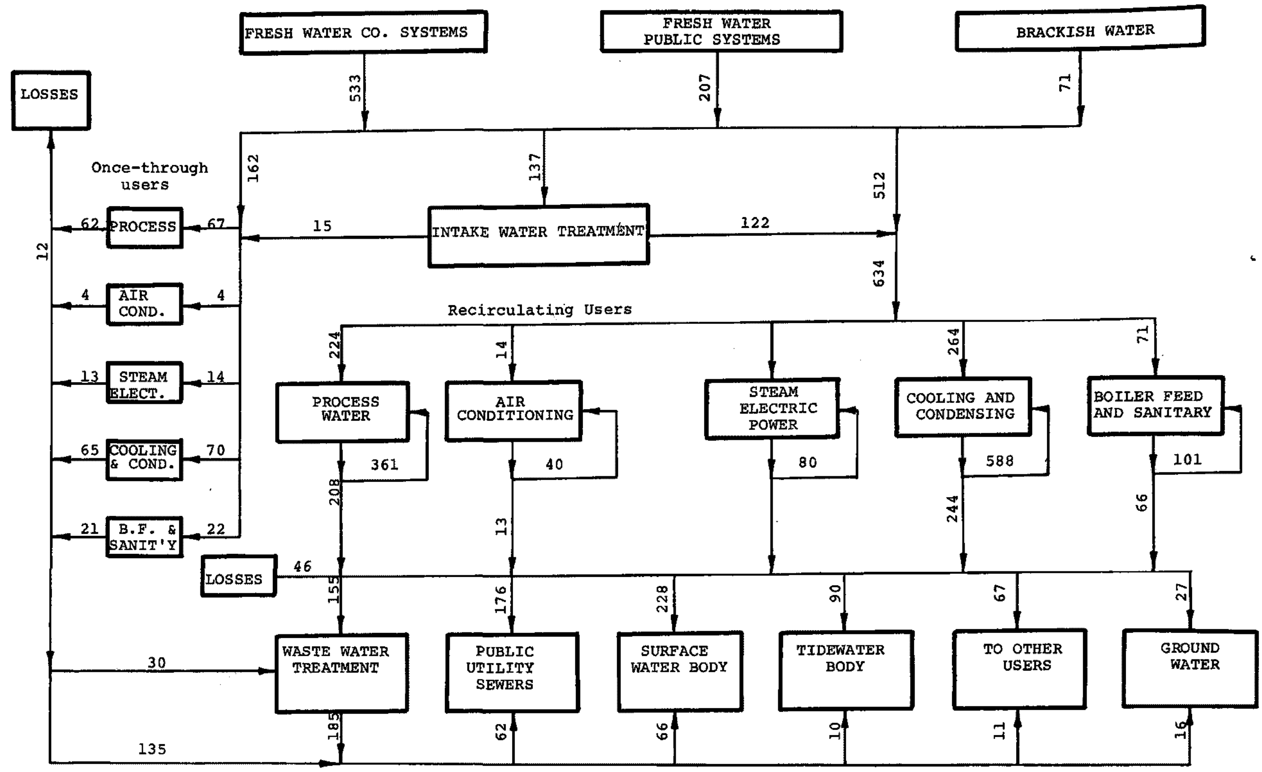

FIGURE 7. SCHEMATIC OF INDUSTRIAL WATER UTILIZATION (FOOD & KINDRED PRODUCTS 20) 1968

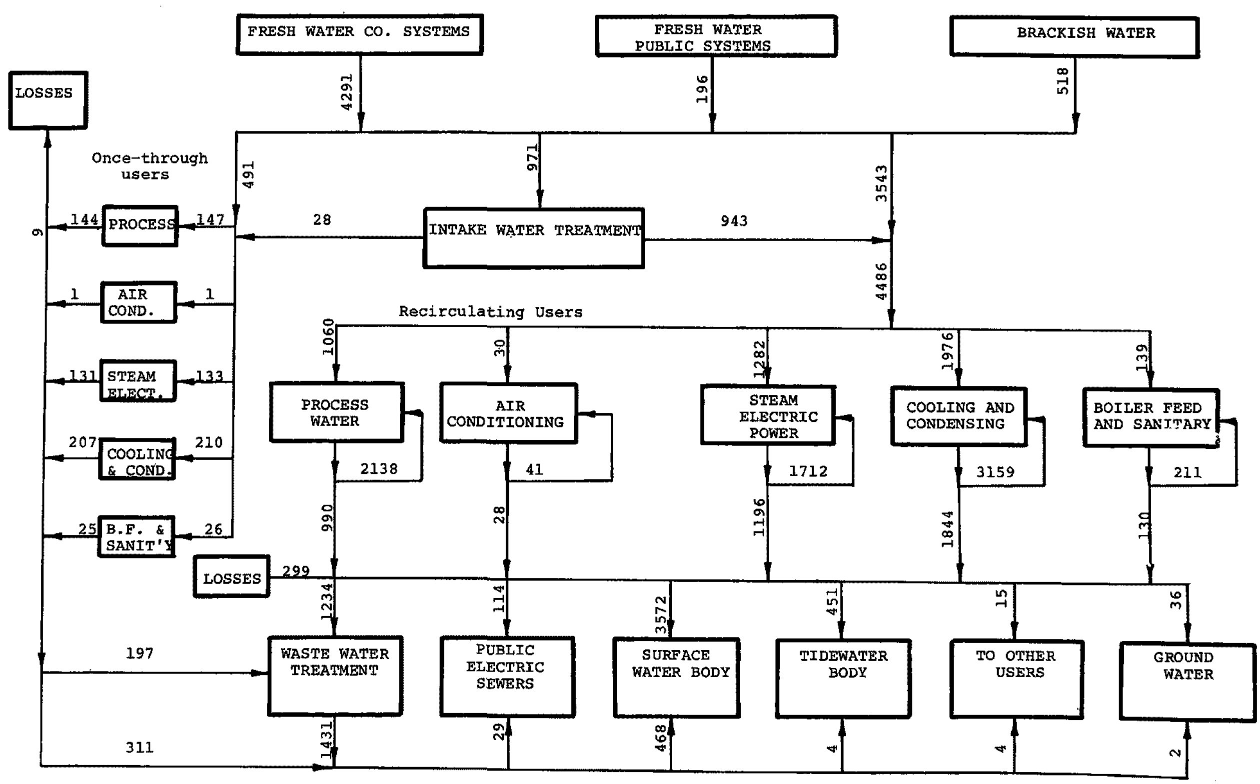

FIGURE 8. SCHEMATIC OF INDUSTRIAL WATER UTILIZATION (PRIMARY METAL INDUSTRIES - 33) 1968

Table 3. Nuclear Electric Power Plants

	1968	1970	1972	1975	1980
No. of units	10	17	38	83	134
Installed Capacity, mw	2,759(1)	7,532(1)	20,667	61,518	112,662
Generation, 10^9 kwh	14.0(1)	23.8(1)	-	-	-
Plant Factor, %	58	36	-	-	-

AEC News Release July 26, 1972 unless noted
(1) 1971 Statistical Abstract of U. S.

Plant capacities and power generation are projected in Table 4 on the basis of the above data, assuming plant factors for nuclear plants of 50% in 1972, in 1975, and 60% in 1980 and for fossil-fueled plants of 55% in 1972, 56% in 1975, and 58% in 1980.

Table 4. Projected Electric Power Plant Capacity and Generation

	1968	1972	1975	1980
Fossil-Fueled Plants:				
Installed Capacity, mw	226,020	291,718	342,080	426,018
Generation, 10^9 kwh	1,072.9	1,405.5	1,678.1	2,164.5
Plant Factor, %	54	55	56	58
Nuclear Plants:				
Installed Capacity, mw	2,759	20,667	61,518	112,662
Generation, 10^9 kwh	14.0	90.5	296.4	592.2
Plant Factor, %	58	50	55	60
Total Thermal Plants:				
Installed Capacity, mw	228,779	312,385	403,598	538,680
Generation, 10^9 kwh	1,086.9	1,496.0	1,974.5	2,756.7
Plant Factor, %	54	55	56	58

Water use and production data are not available for comparable years so that these data had to be estimated.

In 1964, the electric power industry took in 40,680 billion gallons of water for cooling (FWPCA, Industrial Waste Guide on Thermal Pollution, September, 1968). Of the 1,158 billion kwh produced in 1965, 1,055 billion kwh was produced by electric utilities, of which 81.6% or 861 billion kwh was produced in thermal-electric plants. The installed capacity in these thermal-electric plants was 192,000 mw. On the basis of the 1960 installed thermal-electric capacity of 136,000 mw, and generation of 608 billion kwh, the following is estimated for 1964, when about 13 percent of cooling water was recirculated.

Cooling water intake	40,680 billion gallons
Cooling water use	45,968 billion gallons
Installed capacity, mw	181,000 mw
Generation, billion kwh	810 billion kwh

Water use in 1964 was thus 56.75 gallon per kwh, of which 50.2 gallon per kwh was discharged. In 1964 the average rejection to cooling water was 5,480 BTU per kwh (FWPCA, ibid). so that the average heat rise was 11.6°F. These data may be taken as representative of 1968 practice.

A typical nuclear plant such as the Quad Cities plant of Commonwealth Edison, discharges 1.44 billion gallons of water per day during on-line generation with an average heat rise of 23°F; this plant has an installed capacity of 1,600 mw. The water use is thus 37.5 gallon per kwh with a heat rejection of 7,185 BTU/kwh.

These data represent thermal efficiencies of 32.6 percent and 30.6 percent for fossil-fueled and nuclear plants, respectively.

Fossil fuel plants have an upper limit of thermal efficiency of 40 percent while that of presently planned nuclear plants is 33 percent. The following projections assume efficiencies with corresponding heat rejections:

	Nuclear Plants		Fossil-Fueled Plants	
	Efficiency	BTU/kwh	Efficiency	BTU/kwh
1968	30.0	7,395	33.0	5,378
1972	30.6	7,185	35.3	4,806
1975	31.8	6,783	37.1	4,406
1980	33.0	6,400	40.0	3,800

Cooling water uses are assumed at 56.75 gallon per kwh for fossil-fueled plants as in 1968 with 13 percent recirculation and at 37.5 gallon per kwh for nuclear plants, used once-through. These would presumably be the water use practices in the absence of pollution abatement requirements. The electric power industry data developed are summarized in Table 5.

Table 5. Projected Electric Power Industry Waste Loads

	Nuclear Plants	Fossil Plants	Total Thermal
1968:			
Installed Capacity, mw	2,759	226,020	228,770
Generation, 10^9 kwh	14.0	1,072.9	1,086.9
Cooling Water Use, 10^9 gallon	525	60,887	61,412
Cooling Water Discharge, 10^9 gallon	525	53,860	54,385
BTU Discharge, 10^{12} BTU	104	5,104	5,208
1972:			
Installed Capacity, mw	20,667	291,718	312,385
Generation, 10^9 kwh	90.5	1,405.5	1,496.0
Cooling Water Use, 10^9 gallon	3,394	79,762	83,156
Cooling water Discharge, 10^9 gallon	3,394	70,556	73,950
BTU Discharge, 10^{12} BTU	650	5,975	6,625
1975:			
Installed Capacity, mw	61,518	342,080	403,598
Generation, 10^9 kwh	296.4	1,678.1	1,974.5
Cooling Water Use, 10^9 gallon	11,115	95,232	106,347
Cooling Water Discharge, 10^9 gallon	11,115	84,241	95,356
BTU Discharge, 10^{12} BTU	2,010	6,540	8,550
1980:			
Installed Capacity, mw	112,662	426,018	538,680
Generation, 10^9 kwh	592.2	2,164.5	2,756.7
Cooling Water Use, 10^9 gallon	22,208	122,835	145,043
Cooling Water Discharge, 10^9 gallon	22,208	108,658	130,866
BTU Discharge, 10^{12} BTU	3,790	7,276	11,066

SECTION V

ALTERNATIVE DEFINITIONS OF MINIMUM DISCHARGE

A definition of minimum discharge is not as simple as it may first appear. The volumes of water discharged, if any, will depend primarily upon the technology available and upon the cost involved. The availability of technology largely determines the possibility of implementation; the costs to be incurred as balanced against the benefits to be derived determine the desirability of implementation to a large extent. Other determinants are the impacts on the land and air environments and availability of resources. First approximations were thus made of the order-of-magnitude costs of implementing "minimum discharge" under four different definitions.

Zero discharge, in a strictly literal sense, would probably involve the evaporation of waste water to dryness, the condensation of evaporated water for recycle to the plant, and the discharge of the resulting solid wastes underground. Even in this case, the heat rejected in the vapor condensation would go to either the air or water environments.

If an initial qualification is imposed that thermal pollution from the manufacturing industries will not be considered, then the volume of process waste water discharged, assuming segregation of uncontaminated cooling water, determines the treatment needs.

If a further qualification is made that only the contaminants in waste water generated by manufacturing operations are to be considered, the treatment needs are still further reduced. A further qualification might be considered to the effect that neutral salts would not be regarded as significant pollutant materials, i.e., that the criteria applying to total dissolved solids may be modified.

These definitions may be stated as follows; they are illustrated schematically in Figures 9 through 12 and summarized in Table 6.

<u>Definition No. 1 (Figure 9)</u>: Zero discharge is defined as the discharge of no liquid effluent from an industrial operation and the storage underground of all solid residues.

<u>Definition No. 2 (Figure 10)</u>: Minimum practicable discharge is defined as the discharge of no liquid effluent from an industrial operation, other than uncontaminated cooling water from plants with effluent heat loads of less than

Table 6. Definitions of Minimum Discharge

Water Use	Allowable Discharge	Remarks
Definition I (Strict Interpretation)		
Cooling		
Industrial Plants $<20 \times 10^{12}$ BTU/Yr	None	Recirculation with all blowdown distilled and injected in deep wells
Industrial Plants $>20 \times 10^{12}$ BTU/Yr	None	
Steam Electric	None	
Process	None	
Definition II		
Cooling		
Ind. $<20 \times 10^{12}$	Heat and dissolved salts @ Intake +6%	6% increase in concentration covers existing recirculation @ isolated plants
Ind. $>20 \times 10^{12}$	None	Recirculation with blowdown distilled and injected to deep wells
Electric	None	
Process	None	
Definition III		
Cooling		
Ind. $<20 \times 10^{12}$	Heat and intake Dissolved Solids	Intake solids only - no concentration limit
Ind. $>20 \times 10^{12}$ Steam Electric	Intake Dissolved Salts	Intake solids contained in cooling tower blowdown only - no concentration limit
Process	None	Recirculation with blowdown distilled and injected to deep wells
Definition IV (Currently Used - State of Illinois)		
Cooling		
Ind. $<20 \times 10^{12}$	Heat and Dissolved Solids	
Ind. $>20 \times 10^{12}$	Dissolved Solids	
Steam Electric	Dissolved Solids	
Process	Dissolved Solids	Treatment to allow discharge to (i) surface waters (ii) municipal plants (iii) deep wells

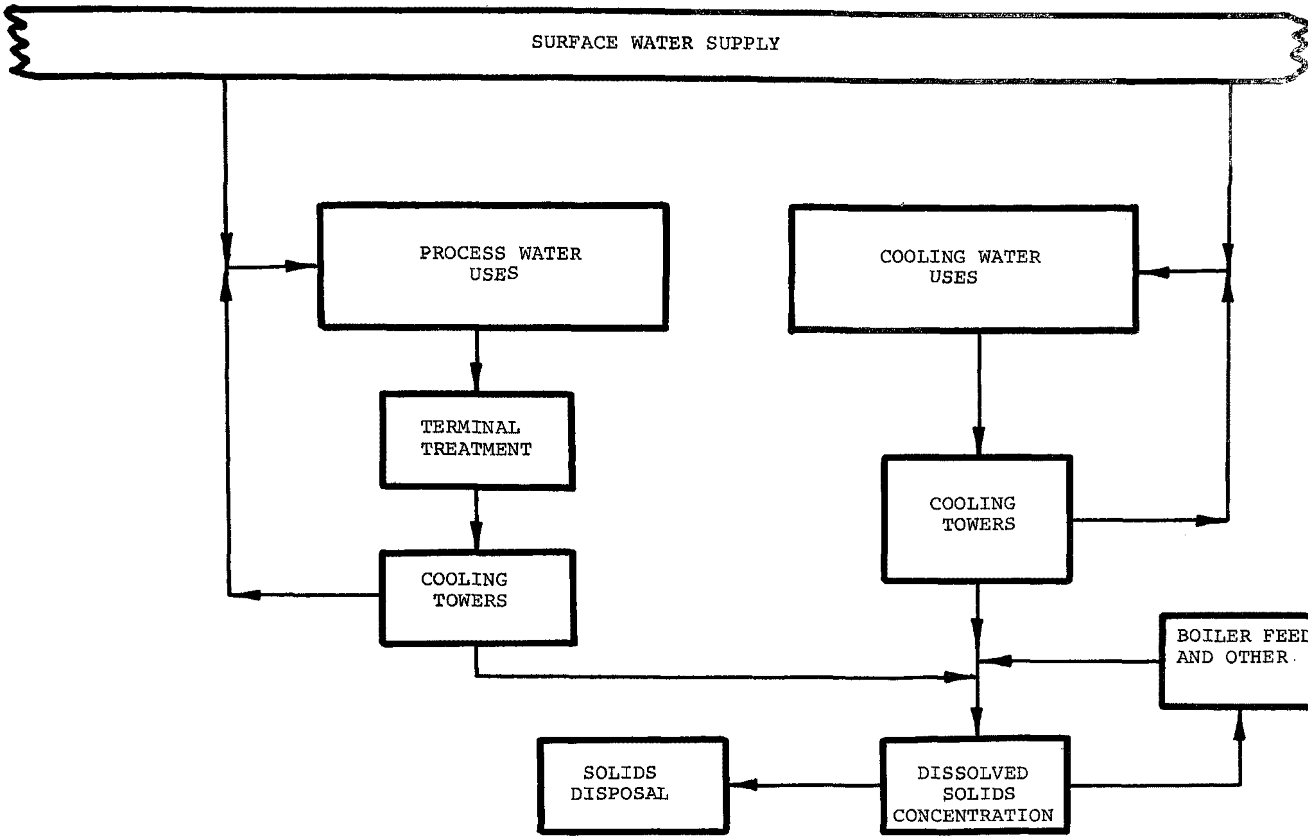

FIGURE 9. DEFINITION NO. 1- ZERO LIQUID DISCHARGE WITH UNDERGROUND STORAGE OF SOLIDS

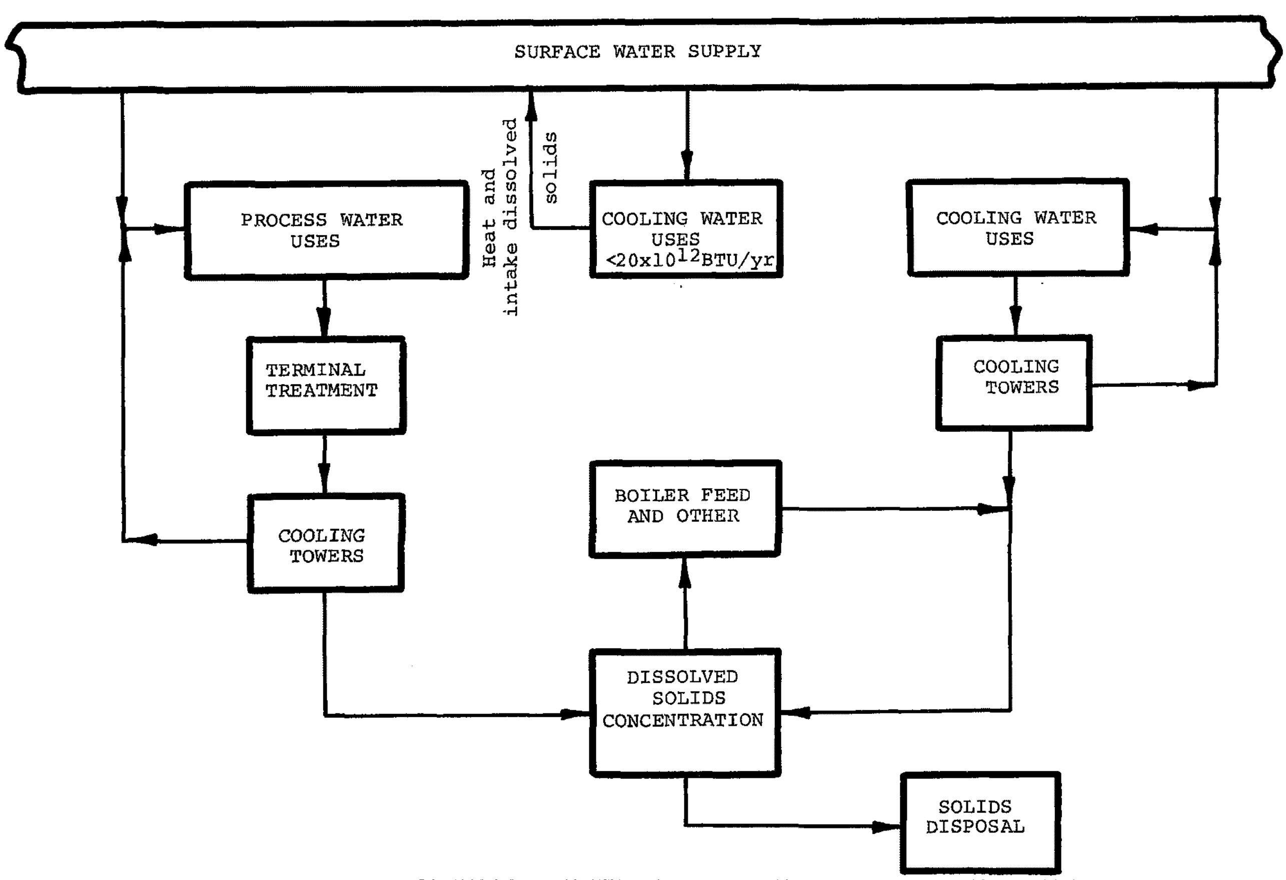

FIGURE 10. DEFINITION NO. 2- DISCHARGE ONLY HEAT AND DISSOLVED SOLIDS AT INTAKE CONCENTRATIONS (+6%)

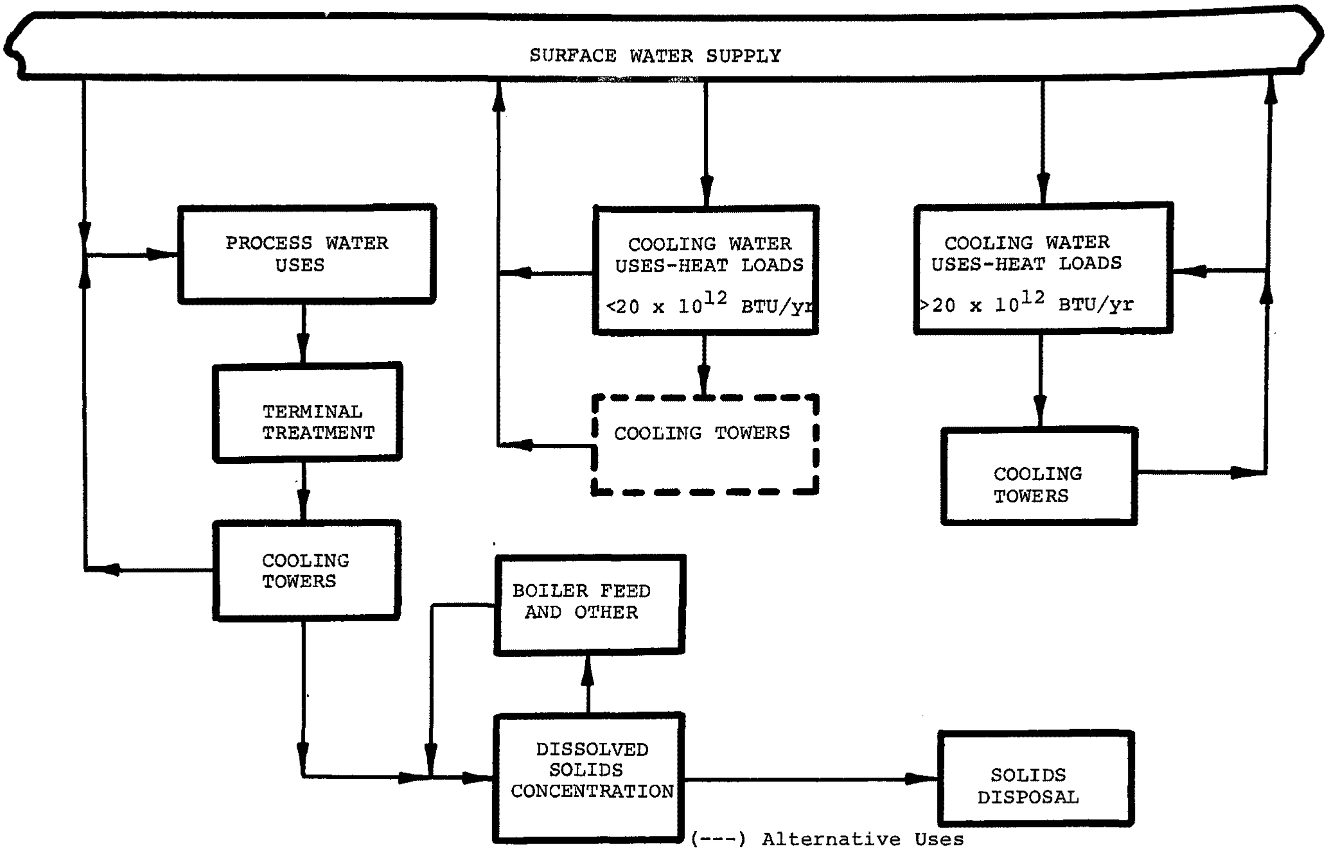

FIGURE 11. DEFINITION NO. 3- DISCHARGE ONLY HEAT AND INTAKE DISSOLVED SOLIDS

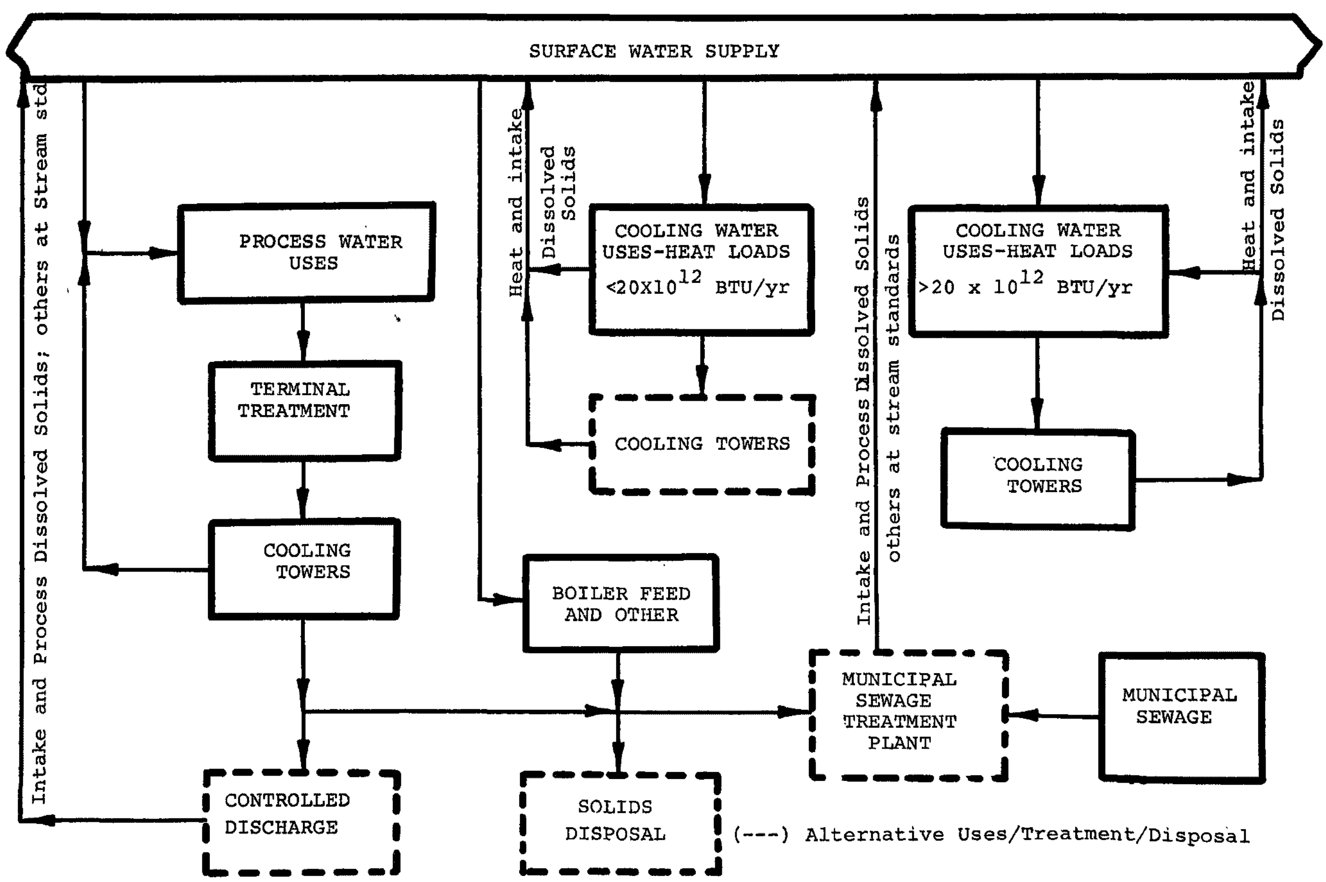

FIGURE 12. DEFINITION NO. 4- DISCHARGE ONLY HEAT AND DISSOLVED SOLIDS

20×10^{12} BTU per year which differs from intake water quality only in temperature and dissolved solids, and the storage underground of all solid residues.

Definition No. 3 (Figure 11): Minimum practicable discharge is defined as the discharge of no liquid effluent from an industrial operation other than water used for indirect cooling in plants where the effluent heat load is less than 20×10^{12} BTU per year and blowdown from indirect cooling uses containing no contaminants generated by the industrial operation other than heat and the storage underground of all solid residues.

Definition No. 4 (Figure 12): Minimum practicable discharge is defined as the discharge of no liquid effluent from an industrial operation other than water used for indirect cooling in plants where the effluent heat load is less than 20×10^{12} BTU per year, and blowdown from indirect cooling uses containing no contaminants generated by the industrial operation other than heat, and the disposal of minimum waste water volumes containing minimum concentrations of contaminants other than dissolved solids, by means including co-treatment in municipal sewage treatment plants.

The order-of-magnitude costs of implementing regulations based upon these various definitions were initially estimated from gross water use data in the manufacturing and electric power industries for the year 1968. The basic assumptions were that water would be internally recirculated to the greatest possible extent and that the blowdown from the recirculation systems would be evaporated to produce a lower volume brine. The brine would then be disposed of by deepwell injection where the definition so required. These initially estimated costs are shown in Table 7.

Table 7. Initial Cost Estimated

Definition	Costs in Billions of 1968 Dollars Capital Costs	Annual Operating Costs
Terminal Treatment	4.000	0.708
No. 4	7.254	1.198
No. 3	12.286	1.886
No. 2	13.746	2.102
No. 1	19.500	3.192

SECTION VI

DEFINITIONS OF COSTS

Definitions of costs vary considerably when evaluated by economists, accountants, cost accountants, or engineers. The background and training, to say nothing of the motivations of the people in these disciplines, are different. Profits to accountants, cost accountants, and engineers are synonymous with net income, i.e., the residual after subtracting outgo from income. Profits in the lay definition, include the return to all factors of production without differentiation. To the economist, profit is specifically the return to entrepreneurial ability and, by definition, accrues only to the super-marginal enterprise. Rent, similarly, is the return to land, again by definition accruing only to super-marginal land. Interest is the return to capital (only superficially the charge made for loaned funds) and wages are the return to labor (including management).

Much more insight into the factors affecting costs could be gained from at least considering the economist's definitions rather than the accountant's or financier's simplistic conceptions. Taking, for example, two steel mills, one might compare the costs of implementing zero waste water discharge. The first is an integrated steel mill with a capacity of about 1.5 million ingot tons per year. The other operates an electric furnace shop some distance away which has about the same capacity. The former has agreed to install terminal treatment facilities which will discharge water of better quality than required for in-plant use and is resisting to the point of litigation the reuse of this water with blowdown to a sanitary sewer. The latter began the installation of a zero discharge system 10 years ago and has recently completed it. The second is a closely-held corporation and the rate of return is not known, but is reportedly high for the industry. Overhead, as reflected in office buildings, furnishings, etc., is obviously low; there are none of the usual executive trappings in offices and the plant engineer designed the water reuse system in-house. This mill has two electric furnaces, both of which have air pollution control levels which exceed emission standards and incorporate closed-cycle use of water in venturi scrubbers. Building evacuation hoods were built voluntarily when the State suggested it; there is no specific legal requirement for such installations.

The former company is one of the large integrated steel producers and the example plant is only one of its smaller plants. While this mill is an integrated facility, i.e., has a coke plant and blast furnace, it is, however, fair to compare the steelmaking and rolling mill facilities alone with the second. The conclusion is inescapable that there are differences in the philosophy and attitudes toward pollution control which are interestingly related to differences in production philosophies and methods. It is suggested that the differences may well lie in the realm of entrepreneurial ability, i.e., in innovation and foresight, and in the factor of rent, i.e., the return to the use of land. Costs, as reflected in interest and wages might be presumed to be about equal for similar size steel plants in the same general area; there is at least the suspicion, however, that wages in the form of more management and other overhead labor may well be greater in the case of the multi-plant firm as allocated to this facility.

While it is probably not practical to attempt to quantify such factors, and is certainly not possible without data that would not be readily available to outsiders, these factors should at least be born in mind when considering relative costs. Costs which were reportedly about equal in terms of capital investment in these two similar instances certainly produced different results. More per dollar spent was realized in one case than in the other and the explanation requires more than a superficial look at dollar amounts.

Leaving philosophy aside, at least for a time, costs must, in practice, be based upon data which can be obtained or reasonably estimated. There are many factors which must be defined in formulating costs, particularly when costs are to be annualized. Compromises must be made between strict economic definitions and those which are, in practice, affected by accounting conventions, tax laws, etc. These factors are discussed below.

Economic Life

The economic life of a facility installed for pollution abatement purposes can hardly exceed that of the production facilities which it serves. A reasonable working definition would appear to be the useful life of the pollution abatement equipment alone or the useful life of the related production facilities, whichever is shorter. Annualized capital costs would thus be the initial capital cost plus capitalized repairs over the useful economic life, less the salvage value. The useful economic life of a production facility may be taken to be the asset guideline period as established by the Internal Revenue Service, examples of which are shown in Table 8. The useful economic lives of some specific pieces of equipment which might together constitute a pollution control facility are illustrated in Table 9.

Table 8. Asset Guideline Periods as Established by the Internal Revenue Service

Asset Guide-line Class	Description of Assets	Asset Depreciation Range (in years) Lower Limit	Asset Guide-line Period	Upper Limit	Annual Asset Guideline Repair Allowance Percentage
13.3	Petroleum refining	13	16	19	7.0
20.4	All other food and kindred products	9.5	12	14.5	5.5
21.0	Manufacture of tobacco and tobacco products	12	15	18	5.0
22.2	Textile mill products, except knitwear	11	14	17	4.5
24.4	Manufacture of lumber and wood products and furniture	8	10	12	6.5
26.1	Manufacture of pulps from wood and other cellulose fibers and rags	13	16	19	4.5
28.0	Manufacture of chemicals and allied products	9	11	13	5.5
30.1	Manufacture of rubber products	11	14	17	5.0
32.1	Manufacture of glass products	11	14	17	6.0
33.1	Ferrous metals	14.5	18	21.5	8.0
33.2	Nonferrous metals	11	14	17	4.5
39.0	Manufacture of products not elsewhere classified	9.5	12	14.5	5.5
49.11	Hydraulic production plant	40	50	60	1.5
49.12	Nuclear production plant	16	20	24	3.0
49.13	Steam Production plant	22.5	28	33.5	2.0
49.3	Water utilities	40	50	60	1.5

Table 9. Estimated Depreciation Rates for Buildings and Equipment

Equipment or Building	Annual Percent
Blowers	7
Buildings	
Mill Construction	4
Corrugated Iron	10
Plumbing	
Sewer and drainage pipe	6
Drainage tile	2
Compressors	5
Condensers	
Steam (atmosphere)	4
Steam (surface)	5
Dust Collector Equipment	5
Filters	
Vacuum continuous	10
Furniture and fixtures	10
Laboratory equipment	7
Motors	5-10
Piping	
Wrought iron	3
Cast iron, 8 in. and larger	1 1/2
Steam	5
Pumps	
Centrifugal	5
Rotary	5
Direct acting	4
Tanks	
Concrete	2
Steel	5

A factor of potential importance in evaluating and comparing capital costs is the choice of materials of construction, i.e., the choice between long-lived, corrosion resistant materials and short-lived materials which are less expensive and may or may not entail increased maintenance costs. Kaiser Steel Corporation, for example, has long adopted the practice of using carbon steel piping, etc. almost exclusively and expecting short-lived performance as opposed to using initially more expensive materials. Ceramic cooling towers, for another example, last longer than wooden towers and are virtually maintenance-free, but cost about twice as much as wooden towers.

According to an Internal Revenue Service engineer, three alternatives are open to industry in depreciating pollution control facilities:

1. A five-year write-off if the facilities qualify under state and federal law relating specifically to pollution control facilities.

2. Write-off at the rate of production facilities.

3. Write-off at a slower rate if it can be shown that the specific equipment will have some other useful life.

According to this engineer, most industries write off pollution control facilities at the same rate as production facilities. An interesting comment was that many industries, particularly electric utilities, attempt to classify as much equipment as possible as pollution abatement facilities for the public relations effects.

Cost of Capital (Money)

Insofar as debt capital is concerned, the cost is at least the interest rate on borrowed funds. This rate will generally be the prime rate for large, financially sound corporations. For smaller corporations or sole proprietors, the interest rate will be higher, particularly if the operation is financially marginal. In some cases of very small, marginal enterprices, the interest rate may be the personal loan rate to the owner.

The cost of equity capital will generally be the opportunity cost, i.e., the rate of return that would be realized if an investment had been made in alternative income-producing. This, on the average, would be equal to the rate of return in the industry considered, but opportunities in diversification should probably be considered.

When borrowing capacity is limited, the cost of debt capital is the opportunity cost, assuming that funds borrowed for pollution control facilities would have been invested in income production and are unavailable for such purposes. Industrial revenue bonds offer a means by which financing can be obtained which presumably does not affect borrowing capacity for other purposes. Such bonds have been authorized in all states except California, Idaho, New Jersey and Texas and must bear a minimum interest rate of 6 percent, which is tax free since the issuing agency is usually a municipal or county government. Since such bonds sell at about 2 percent less than the rate for corporate debentures, the difference is still an overall cost in the sense of taxes foregone. A fifteen-year term is about average. An underwriting fee of 1 percent of the value of the issue is generally charged.

The costs of capital thus seem logically to be the opportunity costs in each industry, or the interest rate on borrowed funds, including bonds, if financing is such that borrowing for income-production is not impaired.

Definitions of Pollution Abatement Facilities

Accelerated depreciation of pollution control facilities or qualifications for industrial revenue bond financing requires certification of state and federal agencies, including the Internal Revenue Service. Such definitions are not clear cut when pollution control equipment serves a production function, but are straightforward for such items as gas scrubbers and waste water treatment equipment.

Problems in definition can arise in separating the costs of water-use facilities necessary for production even with once-through use and no effluent restrictions in a given locality from the costs of changes in water-use practices, production modifications, and reuse facilities installed solely for pollution abatement. Additionally, there must be some definition of increased production costs attributable to pollution abatement methods.

In the cases of mill scale pits and flue dust clarifiers in steel mills and ammonia stills and saturators in coke plants, the annualized costs less credits for by-products probably incorporate these distinctions, since the residual costs can be fairly attributed to pollution abatement.

In the case of a mechanical debarker installed in a pulp mill, it is not so clear as to the cost attributable to pollution abatement. If shell and tube condensers are substituted for barometric condensers in an oil refinery, the cost attributed to pollution abatement is also not clear. In both cases, waste water is eliminated.

When one steel mill has recirculated water because it had no adequate supply and another recirculated water for pollution abatement in the face of an unlimited supply, and both achieve the same degree of pollution abatement, determining the costs of pollution abatement is not clear cut.

Perhaps a general solution would be to base all costs on the once-through use of water of average industry rates per unit of production and attribute all costs which reduce effluent contaminant loads and/or volumes to pollution abatement irrespective of the motivation. To the extent, then that some costs are clearly overstated, suitable adjustments could be made. Errors would, at least, be consistently on the high side. Internal Revenue Service opinions will probably provide a basis eventually, but they are currently few in number and appear very slowly.

Bases of Cost Comparisons

To be meaningful, costs must be related to some measures of business volume, profitability, etc. such as sales, net income, equity, or other parameters. The capital costs of pollution abatement facilities as related to the value of production facilities is probably the most realistic basis upon which to compare the former. Expressing the cost of pollution abatement facilities as a fraction of the original cost of the production facilities, both in constant or current dollars, is the only consistent way to make such a comparison. The use of depreciated values leads to highly variable and fallacious expressions of costs, making comparisons meaningless unless the bases of calculations are precisely defined.

If the capital costs of a new treatment facility are, for example, expressed as a ratio of the costs of depreciated production facilities in terms of original price, a very high ratio results. If such cost comparisons are made in new installations when depreciation rates of treatment and production facilities are taken to be different, such ratios will again vary from case to case. At the limit, the ratio of the value of new treatment facilities to fully depreciated production facilities would be infinite. At least passing consideration must be given to such expressions of investment;

it seems probable that some of the variations in reported ratios of investment in pollution abatement are due to the use of various of these methods of calculation.

The annualized capital costs of pollution abatement facilities as related to the annualized capital costs of the production facilities served, both expressed in constant dollars, seems to be clearly the most logical basis for comparative purposes, assuming that the economic lives and costs of capital can be satisfactorily expressed. The definition of a comparative base for operating costs presents, at least initially, several alternatives.

Since operating costs are, by definition, annualized costs, they are directly relatable to income, expenditures, etc. per unit period of time. Possible comparative bases are thus:

1. Annual sales
2. Annual net income
3. Annual return on sales
4. Annual return on equity
5. Annual value added

The base upon which the costs of pollution abatement facilities are compared should be selected so as to impart some item of information relative to economic effects. The extent to which such costs will cause economic dislocations by reducing production, resulting in unemployment, or reducing income to the factors of production would seem to be those of interest insofar as the cost side of the economic ledger is concerned. At least for the present, the economic benefits of more stringent pollution abatement requirements will not be considered. The former, however, should be measured so as to be comparable with the latter.

Given that potentially adverse economic effects are to be measured and that a consistent basis should be used for future comparisons with beneficial effects, the National Income and Gross National Product data seem to provide the best bases. Macroeconomic statistics can thus be used for the assessment of general effects and used as comparative bases for studies of regional and single plant effects. Such data are applicable and separable for comparing capital and operating costs. Their use in business cycle analysis would also seem to indicate a specific utility here. The ready availability of such data from a government agency and general acceptability are, of course, important considerations.

The expression of the capital costs of pollution abatement as related to Gross Private Domestic Investment is consistent with the previously given measure as a fraction of investment in production facilities. Operating costs as related to annual net income and to value added in the aggregate can be readily determined from these data. Relationships of operating costs to sales, return on sales, and return on equity can be determined for industry groups from ancillary data published by the Department of Commerce. The latter comparative data can also be reduced to at least the corporation unit through annual report data. Reduction of comparative data to the individual plant or other production unit basis cannot generally be done outside of the firm, except by estimation.

Capital Costs

Waste water treatment facilities are generally similar to chemical process equipment and it is thus logical to use chemical engineering estimating techniques in evaluating the cost of such facilities. Guthrie's module cost technique (18) seems particularly appropriate, since it provides some insight into the various cost components and data in this form are available on the basis of considerable experience.

On the basis of a typical chemical process project on a Gulf Coast job site in mid 1968, the cost components shown in Table 10 are regarded as typical:

Table 10. Capital Cost Components

	Relative Cost		Percent of Cost	
F.O.B. cost of equipment		100.0		28.72
Direct field materials:		62.2		17.86
Piping	(32.0)		(9.19)	
Other	(30.2)		(8.67)	
Direct field labor		58.0		16.66
Indirect costs:		128.0		36.76
Freight, insurance, taxes	(13.7)		(3.93)	
Construction overhead	(39.2)		(11.26)	
Engineering	(22.0)		(6.32)	
Contingency	(8.9)		(2.56)	
Contractor fee	(44.2)		(12.69)	
		348.2		100.00

Operating Costs

Operating costs may be formulated from consideration of the typical items of cost in the case of a good manufactured for sale. Considering the nature of pollution abatement facilities, the internal cost to the firm may be expressed as shown in Table 11, eliminating packaging and shipping, sales, etc., and depreciation, since the latter is included in annualized capital costs in the present analysis:

Table 11. Components of Operating Costs

I. Manufacturing Costs

- A. Chemicals
- B. Labor and Supervision
- C. Maintenance and Supplies
- D. Power and Utilities
- E. Royalties and Patents
- F. Payroll and Plant Overhead
- G. Laboratory
- H. Property Taxes and Insurance

II. General Expense

- A. Administration
- B. Research
- C. Interest on Working Capital
- D. Total

III. Total Cost

- A. Manufacturing Cost
- B. General Expense
- C. Subtotal
- D. By-product Credits
- E. Income Tax Credits
- F. Total Credits
- G. Net Cost

These items, of course, refer to the allocations to waste water treatment facilities, including reuse systems to the extent installed for purposes of pollution abatement.

Insofar as the concept of maximum water reuse prior to disposal of a residual is involved in implementing "zero discharge", the costs of pollution abatement become analagous to the costs of water utilization. The components of the latter costs, at any rate, would be expected to be proportionately the same, eliminating purchased water as a cost item.

Table 12. Total Costs of Industrial Water Use

Cost Item	Daily Costs in Dollars (1969) Steel	Paper	Petroleum	Chemical	Total
Raw Materials	8,794	3,932	12,377	4,484	29,587
Labor	7,280	11,039	8,818	3,799	30,936
Maintenance & Power	7,984	7,650	67,721	3,134	86,489
Payroll Overhead	1,820	2,760	2,205	953	7,738
Plant Overhead	3,650	5,519	4,409	1,907	15,485
Depreciation	30,241	12,073	505,276	12,327	559,917
Property taxes & insurance	606	241	10,106	246	11,199
Total	60,375	43,214	610,912	26,850	741,351

"Raw materials" in the above items includes purchased water; chemicals for treatment account for the relative portions of this cost item shown in Table 13. (CEP, Symposium Series, 65, No. 97, 1969):

Table 13. Water Use Cost Components

Industry	Relative Costs Purchased Water % of Daily Cost	Chemicals % of Daily Cost	% for Chemicals
Steel	16.3	5.6	25.6
Paper	0.0	6.7	100.0
Petroleum	0.3	0.7	70.0
Power	1.0	1.0	50.0

Using the above percentages to estimate the chemical costs, assuming that the chemical industry percentage is about the average in the steel and petroleum industries, and eliminating depreciation, the manufacturing cost components are as shown in Table 14.

Table 14. Water Use Costs Less Depreciation

Cost Item	Daily Costs in Dollars (1969) Steel	Paper	Petroleum	Chemical	Total
Chemicals	2,251	3,932	8,664	2,242	17,089
Labor	7,280	11,039	8,818	3,799	30,936
Maintenance and Power	7,984	7,650	67,721	3,134	86,489
Payroll Overhead	1,820	2,760	2,205	953	7,738
Plant Overhead	3,650	5,519	4,409	1,907	15,485
Property Taxes and insurance	606	241	10,106	246	11,199
Total	23,591	31,141	101,923	12,281	168,936
Water used, mgd	1509.6	835.8	5507.5	664.8	8517.7

The above data were used to determine average weighted percentage contributions of these cost components and, together with average relative costs in the chemical process industries for other items as taken from Aries and Newton, yielded the operating cost formulation as in Table 15.

Table 15. Average Operating Cost Components

I.	Manufacturing Costs:		
	A. Chemicals		.098
	B. Labor and Supervision		.170
	C. Maintenance and Power		.533
	D. Royalties and Patents	(0.01 x III.C) =	0.013
	E. Payroll and Plant Overhead		.128
	F. Laboratory	(0.20 x I.B.) =	.034
	G. Property Taxes and Insurance		.071
	H. Total		1.047
II.	General Expense:		
	A. Administration	(0.06 x I.H) =	0.063
	B. Research	(0.10 x I.H) =	0.105
	C. Interest on Working Capital	(0.08 x III.C)	0.106
	D. Total		0.274
III.	Total Cost:		
	A. Manufacturing		1.047
	B. General Expense		0.274
	C. Subtotal		1.321
	D. By-product Credits		
	E. Income Tax Credits		
	F. Total Credits		
	G. Net Cost		

SECTION VII

AVAILABLE TECHNOLOGY FOR MINIMUM DISCHARGE

The technology required for minimum discharge may be grouped as follows:

1. Methods to reduce water use
2. Methods to treat water for reuse
3. Methods to recirculate water
4. Methods to reduce residual waste water volumes
5. Methods for ultimate disposal of minimum residuals

The distinction between water use and water discharge or intake must be borne in mind. It has been a quite general assumption that water use in the steel industry, for example, averages about 40,000 gallons per ton of finished steel and about 30,000 gallons per ton of raw steel. The data on Table 16 demonstrate the fact that the terms are used loosely and incorrectly. The above figures should have been stated as water discharged or taken in per ton, not as the quantity used. Although the volume of water discharged per ton dropped in the 9-year period, the volume of water used increased.

Table 16. Steel Industry Water Use Data

	1959	1964	1968
Steel Production, 1,000 tons:			
Raw Steel	93.446	127.076	131.462
Finished Steel	69.377	84.945	91.856
Water Volumes, 10^9 gallons:			
Intake	2994	3815	4071
Discharge	2876	3569	3811
Used	4571	5427	6154
Water Volumes, gal. per ton:			
Discharged:			
Raw Steel Basis	30800	28100	29000
Finished Steel Basis	41500	42000	41500
Used:			
Raw Steel Basis	48900	42700	46800
Finished Steel Basis	65900	63900	67000

Methods to reduce water use, therefore, do not include cooling towers, for example, as many writers have at least tacitly assumed. Neither are such processes as electrodialysis, reverse osmosis, ion exchange, etc. properly considered effluent treatments for the purposes of this study, since they produce a clean stream and a concentrated stream, which, taken together, still contain the original (or even greater) amounts of contaminants; they are classified here as waste water volume reduction methods. Examples of technology for particular purposes are as follows:

1. Methods to reduce water use:
   a. Electrostatic precipitators (vs. wet scrubbers) for air pollution control
   b. Bag houses (vs. wet scrubbers) for air pollution control
   c. Evaporation chambers (vs. spray towers) in air control
   d. Dry scale removal (vs. flume flushing) in rolling mills
   e. Savealls on paper machines
   f. Long-log debarking in pulp mills
   g. Water flows geared to production rates
   h. Dry floor cleaning (vs. hosing)
   i. Air coolers (vs. water coolers) in petroleum refineries
   j. Surface condensers (vs. barometric condensers) in chemical plants
   k. Process water sewers (vs. combined sewers)

2. Methods to treat water for reuse:
   a. Cooling towers
   b. Spray ponds or canals
   c. Cooling ponds
   d. Sedimentation
   e. Sedimentation-flocculation
   f. Chemical precipitation
   g. Filtration
   h. Oil separation
   i. Chemical treatment

3. Methods to recirculate water:
   a. Recirculation on paper machines
   b. Sequential uses of water for progressively lower uses
   c. Recirculation of flume water in rolling mills
   d. At process recirculation systems
   e. Diversion of treated effluents to present intake pumps
   f. Diversion of treated effluents to new intake pumps

4. Methods to reduce residual waste water volumes:
   a. Evaporation or distillation
   b. Reverse osmosis
   c. Electrodialysis
   d. Ion exchange

5. Methods for ultimate disposal of minimum residuals:
   a. Ocean disposal
   b. Solar evaporation
   c. Deep well disposal
   d. Incineration
   e. Landfill
   f. Burial
   g. Discharge to brackish water

For the purposes of this study, it has been assumed that water use reductions beyond those currently in practice would not be utilized and that water treatment for reuse would be the same as that required currently for discharge with the addition of cooling towers. The method assumed for water recirculation is the diversion of treated effluents to new intake pumps and the provision of new distribution piping. The method assumed for reducing residual waste water volumes is evaporation. The methods assumed for ultimate disposal of minimum residuals are deepwell disposal, solar evaporation, incineration, and ocean disposal to the extent each is geographically possible.

These methods have been used in the study because they are proven technology. They are, together with the assumption of no significant water use reductions, the high-cost alternatives in most cases. On the basis of these assumptions, the cost estimates should be on the high side, i.e., conservative in the sense of not understating costs.

SECTION VIII

RESIDUAL EFFLUENT DISPOSAL

The ultimate disposal of residual waste water, i.e., water containing essentially only dissolved inorganic solids in the minimum practicable volume from an industrial operation could be accomplished by several methods with minimum environmental impact.

Possible methods include:

1. Underground injection (deepwells)
2. Underground cavities
3. Spreading/landfill
4. Solar evaporation
5. Discharge to brackish water
6. Ocean discharge

Ocean Disposal

The applicability of the various methods is a function largely of geographical location. Based upon Koenig's data for the costs of ultimate disposal of waste water from Advanced Waste Treatment processes (WP-20-AWTR-19, 1968), typical costs for disposal to the ocean are as shown in Table 17, based upon a 30-mile ocean outfall and conveyed distances of 100 or 1,000 miles. The costs for conveying 1,000 miles are based upon preconcentration by evaporation.

Table 17. Total Costs for Ocean Disposal

Waste Water Volume, gpd	Costs per 1,000 gallons	
	100 miles	1,000 miles
500,000	$ 1.84	$ 2.76
1,000,000	1.31	1.88
5,000,000	0.72	1.84
10,000,000	0.53	1.02

Koenig's data were optimized on the basis of the most advantageous conveyance (pipe or rail). The operating costs for conveyance were segregated and the operating costs for distillation in the case of the 1,000-mile distance were taken from the Inorganic Chemical Industry Profile data.

Considering the costs of conveyance plus the costs of distillation for the 1,000 miles distance as operating costs with the remainder as annualized capital costs, costs were calculated as in Table 18.

Table 18. Capital and Operating Costs of Ocean Disposal

	100 miles ($/1000 gal.)		1000 miles ($/1000 gal)	
Volume, gpd	Operating Costs	Annual Cap. Costs	Operating Costs	Annual Cap. Costs
500,000	1.00	0.84	1.52	1.24
1,000,000	0.75	0.56	1.08	0.80
5,000,000	0.44	0.28	1.12	0.72
10,000,000	0.29	0.24	0.75	0.27

Deepwell Disposal

For the case of a 100 mgd AWT plant operating at 95 percent product water recovery, Koenig calculated the cost of deepwell disposal at 0.9 cents per 1,000 gallon of product water. Such a plant would produce 95,000 x 10^3 gpd of product water; daily costs would thus be $855 for the disposal of 5 mgd of waste water, or $0.171 per 1,000 gallons. This is essentially the same cost as calculated by Rapier (Burns and Roe, Inc. FWQA Contract No. 14-12-495 [17070 DJW]) at a fixed charge rate of 10 percent; Rapier shows no difference in costs as a function of volume from 10 mgd to 1.0 mgd, but indicates a cost of $0.28 per 1,000 gallon at a daily volume of 100,000 gallons.

Rapier's costs are based upon disposal wells 3,500 feet deep, 30-year project life, electrical power at 12 mils per kwhr, and relatively low injection pressures. A more likely basis for the present purpose are the data in Inorganic Chemicals Industry Profile based upon the work of Moseley and Malina relating specifically to industrial waste disposal. These data are based upon depths generally necessary to prevent groundwater contamination, 20-year project life, electrical power at $0.005 per kwhr, and up to 1,400 psi injection pressure, interest rates are taken at 5 percent. Taking the interest rate at 10 percent, the injection pressure at

1,000 psi, and eliminating depreciation, operating costs were calculated as shown in Table 19.

Table 19. Deepwell Disposal Costs

Daily Volume	Costs per 1,000 gal. injected	
	Operating Costs	Annualized Capital Cost
100,000 gal.	$ 0.4644	$ 0.6436
500,000 gal.	0.2528	0.1512
1,000,000 gal.	0.2020	0.0853

Solar Evaporation

For solar evaporation plus disposal of brine at 100 mile distance, Rapier's data for ponds and Koenig's data for 100 mile conveyance after concentration yield the following data shown in Table 20.

Table 20. Costs of Solar Evaporation Ponds and Conveyance

Waste Volume	Volume Conveyed	Conveyance Cost	Costs,/1,000 gal. waste	
			Conveyance	Ponds Tucson
100,000 gpd	--	--	--	$ 0.455
500,000 gpd	10,000	$ 310/day	$ 0.62	--
1 mgd	10,000	310/day	0.31	0.378
5 mgd	100,000	3000/day	0.60	--
10 mgd	100,000	3000/day	0.30	0.354

Koenig's data assumed concentration by distillation and the degree of concentration was optimized. There would be no such economies in solar evaporation ponds and the maximum concentration can be assumed. Assuming that the pond cost is the capital cost and conveyance cost is the operating cost, costs are shown in Table 21.

Table 21. Solar Evaporation Costs

Daily Volume	Cost per 1,000 gal. Waste Water Disposed Operating Cost	Annualized Capital Cost
100,000	$ 0.300	$ 0.455
500,000	0.300	0.417
1 mgd	0.300	0.378
5 mgd	0.300	0.366
10 mgd	0.300	0.354

Incineration

Koenig estimates the cost of incineration at 4.8¢ per 1,000 gallon of product water in a 100 mgd AWT plant at 95 percent product water production. Daily costs here would thus be $4,560 for the disposal of 5 mgd of waste water, or $0.912 per 1,000 gallons. The ash produced might be disposed of in a landfill. Assuming 1,500 ppm of dissolved solids in 5 mgd, the ash would be about 62,475 lbs or 31.2 tons per day in such a plant. For a 100 mgd AWT plant at a 99.5 percent product water rate the cost of spreading is 0.1¢ per 1,000 gallon of product water, $99.50 per day, or about 20¢ per 1,000 gallon of waste water. These figures seem to confirm the conclusion in WP-20-AWTR-19 that such disposal means cost about the same as ocean disposal.

The limiting factor in the general applicability of incineration would be the availability and cost of fuel. Koenig's data seem to be based upon a minimum fuel cost probably only available at the well for natural gas. Assuming the availability of waste heat and/or by-product fuels in industrial plants, the cost of incineration may be assumed to be the highest cost for ocean disposal, i.e., as in Koenig's data for 500,000 gpd at a distance of 1,000 miles.

Regional Applicability

The states in which solar evaporation probably represents a viable disposal method are: Arizona, New Mexico, Nevada, Utah, Colorado and Wyoming on the basis of the evaporation rates in Table 22 and precipitation rates in the map of Figure 13.

Deepwell disposal is probably a feasible disposal method in the following states as indicated on the map on Figure 14.

Table 22. Mean Monthly Computed Reservoir Evaporation At Selected Stations, in Inches Depth

Station	Month												Annual
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Sacramento, Calif......	0.8	1.4	2.5	3.6	5.0	7.1	8.9	8.6	7.1	4.8	2.6	1.2	54
Seattle, Wash..........	0.8	0.8	1.4	2.1	2.7	3.4	3.9	3.4	2.6	1.6	1.1	0.7	24
Baker, Oregon..........	0.5	0.7	1.4	2.5	3.4	4.4	6.9	7.3	4.9	2.9	1.5	0.6	37
Salt Lake City, Utah...	0.8	1.0	2.0	3.5	5.1	7.9	10.6	10.4	7.3	3.9	2.0	1.0	55
Yuma, Arizona..........	3.9	4.6	6.5	8.0	9.8	11.5	13.4	12.9	10.7	8.0	6.1	4.5	100
Havre, Montana.........	0.5	0.5	1.1	2.5	4.5	6.1	8.2	8.3	5.6	3.3	1.5	0.7	43
Bismark, N. Dakota.....	0.4	0.5	1.0	2.3	4.0	5.3	7.3	7.7	5.8	3.3	1.3	0.5	39
Denver, Colorado.......	1.6	1.8	2.5	3.7	5.0	7.4	8.8	8.4	6.7	4.6	3.0	1.9	55
North Platte, Nebr.....	0.8	1.1	2.2	3.7	5.0	6.5	8.6	8.4	6.9	4.6	2.6	1.1	51
Roswell, N. Mexico.....	2.1	3.2	4.9	6.8	8.3	9.8	9.4	8.3	6.9	5.5	3.5	2.5	71
Oklahoma City, Okla....	1.5	1.9	3.1	4.7	5.5	7.8	10.2	10.7	8.8	6.3	3.5	2.0	66
San Antonio, Texas.....	2.2	3.1	4.5	5.6	6.5	8.4	9.4	9.4	7.6	5.8	3.7	2.4	69
Galveston, Texas.......	0.9	1.3	1.6	2.6	4.1	5.6	6.2	6.1	5.7	4.6	2.7	1.3	43
Minneapolis, Minn......	0.3	0.4	0.9	1.7	3.2	4.4	6.0	5.8	4.6	3.0	1.3	0.4	32
Milwaukee, Wis.........	0.6	0.7	0.9	1.3	2.1	3.2	5.0	5.4	4.7	3.2	1.6	0.6	29
Kansas City, Mo........	0.9	1.1	1.7	3.1	4.4	6.1	8.0	7.8	6.0	4.5	2.5	1.0	47
Vicksburg, Miss........	1.3	1.9	2.9	4.2	5.0	5.7	5.8	5.5	5.2	4.4	2.9	1.6	46
Nashville, Tenn........	0.9	1.3	1.9	3.3	4.1	5.1	5.8	5.4	4.9	3.7	2.1	1.1	39
Columbus, Ohio.........	0.6	0.8	1.1	2.3	3.5	4.6	5.6	5.1	4.1	3.0	1.6	0.6	33
Macon, Georgia.........	1.7	2.2	3.1	4.3	5.1	6.2	6.3	5.8	5.2	4.2	2.8	1.8	49
Miami, Florida.........	3.0	3.4	4.1	4.9	5.0	4.8	5.3	5.1	4.3	4.1	4.3	2.7	51
Columbia, S. C.........	1.6	2.4	3.2	4.5	5.4	6.3	6.6	6.0	5.5	4.4	3.0	1.9	51
Richmond, Va...........	1.3	1.7	2.2	3.5	4.1	5.0	5.6	4.9	4.1	3.2	2.4	1.5	39
Albany, N. Y...........	0.6	0.7	1.1	2.0	3.2	4.3	5.2	4.7	3.4	2.4	1.4	0.8	30
Eastport, Me...........	0.8	0.7	0.9	1.1	1.4	1.7	2.0	2.1	2.0	1.6	1.1	0.7	16
Gulf off Texas Coast...	4.0	4.0	3.5	3.5	4.0	4.5	5.0	5.5	6.5	6.5	6.0	5.0	58
Gulf Stream off Cape... Hatterns, N.C.........	9.0	9.5	8.5	7.0	5.5	3.5	3.5	3.5	5.5	9.0	9.5	10.0	84
Ocean off Mass.........	3.0	2.5	2.0	1.5	1.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0	28

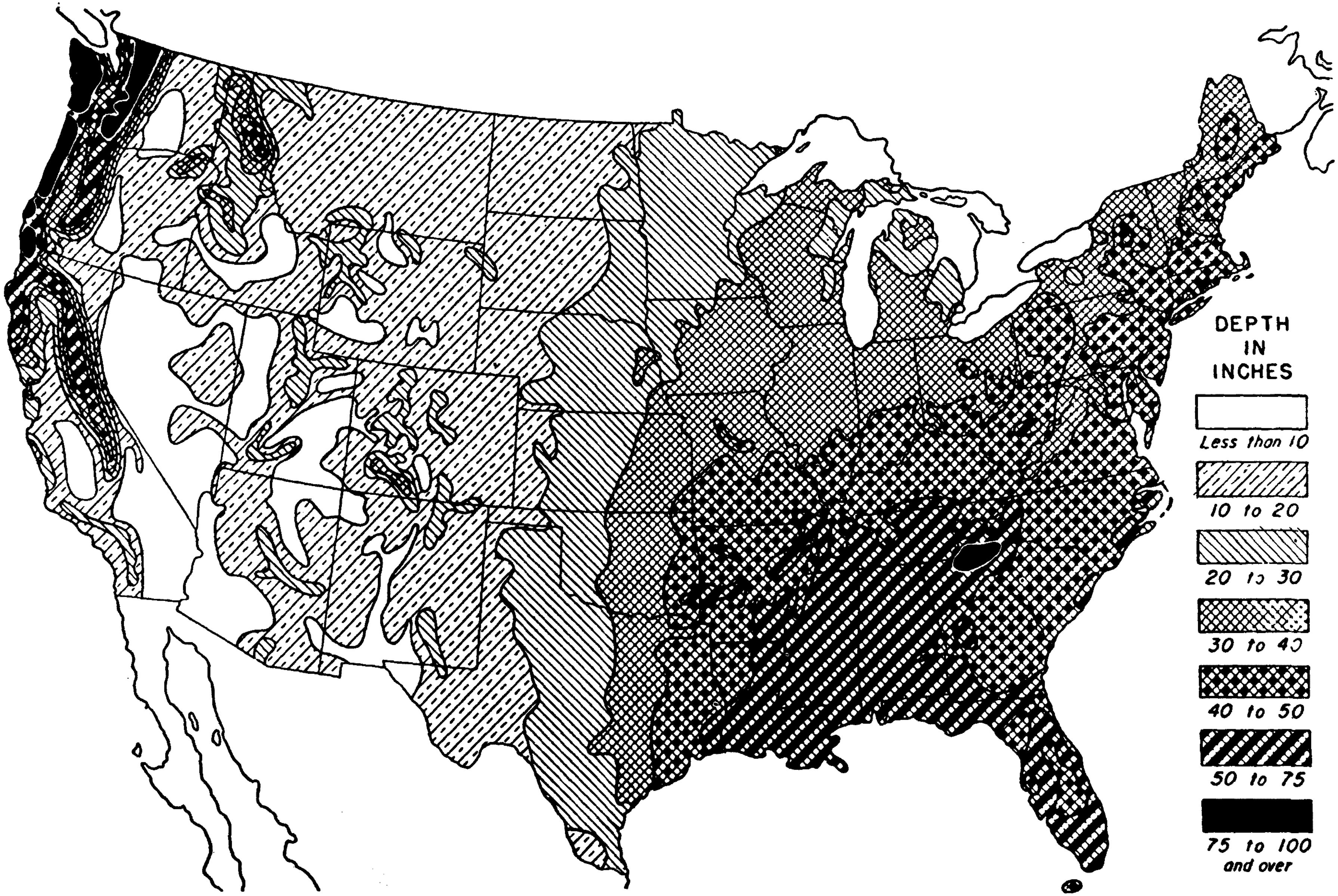

FIGURE 13. AVERAGE ANNUAL PRECIPITATION FOR THE UNITED STATES

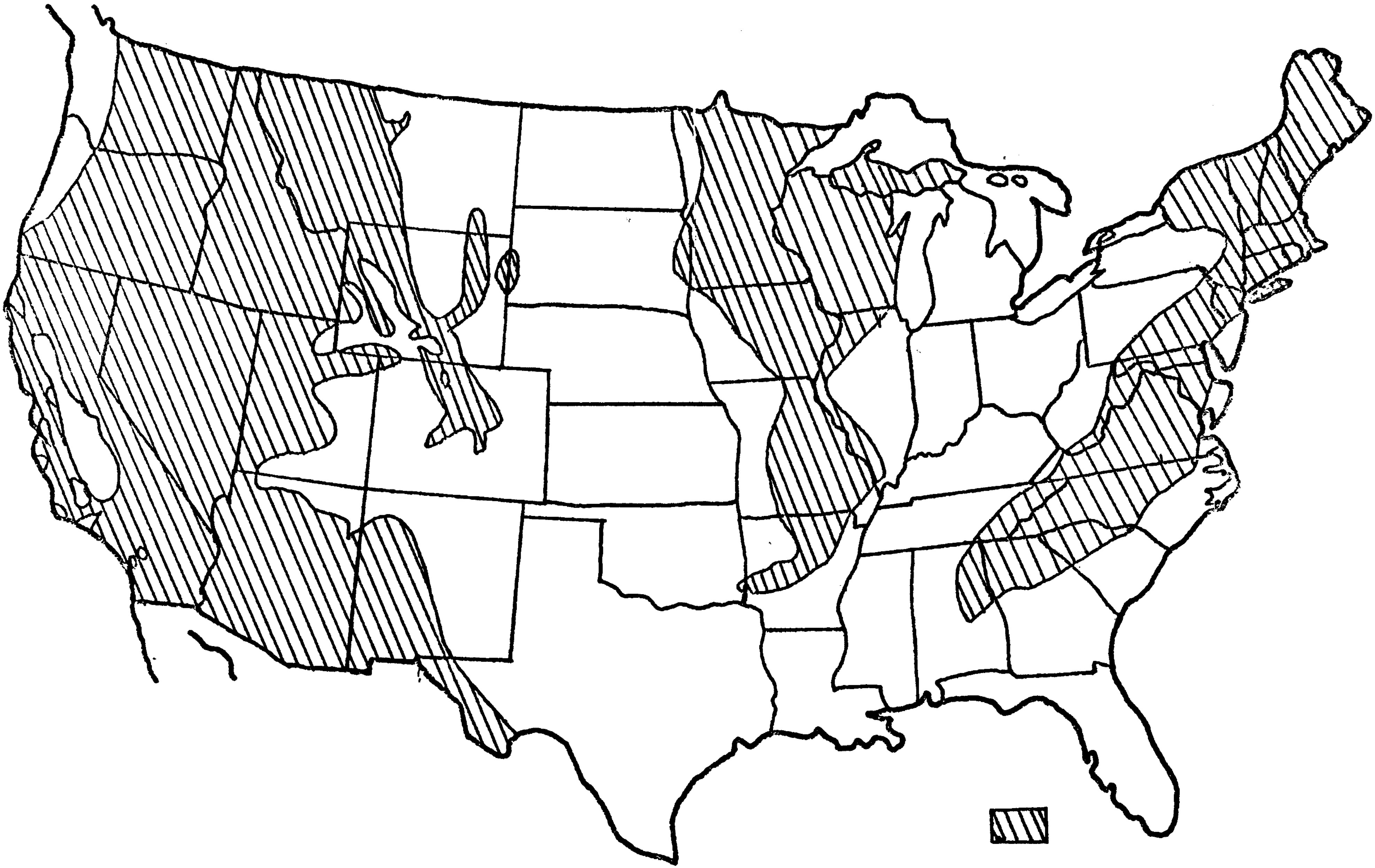

FIGURE 14. AREAS OF POTENTIAL INJECTION SITES (SEDIMENTARY BASINS)

Table 23. Gross Water Uses and Water Intakes of Brackish and Fresh Tidewaters by State

			Billion Gallons Per Year		
State	(1)	Establishments	Gross Water Use	Brackish Intake	Fresh Tidewater Intake
New England	-				
Maine	-	65	317.3	7.4	1.3
New Hampshire	-	57	108.1	0.3	-
Vermont	-	22	17.7	z	-
Massachusetts	-	275	264.3	44.3	0.2
Rhode Island	-	78	30.1	2.5	-
Connecticut	-	214	239.1	34.6	85.0
Middle Atlantic					
New York	-	540	995.9	18.0	7.0
New Jersey	-	418	797.9	195.2	67.3
Pennsylvania	-	678	2559.9	8.5	123.5
East North Central					
Ohio	x	717	2157.1	17.2	-
Indiana	x	347	1621.6	0.5	-
Illinois	x	626	1666.6	10.3	-
Michigan	x	475	1533.0	147.0	-
Wisconsin	-	375	523.0	3.7	-
West North Central					
Minnesota	-	191	231.2	0.7	-
Iowa	-	137	182.1	0.1	-
Missouri	-	185	339.6	4.1	-
North Dakota	x	7	17.5	-	-
South Dakota	x	12	9.1	z	-
Nebraska	x	68	72.7	-	-
Kansas	x	86	348.6	1.7	-
South Atlantic					
Delaware	-	53	259.1	136.5	27.6
Maryland	-	135	581.0	280.2	0.2
D. C.	-	4	0.2	-	-
Virginia	-	156	741.4	63.0	92.2
West Virginia	-	77	824.1	3.6	-
North Carolina	-	302	487.1	0.8	-
South Carolina	-	188	476.7	12.2	0.9
Georgia	-	229	721.9	41.7	-
Florida	x	142	948.7	81.4	0.1
East South Central					
Kentucky	x	140	435.7	0.1	-
Tennessee	x	210	843.9	z	-
Alabama	-	184	971.3	82.6	-
Mississippi	x	95	376.0	5.1	-
West South Central					
Arkansas	-	107	456.8	0.8	-
Louisiana	x	182	2279.1	244.0	5.4
Oklahoma	x	62	309.5	0.6	-
Texas	x	389	6903.3	1368.8	0.5
Mountain					
Montana	-	24	109.1	0.3	-
Idaho	-	63	162.3	0.4	-
Wyoming	0	11	40.5	-	-
Colorado	0	68	160.5	0.2	-
New Mexico	0	12	5.3	-	-
Arizona	0	30	111.3	1.9	-
Utah	0	34	181.4	7.6	-
Nevada	0	11	29.4	-	-
Pacific					
Washington	-	167	1105.7	185.0	33.2
Oregon	-	129	368.0	12.5	15.4
California	-	585	1506.4	132.1	11.7
Alaska	-	12	116.0	1.9	-
Hawaii	-	28	156.7	19.3	0.7
Total		9,402	35,700.6	3,013.0	444.1

(1) Disposal Means: x Deepwell 0 Solar Evaporation - Ocean/Incineration

North Dakota	Louisiana
South Dakota	Mississippi
Nebraska	Florida
Kansas	Kentucky
Oklahoma	Illinois
Texas	Indiana
West Virginia	Ohio
Michigan	Tennessee

In the other states, the most likely disposal means are to the ocean in coastal areas and by incineration/landfill in the inland states or inland portions of coastal states. The costs of such methods will be taken as equal to ocean disposal at 100 miles distance.

Gross water uses and water intakes of brackish and fresh tidewater by state are shown in Table 23. These data are summarized below in Table 24 for the states previously listed in which the three groups of disposal means are applicable.

Table 24. Summary of Water Uses and Residual Disposal Means

Disposal Means	Establish.	Billion Gallons Per Year: Gross Water Use	Brackish Intake	Fresh Tidewater Intake
Deep Well	3,558	19,522.4	1,876.7	6.0
Solar Evaporation	166	528.4	9.7	--
Ocean/Incineration	5,678	15,649.8	1,126.6	438.1

The costs for residual waste water disposal will be assumed herein as summarized in Table 25.

Table 25. Summary of Residual Disposal Costs

Disposal Means	Costs per 1,000 gal. disposed		
	Operating Costs	Annualized Cap. Cost	Total
Ocean Disposal			
@ 100 miles:			
500,000 gpd	$ 1.00	$ 0.84	$ 1.84
1,000,000 gpd	$ 0.75	$ 0.56	$ 1.31
5,000,000 gpd	$ 0.44	$ 0.28	$ 0.72
10,000,000 gpd	$ 0.29	$ 0.24	$ 0.53
Incineration/ Landfill	$ 1.52	$ 1.24	$ 2.76
Deepwell Disposal			
100,000 gpd	$ 0.46	$ 0.64	$ 1.10
500,000 gpd	$ 0.25	$ 0.15	$ 0.40
1,000,000 gpd	$ 0.20	$ 0.085	$ 0.29
Solar Evaporation			
100,000 gpd	$ 0.30	$ 0.46	$ 0.76
500,000 gpd	$ 0.30	$ 0.42	$ 0.72
1,000,000 gpd	$ 0.30	$ 0.38	$ 0.67
5,000,000 gpd	$ 0.30	$ 0.37	$ 0.67
10,000,000 gpd	$ 0.30	$ 0.35	$ 0.65

Total annualized disposal costs, as above, are shown in Figure 15.

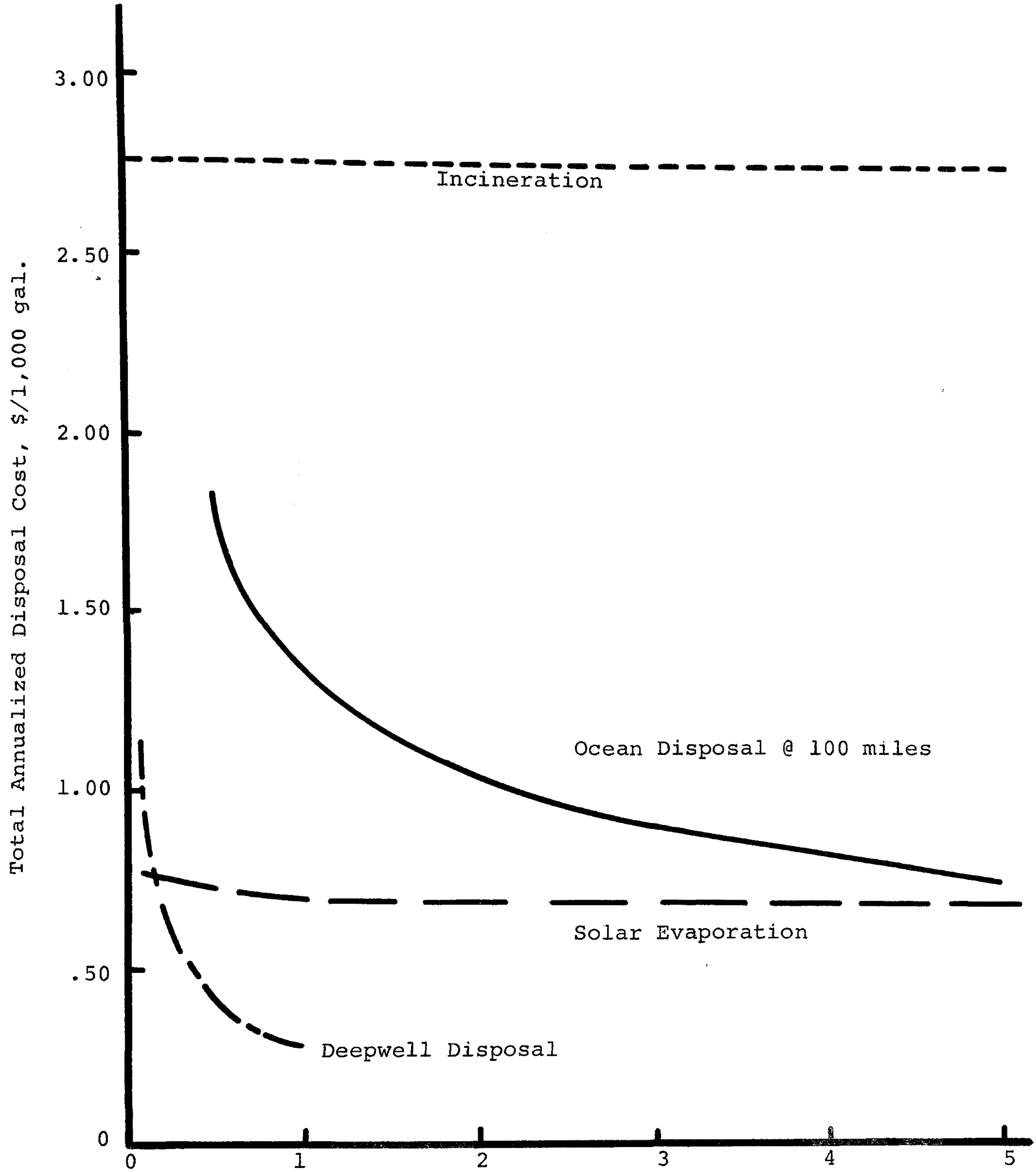

FIGURE 15. TOTAL ANNUALIZED RESIDUAL DISPOSAL COSTS

SECTION IX

COSTS OF INDUSTRY SYSTEMS FOR ZERO DISCHARGE

On the basis of the data developed, the costs of water pollution abatement are estimated for each of the major water-using industries at five levels as follow:

1. Once-through systems
   In such a system, water is used once-through for all uses and process water is treated to the extent required to meet existing water quality standards in a terminal treatment facility.

2. Existing Practice
   Water use is as indicated by the 1968 Census of Manufacturers data and treatment is generally of process water in terminal treatment facilities prior to discharge.

3. Meeting Stream Quality Standards
   Water use is as indicated by the 1968 Census of Manufacturers and treatment is of process water in terminal treatment facilities to meet existing water quality standards.

4. Implement Minimum Discharge (Best Available Treatment)
   Water use is with maximum re-use and treatment is of process water in terminal treatment facilities to meet existing water quality standards.

5. Implement Zero Discharge
   Water use is with maximum re-use, concentration of residual streams from all uses, and non-discharge disposal of brines.

The methods by which these costs were calculated are illustrated below for the Primary Metal Industries, (S.I.C. No. 33). Costs for the other industry groups at the 2-digit S.I.C. level were calculated in an analogous manner.

Projections of physical output were used as data were available; otherwise projections were based on values of shipments. Numbers of establishments in each industry group were used as shown in Table 26.

Primary Metal Industries Calculations

The cost of waste water treatment facilities installed in 1968 was estimated at $1,324.3 million with $1,473.8 million needed to meet current needs. The estimated additional investment needed to meet growth needs through 1972 was

Table 26. Numbers of Large Water-using Establishments

S.I.C. No.		No. of Establishments
Total		9402
20	Food and kindred products	2345
21	Tobacco manufactures	24
22	Textile mill products	684
24	Lumber and wood products, except furniture	188
25	Furniture and fixtures	55
26	Paper and allied products	619
28	Chemicals and allied products	1125
29	Petroleum refining and related industries	260
30	Rubber and miscellaneous plastics products	301
31	Leather and leather products	92
32	Stone, clay, glass and concrete products	586
33	Primary metal industries	841
34	Fabricated metal products, except machinery and transportation equipment	569
35	Machinery, except electrical	471
36	Electrical and electronic machinery, equipment, and supplies	562
37	Transportation equipment	392
38	Measuring, analyzing, and controlling instruments; photographic, medical, and optical goods; watches and clocks	107
39	Miscellaneous manufacturing industries	97

$244.8 million. Bureau of Domestic Commerce estimates of the quantities shipped in these industries through 1980 are as shown in Table 27.

Table 27. Projected Primary Metal Industries Shipments

	1968	1972	1975	1980
Aluminum, 10^6 lbs	9.98	11.6	14	20
Brass Mill, 10^6 lbs	2756	2900	6600	8700
Copper Wire Mill, 10^6 lbs	2214	2525		
Ferrous Castings, 10^6 tons	17.867	17.552	19.1	22.1
Steel Mill Products, 10^6 tons	131.5	139	147	166
Total, 10^6 tons	151.857	159.27	169.4	192.5

Capital Costs

Utilizing the 1968 water use data and the above estimates of costs and industry growth, capital costs are projected on the following bases:

1. Meeting water quality standards: projected proportionately from 1968-1972 costs and growth:

$$\frac{1718.6 - 1473.8}{159.27 - 151.857} = \$\ 33.0 \text{ million/million annual tons}$$

2. Existing practice: projected on the basis of 1968 costs per ton:

$$\frac{1324.3}{151.857} = \$8.72 \text{ million/million annual tons}$$

3. Minimum Discharge

Process water discharge = 5% of recirculation rate = 114

Other discharges = 1% of recirculation rate less boiler feed and sanitary plus boiler feed and sanitary discharges:

= 0.01 (5495-236) + 155 = 208 x 10^9 gal.

Costs for 1968:

Costs of treating discharges to level acceptable for discharge/reuse $ 1,473.8 million

Costs for recirculating:

(1134 + 3562) = 4696 x 10^9 gal. = 8.935 x 10^6 gpm

Intake system = 8.935 x 10^6 x $16.25 = $145 million

Distribution system = 8.935 x 10^6 x $36.50 = $326 million

Costs of cooling towers:

Recirculation rate = 8.935 x 10^6 gpm

No. establishments = 841

Average per plant recirculation rate = 10,624 gpm

Cooling tower cost = $17/gpm $180,000 (13)

Cooling tower cost = $152 million

Total 1968 costs for the industry = $2,096.8 million

Projected proportionately on basis of costs of implementing existing legislation.

for 1972: $\frac{1718.6}{1473.8}$ x \$2096.8 = \$2445.0 million

4. Implement zero discharge:

Costs for 1968:

Blowdown = 114 + 208 = 322 x 10^9 gal. = 882.2 x 10^6 gal/day

No. of establishments - 841

Average blowdown = 1.049 mgd

Distillation cost = \$1.60/gpd(\$1.679 million) (3)

Disillation cost total = \$1412 million

Brine production = 0.10 x 322 x 10^9 gal./year = 88.2 x 10^6 gal./day

No. of establishments = 841

Average brine = 104,900 gpd

The quantities of brine to be disposed of by the various residual disposal means are calculated below from Table 28, which was constructed from the Census of Manufactures data for S.I.C. No. 33 and the regional applicability of each method as shown in Table 23. The calculation of (D) assumes equal volumes in each state.

Ocean	437.1 + 2D
Incineration	3068.6 + 4D
Deepwell	3748.6 + 5D
Sol. Evap.	69.6 + 3D
Total	7323.9 + 14D

14D = (2285 + 5495) - 7323.9 = 456.1; D=32.6

Ocean	502.3 = 6.46%
Incineration	3199.0 = 41.12%
Deepwell	3911.6 = 50.27%
Sol. Evap.	167.4 = 2.15%

Table 28. Brine Disposal Means - S.I.C. 33

	Gross Water Used, 10^9 gallon			
	Ocean	Incineration	Deepwell	Solar Evaporation
Maine	-	-	-	-
New Hampshire	D			
Vermont	-	-	-	-
Massachusetts	4.5	-	-	-
Rhode Island	7.4	-	-	-
Connecticut	-	33.9	-	-
New York	-	331.1	-	-
New Jersey	36.7	-	-	-
Pennsylvania	-	1508.2	-	-
Ohio	-	-	1152.7	-
Indiana	-	-	1118.8	-
Illinois	-	-	531.3	-
Michigan	-	-	626.4	-
Wisconsin	-	13.8	-	-
Minnesota	-	19.1	-	-
Iowa	-	25.7	-	-
Missouri	-	31.7	-	-
North Dakota	-	-	-	-
South Dakota	-	-	-	-
Nebraska	-	-	D	-
Kansas	-	-	D	-
Delaware	D	-	-	-
Maryland	-	372.6	-	-
D.C.	-	-	-	-
Virginia	11.2	-	-	-
West Virginia	-	221.4	-	-
North Carolina	-	4.5	-	-
South Carolina	-	D	-	-
Georgia	-	28.2	-	-
Florida	-	-	D	-
Kentucky	-	-	72.8	-
Tennessee	-	-	33.4	-
Alabama	-	335.5	-	-
Mississippi	-	-	D	-
Arkansas	-	D	-	-
Louisiana	-	-	D	-
Oklahoma	-	-	2.5	-
Texas	210.7	-	210.7	-
Montana	-	D	-	-
Idaho	-	D	-	-
Wyoming	-	-	-	-
Colorado	-	-	-	D
N. Mexico	-	-	-	-
Arizona	-	-	-	69.6
Utah	-	-	-	D
Nevada	-	-	-	D
Washington	-	128.1	-	-
Oregon	-	14.8	-	-
California	166.6	-	-	-
Alaska	-	-	-	-
Hawaii	-	-	-	-

(D) Withheld to avoid disclosing data for individual firms.

Deepwell cost = [0.502 (88.2 x 10^6 gpd) ÷ 100,000] x $200,000
= $88.55 million

Solar evaporation cost:

$0.455 x 104.9 x 365 x 841 x 0.0215 x 8.5136 = $2.68 million

Incineration cost:

$1.24 x 104.9 x 841 x 0.4112 x 8.5136 = $139.8 million

Ocean disposal cost:

$0.84 x 104.9 x 365 x 841 x 0.0646 x 8.5136 = $14.9 million

Added cost for zero discharge = $1657.9 million

1968 costs for best available technology + zero discharge = $3754.7 million

Projected proportionately as for minimum discharge

Operating Costs

Operating costs for the industry in 1968 were estimated to be $137.8 million per year. Since the treatment facilities are of the same type, the ratio of $137.8/$1324.3, or $0.104 per year per dollar of capital investment can be used to estimate and project operating costs for 1968 practice and of meeting water quality standards.

The operating costs for implementation of minimum discharge are the costs of recirculation of the treated effluents. Referring to the previously given steel industry water use costs (p. 32) in 20 plants for 1509.6 mgd:

Manufacturing Costs:

Chemicals	2251
Labor	7280
Maintenance and Power	7984
Payroll and Plant Overhead	5470
Laboratory	0.20 x 7280
Property taxes and insurance	606
Royalties and patents	0.01 x total cost

General Expense:

Administration	0.06 x mfg cost
Research	0.10 x mfg cost
Interest on working capital	0.08 x total cost

Total Cost = General Expense + Mfg Cost = T

Total Cost then is:

($25047 + 0.01 T) + 0.16 ($25047 + 0.01T) + 0.08T

T = $29055 + 0.0916T = $31985/1509.6 mgd = $21.19 per mgd

The additional operating costs then are for recirculating 1134 + 3562, or 4696 x 10^9 gallon per year, i.e., $21.19 x 4696 x 10^3, or $99.5 million per year. These costs may be projected proportionately with the capital costs for implementing minimum discharge.

The operating costs for zero discharge in 1968 are:

Distillation @ 1.049 mgd = $0.80 per 1,000 gallon (3)

Distillation cost total = (322 x 10^9) x ($0.80 x 10^{-3}) = $ 257.6 million

Deepwell cost = 0.5027 x 32.2 x 10^9 x $0.46 x 10^{-3} = $7.4 million

Solar Evaporation Cost = 0.0215 x 32.2 x 10^9 x $0.30 x 10^{-3} = $0.2 million

Incineration Cost = 0.4112 x 32.2 x 10^9 x $1.52 x 10^{-3} = $20.1 mil

Ocean Disposal Cost = 0.0646 x 32.2 x 10^9 x $1.00 x 10^{-3} = $2.1 mil

Total added operating costs then are $287.4 million in 1968 and may be projected in proportion to capital costs.

If all water were used on a once-through basis and treated to meet existing legislative requirements, the costs would presumably be less by the cost of existing recirculation and more by the proportionate residual costs of meeting such requirements by current treatment methods.

For the primary metals industries, 1185-1134, or 51 x 10^9 gallons per year of process water were recirculated in 1968, i.e., 2.190 x 10^6 gpm. The capital costs of such recirculation, as shown previously would be:

Intake system: $2.190 \times 10^6 \times \$16.25 = \$35.6$ million
Distribution: $2.190 \times 10^6 \times \$36.50 = \$79.9$ million
Cooling towers: $2.190 \times 10^6 \times \$17.00 = \$37.2$ million

Total $152.7 million

The residual capital cost in 1968 would have been \$1473.8 - \$152.7 = \$1321.1 million for the treatment of 1431×10^9 gallons of effluent water. The cost of treating the process water flow of 2285×10^9 gallons would have been:

$$\left(\frac{2285}{1431}\right)^{0.6} \times \$1321.1 \text{ million} = \$1749.1 \text{ million}$$

The operating costs, on the basis of the previously shown ratio of \$0.104 per year per dollar of capital investment, would be estimated at:

$$\$1749.1 \text{ million} \times \$0.104/\$ = \$181.9 \text{ million}$$

These costs were projected proportionately by year as with the costs of meeting water quality standards.

The costs then for the primary metals industries as calculated above are summarized in Table 29.

Residual Waste Loads

Net waste loads under existing practice are estimated as shown in Table 30 through 1977.

The dissolved solids listed in Table 30 are from coke plant wastes in 1968, projected by estimated steel production. The apparent anomally in acid wastes loads is due to the lag in treatment installation through 1972, followed by treatment of increasing quantitites due to rising production later.

Net waste loads discharged to meet stream quality standards are estimated in Table 31, assuming the indicated concentration limits, and under minimum discharge requirements in Table 32 with treatment of recirculation blowdowns.

Most water quality standards specify a maximum monthly average of 500 mg/l for dissolved solids and this is assumed as the average concentration in fresh water. The Census data specifies brackish water as containing more than 1,000 mg/l dissolved solids, but a more usual definition is about 5,000 mg/l. Assuming brackish water intake proportionately as in 1968, the dissolved solids concentrated in zero discharge residuals from intake water would be as shown in Table 33.

Table 29. Summary of Costs - Primary Metal Industries S.I.C. 33

	Once-Through Water Use	Existing Practice (1968)	Implement Existing Legislation	Best Available Technology	Implement Zero Discharge
Water Volumes (10^9 gal.)					
Process Uses	2285	2285	2285	2285	2285
Other Uses	5495	5495	5495	5495	5495
Process Discharges	2285	1134	1134	114	0
Other Discharges	5495	3562	3562	208	0
Treated Discharges	2285	1431	1431	114	0
Capital Costs, $\$10^6$					
1968	1749.1	1324.3	1473.8	2096.8	3754.7
1972	2039.6	1388.9	1718.6	2445.0	4378.2
1975	2436.4	1477.2	2052.9	2920.7	5230.0
1980	3341.1	1678.6	2815.2	4005.2	7172.0
Operating Costs, $\$10^6$					
1968	181.9	137.8	153.3	252.8	540.2
1972	212.2	144.5	178.8	294.8	629.9
1975	253.4	153.7	213.6	352.1	752.5
1980	347.5	174.7	292.9	482.9	1031.9

Table 30. Existing Practice Waste Loads

	Loads, 10^6 pounds per year		
	1968	1972	1977
Suspended Solids	1187	1260	1317
Lubricating Oils	236.1	239.6	233.2
Acids and Salts	614	484.6	560.2
Soluble Metals	6.84	7.47	7.42
Emulsified Oils	23.8	28.1	2.75
Organics (91.5% removal)	2.12	2.30	2.75
Fluorides	4.37	4.95	5.80
Dissolved Solids	277.7	293.5	326.5

Table 31. Stream Standards Waste Loads

	Loads, 10^6 pounds per year			
	1968	1972	1975	1980
Suspended Solids (10ppm)	94.5	99.9	105.7	119.3
Oils (5ppm)	47.2	49.9	52.8	59.6
Dissolved Solids	277.7	293.5	310.4	350.6
Iron (7ppm)	66.2	70.0	74.0	83.6
Organics (99% removal)	0.24	0.25	0.27	0.30

Table 32. Minimum Discharge Waste Loads

	Loads, 10^6 pounds per year			
	1968	1972	1975	1980
Suspended Solids	9.45	9.99	10.75	11.93
Oils	4.72	4.99	5.28	5.96
Dissolved Solids	277.7	293.5	310.4	350.6
Iron	6.62	7.00	7.40	8.36
Organics	0.24	0.25	0.27	0.30

Table 33. Intake Dissolved Solids Discharged in Brine

Year	Dissolved Solids, 10^6 pounds per year
1968	6,957
1972	7,353
1975	7,777
1980	8,782

The residual loads then to underground aquifers (deepwell disposal), the oceans (ocean disposal), the air (incineration), and land (solar evaporation) are projected through 1980 in Table 34. The disposition of inorganics from incineration is assumed to be to the land.

Electric Power Industry Calculations

The nature of the electric power industry is such that the calculations are somewhat different than for the manufacturing industries. These calculations are, therefore, separately detailed below. Water uses, and discharges, and waste heat loads are tabulated in Table 35 from the data developed earlier herein.

Table 34. Zero Discharge Residuals
(Million lbs per year)

Substance	Underground '68	'72	'75	'80	Ocean '68	'72	'75	'80
Suspended Solids	4.75	5.01	5.30	5.98	0.61	0.65	0.69	0.78
Oils	2.37	2.50	2.64	2.97	0.31	0.33	0.35	0.40
Dissolved Solids	3636	3843	4064	4589	468	495	524	592
Iron	3.33	3.53	3.73	4.21	0.43	0.45	0.48	0.54
Organics	0.12	0.13	0.03	0.14	0.02	0.02	0.03	0.03

Substance	Air '68	'72	'75	'80	Land '68	'72	'75	'80
Suspended Solids	-	-	-	-	4.09	4.33	4.58	5.17
Oils	1.94	2.05	2.17	2.45	0.10	0.11	0.12	0.14
Dissolved Solids	-	-	-	-	3131	3309	3499	3952
Iron	-	-	-	-	2.86	3.02	3.19	3.61
Organics	0.09	0.09	0.10	0.11	0.01	0.01	0.01	0.02

Table 35. Electric Power Industry Waste Water Parameters

(water volumes, 10^9 gallons, heat discharges, 10^{12} BTU)

	Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Zero Discharge
1968:				
Cooling Water Use	61,412	61,412	61,412	61,412
Cooling Water Discharge	61,412	54,385	614	0
Heat Discharge	5,874	5,208	58.7	0
1972:				
Cooling Water Use	83,156	83,156	83,156	83,156
Cooling Water Discharge	83,156	73,950	832	0
Heat Discharge	7,405	6,625	74.1	0
1975:				
Cooling Water Use	106,347	106,347	106,347	106,347
Cooling Water Discharge	106,347	95,356	1,063	0
Heat Discharge	9,404	8,550	94.0	0
1980:				
Cooling Water Use	145,043	145,043	145,043	145,043
Cooling Water Discharge	145,043	130,043	1,450	0
Heat Discharge	12,015	11,066	120.2	0

Table 36. Power Plant Cooling Water Use

Year	Cooling Water Use 10^9 gal.	No. of Plants	mgd per plant
1968	61,412	984	171
1972	83,156	1,025	222
1975	106,347	1,073	272
1980	145,043	1,140	349

With blowdown at 1% of the recirculation rate, the discharge per plant would be as follows, and multiple-effect evaporation units at the indicated unit costs would result in total industry costs as indicated in Table 37.

Table 37. Power Plant Distillation Costs

Year	Blowdown, mgd per plant	No. of plants	Unit Cost $/gpd	Total Cost, $ Billion
1968	1.71	984	1.30	2.187
1972	2.22	1,025	1.25	2.844
1975	2.72	1,073	1.20	3.502
1980	3.49	1,140	1.10	4.376

Brine production then would be as shown in Table 38, at 10% of the distillation throughout:

Table 38. Power Plant Brine Production

Year	Brine, gpd per plant	No. of Plants	Total Brine per year, 10^9 gal.
1968	171,000	984	61.412
1971	222,000	1,025	83.156
1975	272,000	1,073	106.347
1980	349,000	1,140	145.043

The percentages of brine disposal means were assumed to be the same as the distribution of population in the states in which each of the several methods were previously shown to be applicable and as detailed in Table 39.

The 1968 annualized capital costs for brine disposal then are calculated as follows:

Deepwell = $\frac{\$0.64 - \$(0.64-0.15) \times 71}{400}$ x 61,412,000 x 0.3677

x 8.5136 = $106.3 million

Solar Evaporation = $0.45 x 61,412,000 x 0.0299 x 8.5136 =

$7.03 million

Incineration = $1.24 x 61,412,000 x 0.4500 x 8.5136 =

$291.7 million

Ocean Disposal = $0.84 x 61,412,000 x 0.1524 x 8.5136 =

$66.9 million

Total capital costs for brine disposal = $471.9 million

Operating Costs

The operating costs of recirculation in the electric power industry are estimated at 0.5¢ per 1,000 gallon (4). Capital and operating costs are estimated as above for the year 1968 and projected in proportion to the respective water use volume in the following table.

The recirculation percentage of existing practice is taken at 13 percent, i.e., the capital costs of 1968 practice is 13 percent of that for complete recirculation.

Operating costs for zero discharge in 1968 then are:

Distillation @ 1.71 mgd = $0.71 per 1,000 gallon (3)

Distillation cost total = (614.12×10^9) (0.71×10^{-3}) =

$436.0 million

Deepwell = 61,412,000 x 0.3677 x $0.46 - $\frac{\$(0.46-0.25) \times 71}{400}$ =

$9.55 million

Solar Evaporation = 61,412,000 x 0.0299 x $0.30 = $0.55 million

Incineration = 61,412,000 x 0.4500 x $1.52 = $42.0 million

Ocean Disposal = 61,412,000 x 0.1524 x $1.00 = $9.36 million

The electric power industry water uses, discharges and costs are summarized through 1980 in Table 40, projected by year according to estimated production.

Residual Waste Loads Under Zero Discharge

The electric power industry residual waste loads are the heat rejected in cooling water on a once-through basis, to the air via evaporative cooling, and the dissolved solids in the intake water calculated as previously discussed under the primary metals industries example.

Summaries of Costs and Residual Waste Loads

In Tables 41 through 48, costs and residual waste loads under zero discharge in 1980 are summarized for the manufacturing industries studied and the electric power industry. Capital costs are presented as annualized costs.

Table 39. Percentage Distribution of Disposal Means - Electric Power Industry

State	Ocean	Incineration	Deepwell	Solar Evaporation
Maine	0.24	0.24		
New Hampshire		0.35		
Vermont		0.21		
Massachusetts	1.37	1.37		
Rhode Island	0.23	0.23		
Connecticut	0.74	0.74		
New York		9.05		
New Jersey	1.77	1.77		
Pennsylvania		5.87		
Ohio			5.30	
Indiana			2.53	
Illinois			5.50	
Michigan			4.37	
Wisconsin		2.11		
Minnesota		1.82		
Iowa		1.39		
Missouri		2.31		
North Dakota			0.31	
South Dakota			0.33	
Nebraska			0.72	
Kansas			1.15	
Delaware	0.13	0.13		
Maryland		1.88		
D. C.		0.40		
Virginia	1.15	1.15		
West Virginia		0.90		
North Carolina	1.28	1.28		
South Carolina	0.67	0.67		
Georgia	1.14	1.14		
Florida			3.08	
Kentucky			1.61	
Tennessee			1.99	
Alabama		1.78		
Mississippi			1.17	
Arkansas		0.99		
Louisiana			1.86	
Oklahoma			1.26	
Texas			5.49	
Montana		0.35		
Idaho		0.35		
Wyoming				0.16
Colorado				1.02
New Mexico				0.50
Arizona				0.83
Utah				0.22
Nevada				0.22
Washington	0.82	0.82		
Oregon	0.50	0.50		
California	4.83	4.83		
Alaska	0.07	0.07		
Hawaii	0.20	0.20		
TOTALS	15.24	45.00	36.77	2.99

Table 40. Electric Power Industry Cost and Discharge Summary

	Once-Through Water Use	Existing Practice (1968)	Implementing Existing Legislation	Implementing Zero Discharge
Water Volumes (10^9 gal.):				
Cooling Water Use				
1968	61,412	61,412	61,412	61,412
1972	83,156	83,156	83,156	83,156
1975	106,347	106,347	106,347	106,347
1980	145,043	145,043	145,043	145,043
Water Discharged				
1968	61,412	54,385	614	0
1972	83,156	73,950	832	0
1975	106,347	95,356	1,063	0
1980	145,043	130,043	1,450	0
Capital Costs, $\$10^6$				
1968	0	158	1,215	3,874
1972	0	214	1,645	5,129
1975	0	274	2,104	6,423
1980	0	373	2,870	8,361
Operating Costs, $\$10^6$				
1968	0	39.9	307	497
1972	0	54.0	416	646
1975	0	69.1	532	791
1980	0	94.2	725	1,015

Table 41. Summary of Costs and Residual Waste Loads

PRIMARY METALS

	Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Minimum Discharge	Implement Zero Discharge
Water Volume (10^9 gal. per year): (1968):					
Process Uses	2285	2285	2285	2285	2285
Other Uses	5495	5495	5495	5495	5495
Process Discharge	2285	1134	1134	114	0
Other Discharge	5495	3562	3562	208	0
Treated Discharge	2285	1431	1431	114	0
Annualized Capital Costs ($ million, 1968, 10 year @ 8%):					
1968	205.4	115.6	173.1	246.3	441.0
1972	239.6	163.1	201.9	287.2	514.3
1975	286.2	173.5	241.1	343.1	614.3
1980	392.4	197.2	330.7	470.4	842.4
Annual Operating Costs ($ million, 1968):					
1968	181.9	137.8	153.3	252.8	540.2
1972	212.1	144.5	178.8	194.8	629.9
1975	253.4	153.7	213.6	352.1	752.5
1980	347.5	174.7	292.9	482.9	1032

Residual Waste Loads Under Zero Discharge (10^6 #/yr, 1980):

	Organics and Oils	Suspended Solids	Dissolved Solids
Underground	3.1	10.2	4589
Ocean	0.4	1.3	592
Air	2.6	-	-
Land	0.2	8.8	3952

Table 42. Summary of Costs and Residual Waste Loads

PAPER AND ALLIED PRODUCTS

	Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Minimum Discharge	Implement Zero Discharge
Water Volume (10^9 gal. per year): (1968):					
Process Uses	5166	5166	5166	5166	5166
Other Uses	1356	1356	1356	1356	1356
Process Discharge	5166	1363	1363	517	0
Other Discharge	1356	715	1356	206	0
Treated Discharge	5166	915	1363	517	0
Annual Capital Costs ($ million, 1968, 10 yr @ 8%):					
1968	42.5	28.9	37.8	82.0	431.9
1972	47.3	32.2	42.1	91.3	481.0
1975	50.9	34.7	45.3	98.3	518.0
1980	57.0	38.8	50.7	110.0	579.2
Annual Operating Costs ($ million, 1968):					
1968	49.2	33.3	43.8	182.3	736.3
1972	54.8	37.3	48.7	203.0	820.0
1975	59.0	40.1	52.5	218.6	883.1
1980	66.0	44.9	58.7	244.5	987.4

Residual Waste Loads Under Zero Discharge (10^6 #/yr, 1980):

	B.O.D.	Suspended Solids	Dissolved Solids
Underground	3.5	3.9	4281
Ocean	3.3	3.6	3992
Air	10.0	11.1	-
Land	0.3	0.3	12488

Table 43. Summary of Costs and Residual Waste Loads

CHEMICALS AND ALLIED PRODUCTS

	Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Minimum Discharge	Implement Zero Discharge
Water Volume (10^9 gal. per year): (1968):					
Process Uses	1270	1270	1270	1270	1270
Other Uses	8146	8146	8146	8146	8146
Process Discharge	1270	693	693	63.5	0
Other Discharge	8146	3481	3481	274.0	0
Treated Discharge	1270	674	693	63.5	0
Annualized Capital Costs ($ million, 1968, 10 yr, @ 8%):					
1968	119.1	50.8	92.3	160.6	361.9
1972	138.0	55.6	106.9	186.1	419.3
1975	156.8	61.6	121.5	211.4	476.5
1980	187.1	73.6	144.9	252.3	568.6
Annual Operating Costs ($ million, 1968):					
1968	201.8	76.9	156.6	255.2	559.8
1972	236.7	83.3	183.7	299.4	648.6
1975	272.3	92.7	211.3	344.3	737.1
1980	325.1	110.7	252.3	411.2	879.6

Residual Waste Loads Under Zero Discharge (10^6 #/yr, 1980):

	Organics	Suspended Solids	Dissolved Solids
Underground	5.6	34.6	41,927
Ocean	2.8	17.0	20,591
Air	2.3	-	-
Land	0.1	14.8	18,006

Table 44. Summary of Costs and Residual Waste Loads

PETROLEUM AND COAL PRODUCTS

	Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Minimum Discharge	Implement Zero Discharge
Water Volumes (10^9 gal. per year): (1968):					
Process Uses	346	346	346	346	346
Other Uses	6944	6944	6944	6944	6944
Process Discharge	346	80	80	17.3	0
Other Discharge	6944	1137	1137	159.9	0
Treated Discharge	346	918	918	17.3	0
Annualized Capital Costs ($ million, 1968, 10 year @ 8%):					
1968	31.8	35.5	44.6	63.8	150.3
1972	34.7	38.7	48.6	69.5	163.9
1975	36.8	41.0	51.5	73.7	173.7
1980	40.3	45.0	56.5	80.9	190.5
Annual Operating Costs ($ million, 1968):					
1968	61.3	60.5	75.9	105.1	243.6
1972	66.9	65.9	82.7	114.6	265.5
1975	70.9	69.9	87.7	121.4	281.5
1980	77.7	76.6	96.2	133.2	308.7

Residual Waste Loads Under Zero Discharge (10^6 #/yr, 1980):

	Organics	Dissolved Solids
Underground	17.5	3961
Ocean	11.1	2510
Air	3.1	-
Land	0.5	811

Table 45. Summary of Costs and Residual Waste Loads

FOOD AND KINDRED PRODUCTS

	Once-through Water Use	Existing[1] Practice (1968)	Implement Existing Legislation	Implement Minimum Discharge	Implement Zero Discharge
Water Volumes (10^9 gal. per year): (1968):					
Process Uses	428	428	428	428	428
Other Uses	918	918	918	918	918
Process Discharge	428	270	270	21.4	0
Other Discharge	928	483	483	95.0	0
Treated Discharge	428	185	270	21.4	0
Annualized Capital Costs ($ million, 1968, 10 yr @ 8%):					
1968	110.6	61.4	87.3	97.9	183.4
1972	124.4	65.4	98.2	110.1	206.1
1975	136.3	68.8	107.5	120.5	225.8
1980	183.2	82.4	144.5	162.1	303.5
Annual Operating Costs ($ million, 1968):					
1968	153.5	85.4	121.1	134.3	250.4
1972	172.6	90.8	136.2	151.0	281.5
1975	189.0	95.5	149.1	165.4	308.4
1980	254.1	114.4	200.5	222.4	414.7

Residual Waste Loads Under Zero Discharge (10^6 #/yr, 1980):

	B.O.D.	Suspended Solids	Dissolved Solids
Underground	13.8	21.1	798
Ocean	10.8	16.6	626
Air	14.2	-	-
Land	1.2	23.4	888

Table 46. Summary of Costs and Residual Waste Loads

TEXTILE MILLS

	Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Minimum Discharge	Implement Zero Discharge
Water Volumes (10^9 gal. per year): (1968):					
Process Uses	97	97	97	97	97
Other Uses	230	230	230	230	230
Process Discharge	97	95	95	9.7	0
Other Discharge	230	41	41	21.9	0
Treated Discharge	97	54	95	9.7	0
Annualized Capital Costs ($ million, 1968, 10 yr @ 8%):					
1968	26.8	16.3	19.4	22.6	33.4
1972	27.4	16.7	21.9	25.6	37.7
1975	27.7	16.9	23.5	27.4	40.3
1980	28.5	17.4	26.8	31.2	46.0
Annual Operating Costs ($ million, 1968):					
1968	64.0	39.0	46.4	53.3	67.6
1972	65.4	39.8	52.5	60.3	76.5
1975	66.3	40.4	56.1	64.4	81.7
1980	68.2	41.5	64.0	73.5	93.2

Residual Waste Loads Under Zero Discharge (10^6 #/yr, 1980):

	B.O.D.	Suspended Solids	Dissolved Solids
Underground			
Ocean			
Air	125	38	-
Land	-	-	664

Table 47. Summary of Costs and Residual Waste Loads

TOTALS OF MANUFACTURING INDUSTRIES STUDIED

	Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Minimum Discharge	Implement Zero Discharge
Water Volumes (10^9 gal. per year): (1968):					
Process Uses	9592	9592	9592	9592	9592
Other Uses	23089	23089	23089	23089	23089
Process Discharge	9592	3635	3635	743	0
Other Discharge	23089	9420	10061	965	0
Treated Discharge	9592	4177	4770	743	0
Annualized Capital Costs ($ million, 1968, 10 yr @ 8%):					
1968	536.2	348.5	454.5	673.2	1602
1972	611.4	371.7	519.6	769.8	1788
1975	694.7	396.5	590.4	874.4	2049
1980	888.5	454.4	754.1	1107	2530
Annual Operating Costs ($ million, 1968):					
1968	711.7	432.9	597.1	983.0	2398
1972	808.6	461.6	682.6	1123	2722
1975	910.9	492.3	770.3	1266	3044
1980	1139	562.8	964.6	1568	3715

Residual Waste Loads Under Zero Discharge (10^6 #/yr, 1980):

	Organics	Suspended Solids	Dissolved Solids
Underground	43.5	69.8	55,556
Ocean	28.4	38.5	28,311
Air	157.2	49.1	-
Land	2.3	47.3	36,809

Table 48. Summary of Costs and Residual Waste Loads

ELECTRIC POWER INDUSTRY

		Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Zero Discharge
Water Volume (10^9 gal. per year):					
Water Uses:	1968	61412	61412	61412	61412
	1972	83156	83156	83156	83156
	1975	106347	106347	106347	106347
	1980	145043	145043	145043	145043
Water Discharge:					
	1968	61412	54385	614	0
	1972	83156	73950	832	0
	1975	106347	95356	1063	0
	1980	145043	130043	1450	0
Annualized Capital Costs ($ million, 1968, 10 yr @ 8%);					
	1968	0	18.6	142.7	455.0
	1972	0	25.1	193.2	602.4
	1975	0	32.2	247.1	754.4
	1980	0	43.8	337.1	982.1
Annual Operating Costs ($ million, 1968):					
	1968	0	39.9	307	497
	1972	0	54.0	416	646
	1975	0	69.1	532	791
	1980	0	94.2	725	1015

Residual Waste Loads Under Zero Discharge (1980):

	Heat, 10^{12} BTU/yr	Dissolved Solids, 10^9 #/yr
Underground	-	9.44
Ocean	-	3.91
Air	12,015	-
Land	-	12.32

SECTION X

ECONOMIC ANALYSIS

Those industries studied represent 93.3% of the industrial water use in the United States, and extrapolation to all of the manufacturing industries thus represents little potential error. Such an extrapolation is made in Table 49 based upon the ratios of process or total water uses as appropriate.

Production-related data by industry category must be used with caution in analyzing the economic impact of pollution control. The proportions of various industries which include facilities using significant amounts of water can be seen in the following tabulation. The 1968 values of shipments for the respective total industries and those facilities which take in more than 20 million gallons of water annually are compared in Table 50.

Table 50. Values of Shipments in Large Water-Using Plants

S.I.C. No.	Industry	Total Industry	$20x10^6$ gpy Plants
20	Food and Kindred	78,259	38,685
208	Beverages	10,031	5,304
22	Textile Mills	21,969	9,236
24	Lumber and Wood	5,257	1,377
26	Paper and Allied	22,512	9,996
(1)	Paper and Board	8,708	7,647
28	Chemical and Allied	44,826	27,635
281	Industrial Chemicals	14,988	11,756
29	Petroleum and Coal	23,240	19,742
2911	Petroleum Refining	21,395	19,420
33	Primary Metals	44,274	34,803
331	Blast Furnace Steel	24,733	20,402
-	All Manufacturing Industries	631,911	278,037

(1) S.I.C. 2621, 2631, 2661, and (2) 3312, 3345, 3316, and 3317

The data of Table 51 summarizes data on water uses, the annual costs of implementing existing legislation, values added and values of shipments in the large water-using facilities, and profits for the year of 1968 for the manufacturing and electric power industries. These data provide some first-order measures of the economic significance of

Table 49. Summary of Costs and Residual Waste Loads

TOTAL MANUFACTURING INDUSTRIES

	Once-through Water Use	Existing Practice (1968)	Implement Existing Legislation	Implement Minimum Discharge	Implement Zero Discharge
Water Volumes (10^9 gal. per yr) (1968):					
Process Uses	10245	10245	10245	10245	10245
Other Uses	25456	25456	25456	25456	25456
Process Discharge	10245	3972	3972	794	0
Other Discharge	25456	10304	10304	1064	0
Treated Discharge	10245	4353	4770	794	0
Annualized Capital Costs ($ million, 10 yr @ 8%):					
1968	572.7	372.2	485.4	735.1	1749
1972	653.0	397.0	554.9	840.6	1952
1975	741.9	423.5	630.5	954.8	2238
1980	948.9	485.3	805.4	1209	2763
Annual Operating Costs ($ million, 1968):					
1968	760.1	462.3	637.7	1073	2619
1972	863.6	493.0	729.0	1226	2972
1975	972.8	325.8	822.7	1382	3324
1980	1216	601.1	1030	1712	4057

Residual Waste Loads Under Zero Discharge (10^6 #/yr, 1980):

	Organics	Suspended Solids	Dissolved Solids
Underground	46.5	74.5	60667
Ocean	30.3	41.1	30916
Air	167.9	52.4	-
Land	2.5	50.5	40195

pollution control costs, as shown in Table 52.

Table 52. Pollution Abatement Cost Comparisons

	Manufacturing Industries	Electric Power Industry
Total Annual Costs as a percentage of:		
Value Added	0.90	2.84
Value of Shipments	0.40	2.32
Before-Tax Profits	4.59	9.39
After-Tax Profits	7.92	14.98
Total Annual Costs per:		
1,000 gallons of water used	$0.0315	$0.0073

In Table 53, the total annual costs of implementing the various degrees of discharge reductions are compared with 1968 profits and the effects are estimated under the assumption that such costs would reduce before-tax profits, i.e., that there would be no compensating price increases and that demand would not change. Such effects would, of course, be the maximum in the short-term; in the long run these effects would be less. Profits in 1968 were made with the costs of 1968 pollution abatement practices included in production costs. From these data, the cost burdens of all industry and power, as reflected in lower after-tax profits, and the direct public cost, as reflected in reduced taxes, would have been as shown in Table 54.

Table 54. Allocations of Costs of Pollution Control

Pollution Abatement Practice	Annual Costs, $ million		
	Total	Industry	Public
1968 Practice	893.0	524.0	369.0
Existing Legislation	1573	936.0	637.0
Minimum Discharge	2258	1333	925.0
Zero Discharge	5320	3132	2188

Table 51. Costs, Production, and Water Use Data - 1968

S.I.C. No.	Industry Description	Water Used, 10^9 gal, Gross Use	Process Intake	Costs to Implement Existing Legislation: Annualized Capital, $\$10^6$	Annual Operating $\$10^6$
-	All Industries	35,701	4,295	485.4	637.7
20	Food and Kindred	1,346	291	87.3	121.1
208	Beverages	211	31	(9.3)[2]	(12.9)[2]
22	Textile Mills	328	109	19.4	46.4
24	Lumber and Wood	205	37	(4.2)[3]	(5.5)[3]
26	Paper and Allied	6,522	1,478	37.8	43.8
28	Chemical and Allied	9,416	733	92.3	156.6
29	Petroleum & Coal	7,290	95	44.6	75.9
2911	Petroleum Refining	7,279	92	(43.2)[4]	(73.5)[4]
33	Primary Metals	7,780	1,207	173.1	153.3
331	Blast Furnaces and Steel	6,504	1,049	(113.2)[5]	(100.2)[5]
-	Electric Power	61,412	-	142.7	307.0
-	All Industry & Power	97,113	-	628.1	944.7

S.I.C. No.	Value Added (1) $ Million	Value of Shipments (1) $ Million	Profit on Sales: % After Tax	% Before Tax	$ Million After Tax	$ Million Before Tax
-	125,417	278,037	(5.1)[8]	(8.8)[13]	14,180	24,467
20	12,067	38,685	(2.6)[10]	(4.2)[11]	1,006	1,625
208	2,835	5,304	(3.9)[6]	(6.2)[11]	207	329
22	3,732	9,236	(3.1)[10]	(5.0)[11]	286	462
24	643	1,377	(5.3)[10]	(8.5)[11]	73.0	117
26	4,968	9,996	(4.7)[10]	(7.5)[11]	470	750
28	16,131	27,635	(6.8)[8]	(10.9)[11]	1,879	3,012
29	4,612	19,742	(10.6)[7]	(17.0)[11]	2,093	3,356
2911	4,495	19,420	(10.7)[10]	(17.1)[11]	2,078	3,321
33	14,798	34,803	(5.3)[8]	(9.8)[12]	1,845	3,411
331	9,206	20,814	(5.3)[9]	(9.8)[12]	1,103	2,040
-	15,859	19,421	-	-	3,002	4,789
-	141,276	297,458	-	-	17,182	29,256

Values in plants taking in more than 20 million gallons annually.
Calculated on ratio of process intakes and total costs in S.I.C. 20.
Calculated on ratio of process intakes and total costs for all industry.
Calculated on ratio of process intakes and total costs in S.I.C. 29.
From "Cost of Clean Water" data.
On basis that profit on sales of 8 largest beverage companies was 1.5 times the profit of 35 largest food and beverage companies (Fortune, May 1972)
Other than petroleum refining taken at 5.1%.
(8) 1970 Outlook
(9) 1972 Outlook
(10) 1970 Statistical Abstracts
(11) Non-Durable before tax = 1.60 x after tax (1970 Abstract)
(12) Durable before tax = 1.85x after tax (1970 Abstract)
(13) All Mfg. before tax = 1.73x after tax (1970 Abstract)
(14) On basis of fuel at 2.68 miles per kwh.

Table 53. Industry Costs and Profit Effects - 1968

S.I.C. No.	Industry Description	Total Annual Abatement Costs - $ Million, 1968			
		1968 Practice	Ex-Legislation	Minimum Discharge	Zero Discharge
-	All Industries	834.5	1,123	1,808	4,368
20	Food and Kindred	146.8	208.4	232.2	433.8
208	Beverages	15.6	22.2	24.7	46.2
22	Textile Mills	55.3	65.8	75.9	101.0
24	Lumber and Wood	6.7	9.7	15.6	37.7
26	Paper and Allied	62.2	81.6	264.3	1,168
28	Chemical and Allied	127.7	248.9	415.8	921.7
29	Petroleum and Coal	96.0	120.5	168.9	393.9
2911	Petroleum Refining	93.0	116.7	163.6	381.5
33	Primary Metals	293.4	326.4	499.1	981.2
331	Blast Furnace and Steel	191.8	213.4	326.3	641.5
-	Electric Power	58.5	449.7	449.7	952.0
-	All Industry Power	8,930	1,573	2,258	5,320

S.I.C. No.	Profits Before Taxes, $Million, 1968				Profits After Taxes, $Million, 1968			
	1968 Practice	Ex-Legislation	Minimum Discharge	Zero Discharge	1968 Practice	Ex-Legislation	Minimum Discharge	Zero Discharge
-	24,467	24,179	23,494	20,934	14,180	14,013	13,616	12,132
20	1,625	1,564	1,540	1,338	1,006	968	953	828
208	329	322	320	298	207	206	201	187
22	462	452	441	416	286	280	273	259
24	117	114	108	86.0	73.0	71.1	67.4	53.7
26	750	731	548	(356)	470	458	343	(356)
28	3,012	2,891	2,724	2,218	1,879	1,804	1,699	1,384
29	3,356	3,331	3,283	3,058	2,093	2,077	2,047	1,907
2911	3,321	3,297	3,250	3,032	2,078	2,063	2,034	1,897
33	3,411	3,378	3,205	2,723	1,845	1,827	1,734	1,473
331	2,040	2,019	1,906	1,590	1,103	1,092	1,031	860
-	4,789	4,398	4,398	3,896	3,002	2,757	2,757	2,442
-	29,256	28,576	27,891	24,829	17,182	16,770	16,373	14,574

The costs of 1968 practice were estimated as follows:

Before-tax profit with control costs =	$29,256
Cost of pollution controls =	893
Before-tax profit with no control costs =	$30,149
After-tax profit (x 17182/29256)=	17,706
Taxes with no control costs	$12,443

After tax profits then on those facilities within each industry which take in more than 20 million gallons annually would be reduced as shown in Table 55, assuming 1968 after-tax profits on sales with no compensating price increases;

Table 55. 1968 After-Tax Profit Effects

		After-tax profits as % of 1968 Experience		
S.I.C. No.	Industry	Existing Legislation	Minimum Discharge	Zero Discharge
-	All Mfg. Industries	98.8	96.0	85.6
20	Food and Kindred	96.2	94.7	82.3
208	Beverages	99.5	97.1	90.3
22	Textile Mills	97.9	95.5	90.2
24	Lumber and Wood	97.4	92.3	73.6
26	Paper and Allied	97.4	73.0	0
28	Chemical and Allied	96.0	90.4	73.7
29	Petroleum and Coal	99.2	97.8	91.1
2911	Petroleum Refining	99.3	97.9	91.3
33	Primary Metals	99.0	94.0	79.8
331	Blast Furnace and Steel	99.0	93.5	78.0
-	Electric Power	91.8	91.8	81.3
-	All Mfg. and Electric Power	97.6	95.3	84.8

If it is assumed that a reduction of after-tax profits of 10 percent defines a significant cost, it might be concluded that implementing existing legislation will not be a significant burden, that implementing minimum discharge would be a substantial burden only in the pulp and paper industry, and that zero discharge would be of greatly variable but significant cost impact in the other industry group.

The economic effects of zero discharge vary widely between industries. The effects on after-tax profits, assuming no compensating price increases, indicate the relative impacts on the various industries in the short run, i.e., in the time period until costs could be recovered via price increases, and in the long run if there is relatively less ability to increase prices. These effects are shown in Table 56 for the large water-using plants in each industry.

Table 56. After-tax Profit Effects - Large Water Using Plants

S.I.C. No.	Industry	1968 After-Tax Profit Reduction (%)
26	Paper and Allied	100.0
24	Lumber and Wood	26.4
28	Chemical and Allied	26.3
331	Blast Furnace and Steel	22.0
33	Primary Metals	20.2
-	Electric Power	18.7
20	Food and Kindred	17.7
22	Textile Mills	9.8
208	Beverages	9.7
29	Petroleum and Coal	8.9
2911	Petroleum Refining	8.7
-	All Mfg. Industries	14.4
-	All Mfg. and Electric Power	15.2

Looking at the effects on the entire industries, including those facilities using relatively little water, as shown in Table 57.

Ordering the data of Table 57 as to relative impact and expressing the results as percent of after-tax profit reduction yields the data of Table 58.

The net value of structures and equipment in the manufacturing industries in 1968 was $92.3 billion in 1958 dollars. This represented about $109.6 billion in 1968 dollars. Capital expenditures in 1968 totaled $20.3 billion; depreciation on current plant in that year totaled $16.1 billion. The value of electric utility plants in 1968 was $64.9 billion, increasing to $71.5 billion in 1969.

The 1968 capital expenditures required, over and above 1968 practice would have been as shown in Table 59.

Table 57. After-tax Profit Effects - Entire Industries

S.I.C. No.	Industry	1968 After-tax Profits (zero discharge) (Millions of 1968 Dollars) Large Water Users	Other Plants	Industry Total	Percent of 1968
20	Food and Kindred	828	1029	1857	91.3
208	Beverages	187	184	371	94.9
22	Textile Mills	258	395	653	95.9
24	Lumber and Wood	53.7	206	260	93.2
26	Paper and Allied	(356)	588	232	21.9
28	Chemical and Allied	1384	1169	2553	83.8
29	Petroleum and Coal	1907	371	2278	92.5
2911	Petroleum Refining	1897	211	2108	92.1
33	Primary Metals	1473	502	1975	84.1
331	Blast Furnace and Steel	860	208	1068	81.5
-	Electric Power	2442	0	2442	81.3

Table 58. Profit Reductions due to Zero Discharge

S.I.C. No.	Industry	1968 After-Tax Profit Reduction (%)
26	Paper and Allied	78.1
-	Electric Power	18.7
331	Blast Furnace and Steel	18.5
28	Chemical and Allied	16.2
33	Primary Metals	15.9
20	Food and Kindred	8.7
2911	Petroleum Refining	7.9
29	Petroleum and Coal	7.5
24	Lumber and Wood	6.8
208	Beverages	5.1
22	Textile Mills	4.1

Table 59. Capital Expenditures for Control in 1968

S.I.C. NO.	Industry	Added Capital Cost, $ Million Minimum Discharge	Zero Discharge	Capital Expenditure 1968,$ million
20	Food and Kindred	311	1039	1740
22	Textile Mills	54	146	691
24	Lumber and Wood	27	101	484
26	Paper and Allied	452	3431	1238
28	Chemicals and Allied	935	2649	2789
29	Petroleum and Coal	241	977	1065
33	Primary Metals	772	2430	3102
-	Electric Power	1057	3716	6561(1)
-	All Mfg. Industries	3090	11721	20613

(1) 1968-69

The above costs as percentages of the total annual capital expenditures for new plant and equipment are shown in Table 60.

Table 60. Pollution Control Costs as Percentages of Capital Expenditures

S.I.C. NO.	Industry	Minimum Discharge	Zero Discharge
20	Food and Kindred	17.9	59.7
22	Textile Mills	7.8	21.1
24	Lumber and Wood	5.6	20.9
26	Paper and Allied	36.5	277.1
28	Chemicals and Allied	33.5	95.0
29	Petroleum and Coal	22.6	91.7
33	Primary Metals	24.9	78.3
-	Electric Power	16.1	56.6
-	All Mfg. Industries	15.0	56.9

By the above measure, there are again great differences in the impact of additional control costs between the various industries, with the greatest effect again on the pulp and paper industries. By 1980, the required additional capital investment for zero discharge would total $22.2 billion over and above the cost of implementing existing legislation. Assuming that these costs would be incurred in a 10-year period, about 8 percent of the annual expenditure for new plant and equipment would be annually devoted to this purpose. The consequences of such expenditures would depend to a large extent on whether or not they would add to total capital expenditures or use money which would otherwise be used to increase productive capacity. The later consequence would be significant. To place this effect in context, the expenditures for new plant and equipment in the manufacturing industries declined about 10.9% in 1949 from 1948, 5.2% in 1954 from 1953, and 5.0% in 1961 from 1960, periods closely related in short rises in unemployment and to slowing economic growth as measured by GNP in constant dollars. This is not to say that there was any direct causative effects, but only to indicate that this magnitude of change in capital expenditures is not insignificant.

Another way of looking at the costs involved is to compare the added costs with a rise in wages. For each industry group, the 1968 cost increase due to wage increases of 1 to 10 percent are compared with pollution abatement costs in Tables 61 and 62.

Table 61. Cost Increases Due to Wage Increases

S.I.C. No.	Industry	1968 Wages Total	Cost Increase-Wage % Rise 1%	5%	10%
20	Food and Kindred	10607	106	530	1061
208	Beverages	1626	16	81	163
22	Textile Mills	4770	48	239	477
24	Lumber and Wood	3016	30	151	302
26	Paper and Allied	4794	48	240	479
28	Chemical and Allied	7014	70	351	701
29	Petroleum and Coal	1292	13	65	129
2911	Petroleum Refining	1027	10	51	103
33	Primary Metals	10620	106	531	1062
331	Blast Furnace and Steel	5411	54	271	541
-	Electric Power (1)	12935	129	647	1294
-	All Mfg. Industries	132902	1329	6645	13290

(1) 229,000 production workers @ $3.72 per hour, 41.6 hours per week.

Table 62. Added Control Costs vs. Wage Increase Costs

S.I.C. No.	Industry	Annual Costs Over 1968 Practice: Minimum Discharge	Zero Discharge	5% Wage Rise
20	Food and Kindred	85	287	530
208	Beverages	9.1	30.6	81
22	Textile Mills	20.6	45.7	239
24	Lumber and Wood	8.9	31.0	151
26	Paper and Allied	202	1106	240
28	Chemical and Allied	288	794	351
29	Petroleum and Coal	72.9	298	65
2911	Petroleum Refining	70.6	286	51
33	Primary Metals	206	688	531
331	Blast Furnace and Steel	135	450	271
-	Electric Power	391	893	647
-	All Mfg. Industries	973	3533	6645
-	All Mfg. Industries and Power	1364	4426	7292

Minimum and zero discharge total annual costs over 1968 practice, from the above, correspond to the indicated rises in wages in Table 63.

Table 63. Added Control Costs as Percentage Wage Increases

S.I.C. No.	Industry	Equivalent % Rise in Wages: Minimum Discharge	Zero Discharge
20	Food and Kindred	0.80	2.71
208	Beverages	0.56	1.89
22	Textile Mills	0.43	0.96
24	Lumber and Wood	0.29	1.03
26	Paper and Allied	4.21	23.0
28	Chemical and Allied	4.10	11.3
29	Petroleum and Coal	5.61	22.9
2911	Petroleum Refining	6.92	28.0
33	Primary Metals	1.94	6.48
331	Blast Furnace and Steel	2.49	8.30
-	Electric Power	3.02	6.90
-	All Mfg. Industries	0.73	2.66
-	All Mfg. Industries and Power	0.94	3.03

The preceeding seem to fall into three distinct groups with the major effects evident in the paper and petroleum industries and intermediate effects in the chemical, metals, and electric power industries.

Short run burdens on industry may be in part reduced from relative profit positions as shown in the data on Table 64.

Table 64. Profit Positions of Various Industries

S.I.C. No.	Industry	Profit on Sales 1970-% of 1968	Profit on Equity 1970 % of 1968	Profit on Equity 1970
-	All Mfg. Industries	78.4	76.9	9.3
20	Food and Kindred	96.2	100.0	10.8
22	Textile Mills	61.3	58.0	5.1
24	Lumber and Wood	47.2	40.4	5.9
26	Paper and Allied	72.3	72.2	7.0
28	Chemical and Allied	86.8	86.5	11.5
2911	Petroleum Refining	86.9	89.4	11.0
33	Primary Metals	72.4(1)	77.4(2)	6.9(2)
331	Blast Furnace and Steel	50.9	50.6	4.0

(1) Weighted by volume of sales in steel, copper, aluminum based on large nonferrous companies.

(2) Weighted by volume of sales in steel and nonferrous metals.

There are clearly current differences in profit positions with the food, chemical, and petroleum industries in the best relative positions.

The data of Table 65 indicate to what extent prices would have to be raised in order that the added costs of zero discharge be recovered via price increases, i.e., passing the costs to the customers. All except the last item refer to the entire industry assuming the cost burden; the last item shows the cost burden if assumed by the large water-using plants only.

The consequences of the implementation of zero discharge requirements may readily be determined from the foregoing, assuming that implementation would utilize the technology outlined and that costs would be passed on to the ultimate

Table 65. Price Increases due to Zero Discharge

S.I.C. No.	Industry	1968 Value Added In Water-Using Plants	1963 Value of Shipments In Industry	Ratio	Added Cost for Zero Discharge	Value Added With Zero Discharge	Value of Shipments With Zero Discharge	% Price Increase Zero Discharge
20	Food and Kindred	12067	78259	6.485	287	12354	80120	1.02
208	Beverages	2835	10031	3.538	30.6	2866	10141	1.01
22	Textile Mills	3732	21969	5.887	45.7	3778	22240	1.01
24	Lumber and Wood	643	5257	8.176	31.0	674	5510	1.05
26	Paper and Allied	4968	22512	4.531	1106	6074	27524	1.22
28	Chemical and Allied	16131	44826	2.779	794	16925	47032	1.05
29	Petroleum and Coal	4612	23240	5.039	298	4910	24742	1.06
2911	Petroleum Refining	4495	21395	4.760	286	4781	22756	1.06
33	Primary Metals	14798	44274	2.992	688	15486	46332	1.05
331	Blast Furnace and Steel	9206	24733	2.687	450	9656	25942	1.05
-	Electric Power	15859	19421	1.225	893	16752	20515	1.06
-	All Mfg. Industries	125417	631911	5.038	3533	128950	649712	1.03
-	All Mfg. Ind. and Power	141276	651332	4.610	4426	145702	671737	1.03
-	Water-Using Mfg. and Power	141276	297458	2.106	4426	145702	306848	3.16

consumer. In the short run, varying degrees of economic hardship would be imposed on different industries. Marginal production facilities would probably be closed in these industries bearing the highest costs relative to other production costs and in which profit margins have been low. Increased costs must, of course, be recovered in the long run where such costs have a significant effect on profits.

The ability to pass on increased costs via price increases without loss in revenue depends upon the aggregate demand function for a particular good, institutional factors such as price controls and import restrictions, and the availability of substitutes and/or imports. Whether or not the assumed technology would be primarily determined by the ability to reduce total water use and whether or not effluents under minimum discharge could be reduced to less than assumed here.

Whether or not zero discharge should be implemented at all depends upon whether or not the improvement in the surface waters are judged to be worth the cost as well as upon whether or not the physical resources are available; the effects on other parts of the environment are tolerable, and the financial resources can be marshalled in such a way that significant economic dislocations do not result in the long run.

To some extent the effects of an increase in price due to increased costs can be deduced from the supply and demand characteristics of the market for a good. In the classical case, the analysis would be straightforward and can be illustrated by the instance of a tax added per unit of product. In Figure 16, a relatively elastic demand curve (d-d) and a supply curve of unitary elasticity ($s_1 - s_1$) illustrate the effect of a price increase, defining a new supply curve ($s_2 - s_2$). In Figure 17, a similar effect is illustrated with a relatively inelastic demand curve. The more elastic demand results in a shift of most of the tax backward to the producer. A more inelastic demand shifts most of the tax forward to the consumer.

The effect of a nonproductive cost increase such as for pollution control can theoretically be analyzed in the same way as the tax increase. The principal difficulties lie in that the theoretical supply curve can hardly ever be constructed, and that a demand curve constructed upon data over time is only an approximation to the actual curve at one particular time.

Demand elasticity is defined as the percent increase in the quantity (Q) divided by the percent decrease in the price (P). A usual convention is to use the average of the two quantities which define each change:

$$E = - \frac{\Delta Q}{\Delta P} \times \frac{(P_1 + P_2)/2}{(Q_1 + Q_2)/2}$$

The demands for most products of the manufacturing industries are inelastic, i.e., the quantities of goods taken are not relatively responsive to price changes insofar as aggregate demand is concerned. This is to say that a cut in price will generally increase the quantity taken so little that total revenue will fall. By the same token, an increase in price will generally reduce the quantity taken so little that total revenue will increase. The quantities taken of most products of the water-using manufacturing industries depend primarily on the general level of economic activity rather than upon the prices at which they are offered. At the 2-digit S.I.C. level there is little substitution, thus little opportunity for the consumer to switch to other products.

The supply of most products of these industries probably depends more upon the percentage of productive capacity being utilized and upon the availability of imports than on any other factors. Supply tends to be relatively elastic as compared to demand. So long as there is highly efficient, unused productive capacity, supply is relatively elastic; marginal capacity used to produce additional quantities wanted will tend to make supply more inelastic. The availability of imports will tend to increase supply in total, i.e., shift the entire supply curve to the right, as these industries attempt to meet foreign competition.

Statistical studies of demand for food products indicates an elasticity of about 0.3 and for steel industry products as "inelastic" demand (8,9), tending to substitute the above qualitative conclusions on demand elasticity. If it is assumed that production is in the most efficient plants, most of the added burden is passed on to the consumer. As increased quantities are taken and supply becomes more inelastic, the costs are shifted more to the producer.

As the domestic supplier offers larger quantities at higher prices, the availability of lower price substitutes or imports increasingly limits his share of the market. Figure 18 illustrates the recent market situation for steel in a semi-quantitative manner, i.e., the data are for a period of 5 years and only approximate true supply and demand curves. Domestic steel was only taken to the extent of 96 million tons

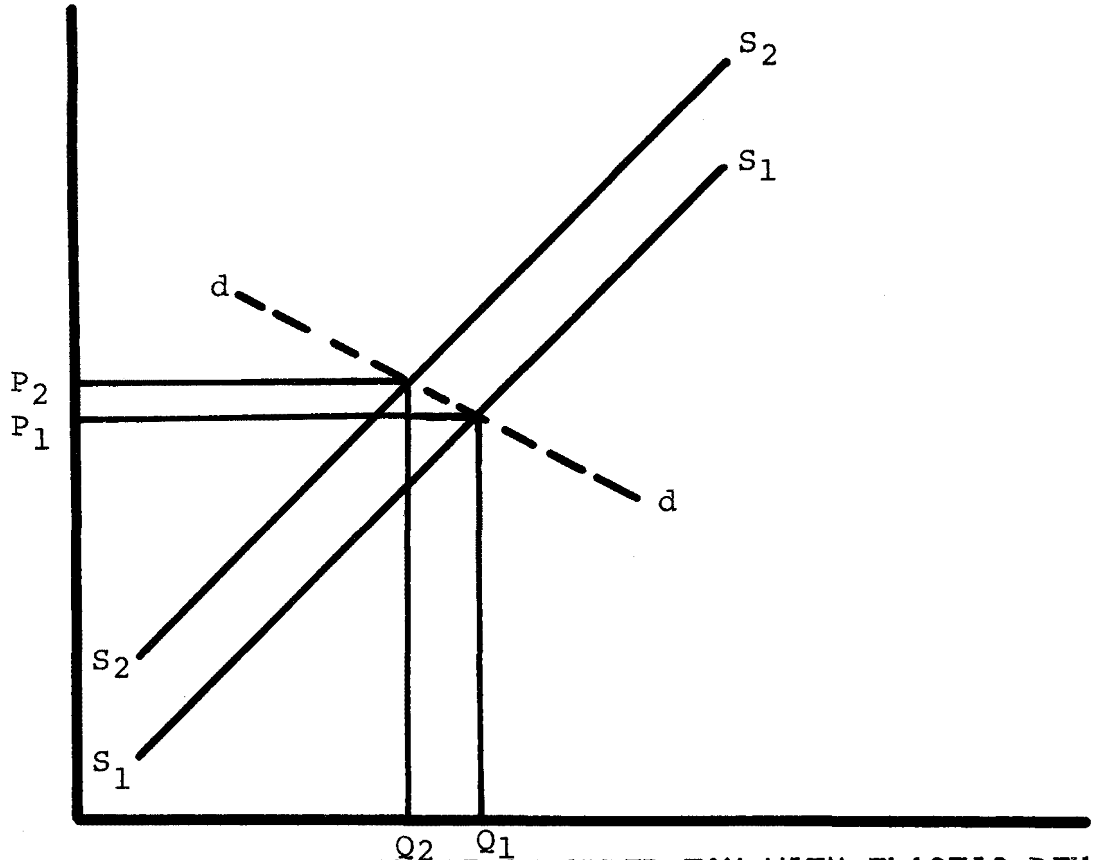

FIGURE 16. MARKET EFFECTS OF AN ADDED TAX WITH ELASTIC DEMAND

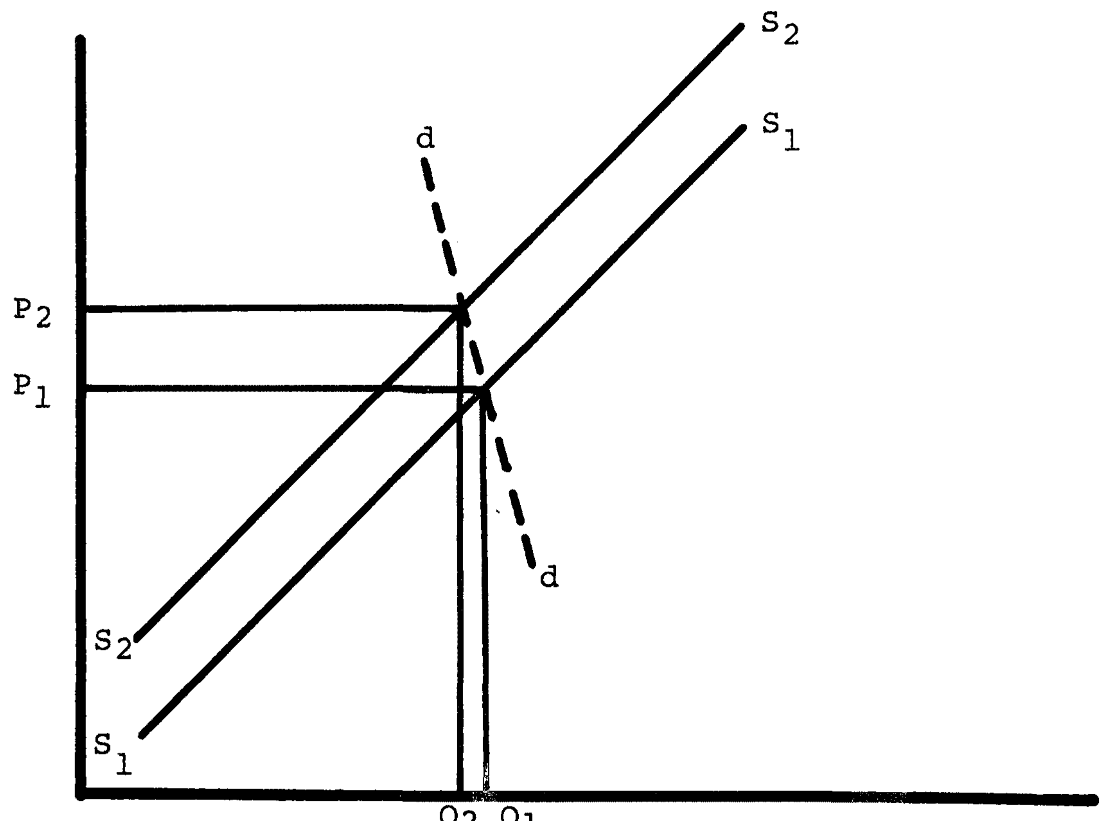

FIGURE 17. MARKET EFFECTS OF AN ADDED TAX WITH INELASTIC DEMAND

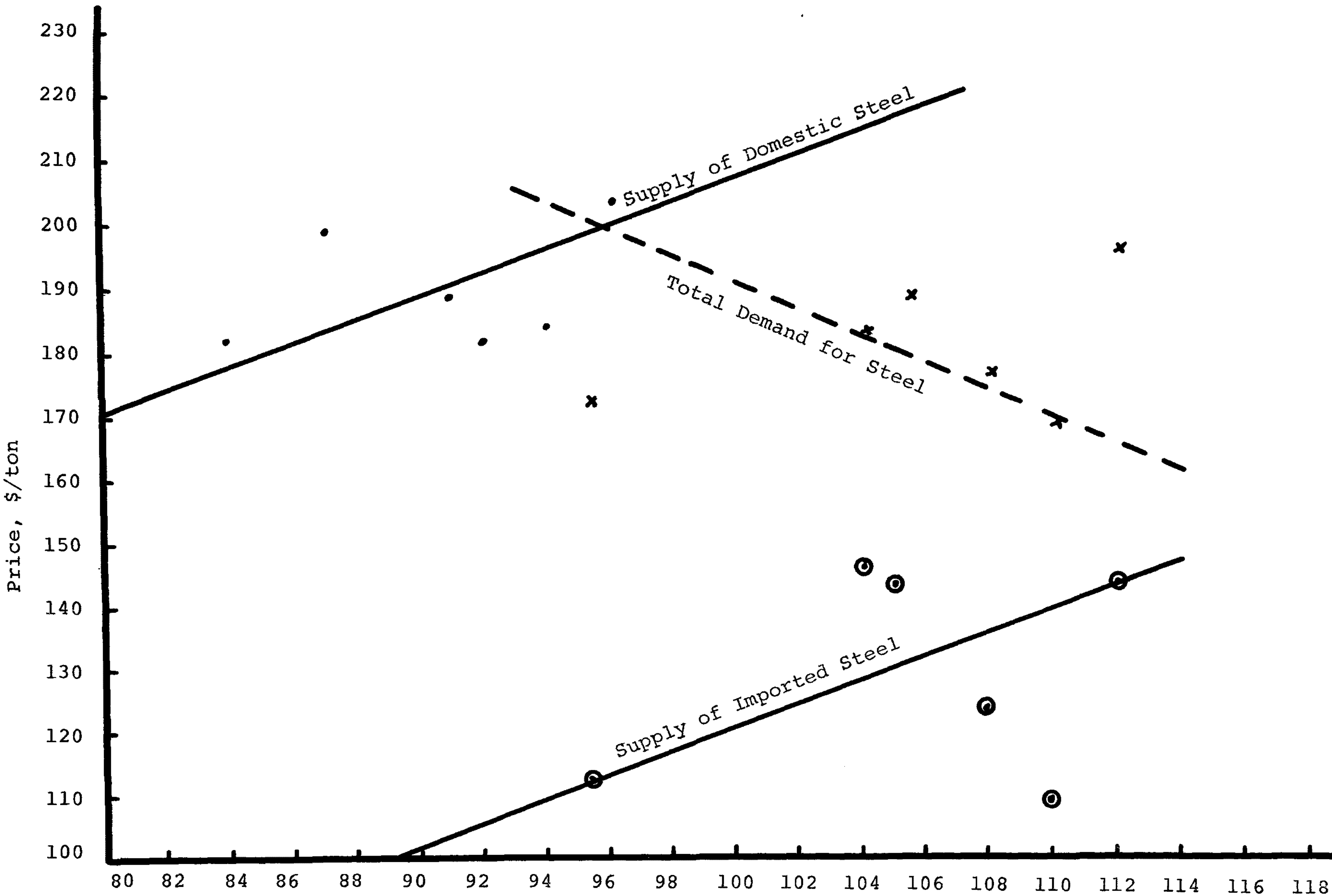

FIGURE 18. DEMAND AND SUPPLY - STEEL INDUSTRY (1967-72)

at a price of $204 per ton; the remaining steel consumed was taken from lower priced imports. The general case of such a market situation is illustrated in Figure 19.

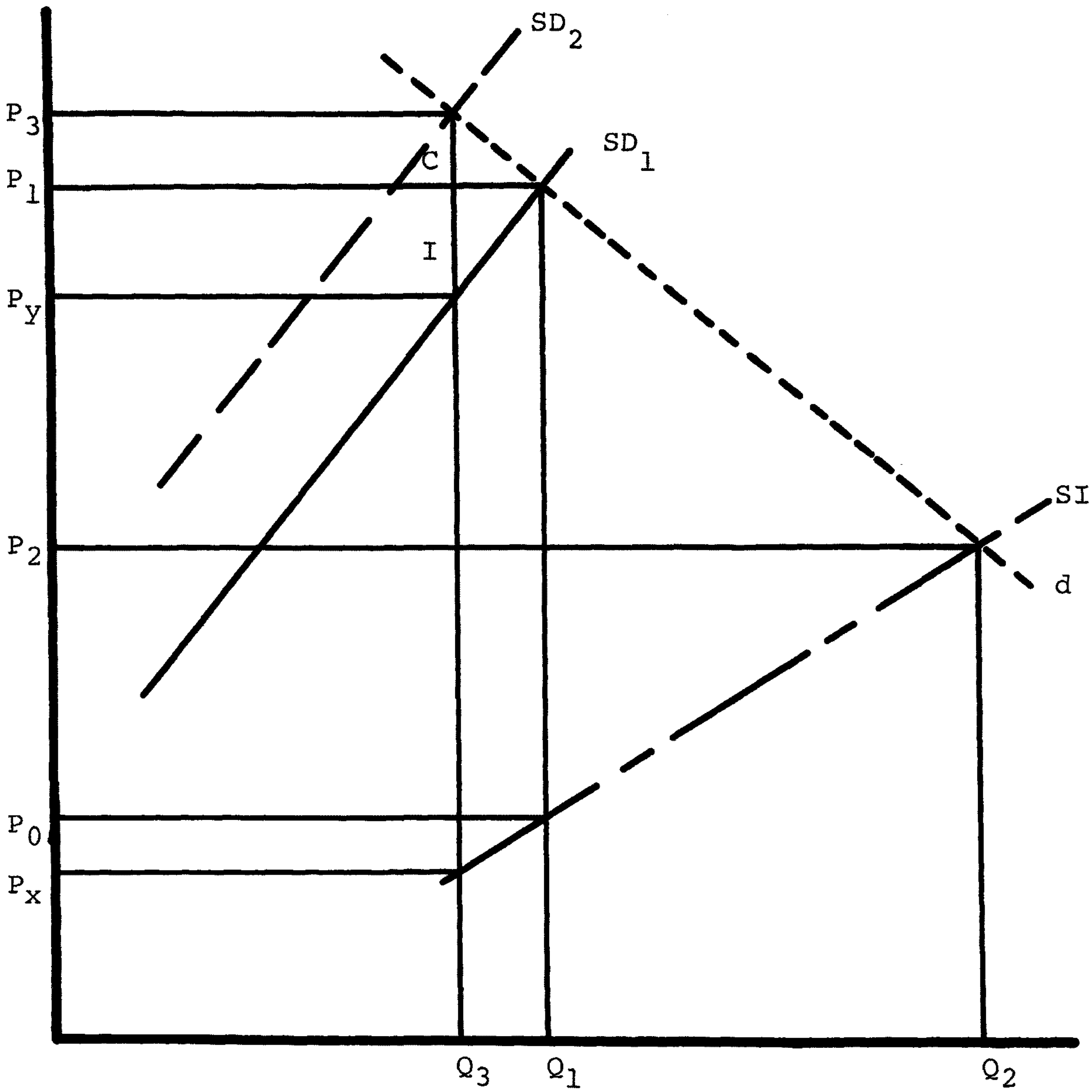

FIGURE 19. INCREASED DOMESTIC COST AND IMPORTS

Before the increase in the cost of domestic steel, the quantity Q_1 of domestic steel is taken at price P_1. The quantity (Q_z - Q_1) of imported steel is taken at price P_2. The revenue to domestic producers is (P_1 Q_1) and to importers is P_2 (Q_2 - Q_1). After the increase in the cost of domestic steel (a non-productive cost) the quantity Q_3 of domestic steel is taken at price P_3. The smaller quantity costs the consumer about the same total amount as the former larger quantity and represents the consumer's burden. The domestic producer's revenue falls to P_y Q_3 and represents the producer's burden. The importer's revenue rises to P_2 (Q_2 - Q_3) and the importer, of course, thus benefits from the domestic cost increase.

The electric power industry, as a regulated public utility, can, in the long run, shift such a cost increase completely to the consumer. The available quantity of electric power will be taken at the regulated price (generating capacity being limited as compared to the amount wanted); the consumer will pay more for less total power, because the requirement of cooling towers would reduce generating capacity due to the higher condenser temperature.

Resource Requirements

Under the assumed zero discharge technology, about 1,672 billion gallons of water annually would be evaporated, i.e., the effluent volume under minimum discharge less the residual brine. At 1,000 BTU per lb, the energy required would be 13.9×10^{15} BTU annually as of 1968, increasing to about 22.9×10^{15} BTU annually in 1980. The heat energy required in 1980 would be about twice that rejected in electric power plant condensers in 1980, equal to about 33 percent of the total U. S. energy consumption in 1970, and equal to the total natural gas use in the U. S. in 1969.

The 40 billion pounds per year of solids disposed of on the land in 1980 would be about 65 percent of the total salt produced as a product in the U. S. in 1969. At a density of 48 lbs per cu ft, the 40 billion pounds of solids would occupy 838 million cu ft, i.e., about 19,000 acre feet, or about 30 square miles.

The combustible material to be incinerated and thus discharged to the air amounts to 220 million pounds per year, mostly expressed as B.O.D., thus equivalent to 290 million pounds of CO_2 and 20 million pounds of CO at 90 percent combustion efficiency. The carbon monoxide emissions would be about 0.5 percent of that resulting from stationary fuel combustion in the U. S. in 1969.

The 1,672 billion gallons of water to be evaporated annually in 9,402 establishments would require that number of distillation units averaging 500,000 gpd, and would require some 5,000 deep wells for disposals of brine where this method is feasible. There are presently about 30,000 oil wells annually drilled; therefore, 5,000 wells would not represent a major problem. The peak production of power boilers in 1969 was valued at $645 million and represented steam productions 300 million pounds per hour. The total value of fabricated products in S.I.C. 344 in 1969 was $11.26 billion. The evaporator capacity required in 1968 was thus equivalent to above 5 times the power boiler production capacity, since boiler manufacturers have been at production capacity for several years. A waste treatment market estimated at only about $150 million has been a major marketing target of a large company producing evaporators. If reverse osmosis were a feasible alternative to evaporation, power requirements at 35 KW-hr per 1,000 gallons would total 58.5 million KW-hr per year.. This is about 50 percent of the electric energy generated by industrial plants and about 5 percent of that generated by electric utilities in 1968.

SECTION XI

ACKNOWLEDGEMENTS

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The credit information regarding financing of pollution control equipment, provided by Mellon Bank, N.A., Western Pennsylvania National Bank and the Union National Bank of Pittsburgh is appreciated.

SECTION XII

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SECTION XIII

APPENDICES

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APPENDIX A

FACTORS DETERMINING TECHNOLOGY UTILIZATION

This phase of the project to evaluate the Economic Feasibility of Universal Requirements of Minimum Practicable Industrial Waste Load Discharges was devoted to research and study of the determinants of the adoption and utilization of available technology, as distinct from the degree to which it has in fact been adopted and utilized. Whereas the latter approach would constitute an instant picture of the present state of affairs, it sheds no light on the factors which brought it about or the pressures operating to accelerate or retard the rate of adoption of available technology in the future. The former approach, on the other hand, provides an understanding of the motivating factors which have led to the present state and which can be relied upon to influence the rate of adoption in the future.

These determinants or factors, both positive and negative, have been identified, and an attempt has been made to evaluate the importance of each in isolation, in its affect on management decisions concerning the adoption of available technology.

The conclusions and results of this phase of the Project are based, for the most part, on data collected in an earlier study conducted by Frederick D. Buggie, a Datagraphics associated consultant. Secondary data supplementing this material included "Industry Cleanup Actions in Progress", by the National Industrial Pollution Control Council; "A Nationwide Survey of Environmental Protection", by the Wall Street Journal; recent polls conducted by Louis Harris & Associates; and selected articles and reports from business, technical and professional journals.

American industry has not done their part in controlling pollution, according to 57% of the respondents to a 1971 poll by Louis Harris & Associates. However, 60% of the general public who responded to the poll indicated that they felt industry had installed the latest improvements in equipment, generally. The results indicate a deterioration in industry's reputation for adopting the latest technology for pollution control, since five years earlier when a similar poll yielded figures of 42% and 89%, respectively.

This "image" problem has become increasingly recognized by business executives and in fact appears to constitute one of the three fundamental positive factors motivating industry to adopt and utilize available technology for pollution control. In an independent survey of executives conducted this year, almost two-thirds of the respondents said they believe that their corporate image has suggered from adverse publicity and slanted news reporting. There are indications of a certain amount of resentment and despondency in the attitudes of businessmen regarding their pollution-control reputation. A 1971 survey by The Wall Street Journal showed that only 35% of the respondents felt that even their most impressive environmental achievements would improve their image among consumers, and a substantially-lower proportion thought it would favorably influence stockholders and the financial community.

But there is not much question that the "image" problem does serve as a spur to businessmen to adopt available pollution-control technology so that they can then promote and publicize what they are doing to improve the environment (or at least minimize its degradation), among the various publics on which they rely for long-run success.

The second major factor influencing industry to utilize available pollution-control technology is seen as "regulatory pressure". Those charged with the responsibility of enforcing water-pollution control have by and large succeeded in calling industry's attention to the problem of water pollution, and convincing management that something must be done to control it. The Federal efforts (including permit application, voluntary questionnaires, publicity concerning enforcement actions and administrative decisions by E.P.A., and the activities of the E.P.A. Regional Officials) in combination with, in some cases, an extremely active effort by state and local regulatory authorities, have led to a situation wherein practically no manufacturer is now unaware of pressures to control industrial waste discharges, and not persuaded that some kind of management response is necessary. As a matter of fact, over half the respondents to a recent survey indicated that they had been subject to overlapping and duplicative regulatory requirements by various levels of authority. But the point is, "regulatory pressure" has had fundamental influence on management to seek out the available technology for controlling pollution.

The third positive factor -- the only other observed major influence on industry to adopt and utilize available technology for pollution control -- could be called "corporate conscience", or management's desire to do what is right. Whether such a corporate policy derives from a concern for corporate image, or from fear of prosecution by the regulators, or pragmatic long-run self-interest, or simply the American ethic, is a matter for speculation. Regardless, it is a discernible force motivating industry to adopt available technology for controlling pollution. Industry attitudes, from the perspective of a recent survey, clearly seem to be cooperative. Excerpts from comments volunteered:

> "...I believe that both government and industry have a responsibility to clean it up together..."
>
> "We believe we have a responsibility to control these (dangerous components in our effluent)..."
>
> "The present crunch should not surprise anyone who has had his eyes open for the last 15 years."
>
> "Too long have we lived like slobs---..."

These comments typified the underlying current of the general attitude of polluters toward the task of improving the environment. The results of the survey turned up widespread acceptance of the desirability of adopting available pollution-control technology. The overall impression created by comments of respondents was one of a willingness to do their best ultimately to solve the problem.

On the other side, there are several negative factors influencing management decisions at this point on the adoption and utilization of available technology for pollution control. These negative determinants, mostly uncovered in the survey conducted earlier this year, lead one to two fundamental conclusions: 1) They are transitory. The individual manufacturers will eventually discontinue postponement actions (i.e. stop foot-dragging) and take positive measures to adopt current pollution-abatement technology. 2) In most instances, it is apparent that something can be done, in time, to eliminate or ameliorate these negative factors. This may constitute the most useful practical purpose served by the present study: To serve as a guide to the areas in which effort can be devoted effectively to spur the earlier adoption of current technology for pollution control.

One qualification to these two conclusions --- in cases where nothing can be done and an individual plant must be closed (or operations cannot be expanded) in the judgment of management responsible for those operations, on the macroeconomic scale over time, it will be found that those manufacturers which have survived will have adopted current pollution-control technology.

Eleven of the companies surveyed had already closed 43 plants affecting 1,434 employees; eight companies were considering closing nine marginal plants affecting a total of 3,200 employees; and three companies had decided not to expand, canceling plans for new plants with probably between 800 and 1,600 new jobs.

A consultant to the mining industry foresees that "up to 20" marginal facilities in that industry may be shut down. The American Paper Institute recently claimed that 40 paper mills were closed during 1971 because of environmental problems; reportedly some 160 iron foundries have ceased operations over the past three years; and the Department of Commerce reports 60 plant closings in other industries, as a result of environmental pollution-control pressures.

It should come as no surprise to anyone that marginal firms will be unable to survive in the face of sudden, forced outlays of cash for nonproductive assets. The social cost and inequities of frictional dislocations caused by mandatory environmental pollution-control requirements are inherent in restructuring the priorities of our society.

In this setting then, the negative determinants, or the factors discouraging the immediate adoption of available pollution-control technology by industry, many of which are inter-related, will be enumerated:

(1) The cost of pollution-abatement equipment.

Aggregate costs to certain industries for controlling their pollution to current required levels has been recently dealt with by contractors to the President's Council on Environmental Quality. Comparative costs of alternative methods for controlling pollution will be dealt with elsewhere in this study. The main point we wish to make here is that the high cost of pollution control, as perceived by management, is a factor discouraging the immediate adoption by industry of the available technology. Two-thirds of the surveyed companies indicated that they are experiencing "serious cost problems" stemming from current pollution-control regulations. One-third felt that it is necessary for pollution-control equipment manufacturers to reduce their prices. This gives rise to the thought that when pollution control systems are purchased in greater quantity, prices will surely come down due to economics of scale made possible thereby. But, on the other hand, there has been recent speculation in the press (viz. Business Week, March 18, 1972, p. 20) that the result will be just the opposite -

that increased demand in the face of fixed supply will tend to increase prices. The answer will lie in a study of the specific cost structures of firms in the pollution-control equipment industry, barriers to entry into the industry, the competitive climate, and cross-elasticities of demand as among alternative pollution-control devices.

(2) Competitive pressures

Manufacturers are (rightly) sensitive to cost advantages which their competitors may be able to gain. In the survey, 39% of the respondents indicated they are having competition problems, and 26% felt that some of their competitors are located in geographical areas where they are subject to less stringent pollution-control regulations. Foreign competition is of particular concern, for some industries, including the mining industry. In addition to spatial competitive disadvantage, temporal competitive disadvantage was of major concern. For example, "Competitors with more modern mills can achieve new pollution goals at less cost." The president of one prominent consulting engineering firm was especially concerned about competitive parity in the steel industry between new mills which could design in available pollution-control technology, and old mills which faced the "extensive retrofit problem" in meeting the necessary standards for the industry. He suggested more R & D by the Federal Government and construction grants to industry for retrofit of old plants.

(3) Economic conditions

This factor is intrinsically neither positive nor negative. It may explain in part why available technology for pollution control has not been adopted in the past couple of years; but it may also contribute toward greater utilization of available technology in the next couple of years ('72-'74). The point must simply be made that it is a factor which is to be taken into account.

(4) Moving target (no. 1)

An attitude of incredulousness has been exhibited in some quarters concerning existing and proposed pollution-control regulations. There is the feeling that they are not realistic and that reasonable compromise will eventually prevail. In the words of a management representative of one industry, there is a need "to determine standards divorced from environmental hysteria and political gamesmanship, that would represent not the maximum achievable reduction in pollution, but a degree of pollution abatement commensurate with the maximum social good." This feeling of impending change in the ground rules is fostered and reinforced by perceived confusion, complexity, duplication, conflicts, and inconsistency in the present regulations and enforcement activities of the various pollution-control regulatory authorities. In the survey, 45% of the respondents saw inconsistency on the part of E.P.A., and slightly more than one-third complained of changing policies by State regulatory authorities. In the case of 13% of the companies, there has been what could be called "counterproductive impact" of such regulatory efforts. These firms have assumed the posture that they will just sit tight until the situation is clarified and they are told exactly what to do.

(5) Overkill

In some instances, there has been rigid all-or-none approach by the regulatory authorities, a lack of pragmatism, a failure to understand that degree of perfection and time delay represent trade-offs. One manufacturer reported that he offered to adopt measures that would result in a 50% reduction in pollution immediately, but that this was rejected as unacceptable because it fell short of the requirements, and therefore considerable delay ensued before any pollution abatement at all was achieved. This is regarded as an atypical case. The implementation plans and compliance schedules are designed for just the purpose of bringing pollutors gradually up to required standards over a reasonable period of time. But the point remains: Excessive rigidity can retard the adoption of available technology. And the corollary, insistence on the adoption of latest available technology can forestall the utilization of immediate temporary expedients, perhaps to the detriment of the environment.

(6) Absolute unavailability of products embodying available technology.

The need for pollution-control equipment manufacturers to improve their products was expressed by 47% of the survey respondents. As one manufacturer put it, "most abatement equipment manufacturers are municipally-oriented; better equipment for industrial waste treatment needs to be developed." The need for improved maintenance service and response to complaints regarding operation of equipment, by manufacturers was also expressed.

(7) Moving target (no. 2)

In some cases, pollution-control systems are being developed to incorporate the latest technology, and in other areas, the technology itself is advancing. There is some irreducible minimum reasonable time period required for planning, budgeting, engineering specifying, purchasing, installation, and start-up of new pollution control systems embodying the latest available technology. Time must be allowed to study and install process changes and/or new pollution control systems, between the time the available technology is discovered and the time it can be utilized by the manufacturer. And after it is installed, it is reasonable to permit a utilization period (5 years ?) during which the newly-installed equipment can be depreciated/worn out/used up, notwithstanding continuing advances in technology which may take place during that period. In the words of one industrial executive, "We must remove the threat of having to replace the best of today's equipment with the new equipment of a few years hence. Some longer planning period, say 11 years, must be allowed." It is clear that the anticipation of a significant advance in pollution-abatement technology can, of itself, immobilize prospective users of currently-available technology.

(8) Lack of Information

Although the technology may be adequate and the products and systems incorporating it may be available, ignorance of their applicability may deter adoption by those most requiring them. Some 45% of the survey respondents indicated the need for more information concerning pollution control technology. About one-third desired an advisory service on call, and a like number of those surveyed felt that seminars held on a regional level would be helpful in disseminating the needed information. Some 30% thought that more dialogue among firms in their own industry, including case histories on typical problem solutions, would be salutory, provided that such cooperation would not run afoul of the anti-trust laws. We believe that the Technology Transfer program of E.P.A. has an important role to play in this area and can, through its efforts, encourage the adoption of available technology for pollution control.

(9) Truth in Advertising

Closely related to the preceding factor, is the difficulty of evaluating among alternative pollution-abatement systems which are promoted by their manufacturers. It has been found that in some cases, the advertisers' puffery and misleading claims only add to the confusion, fallacious assumptions, and invalid conclusions, rather than elucidating the proper course of action.

(10) Safety in Numbers

Some resentment has continually cropped up, in arguments by polluters, that there are inequities in the treatment of municipalities and industrial manufacturers by the enforcement officials. This is simply a red herring, albeit oft used as a tactic to support delay in adopting available technology for the control of pollution.

(11) Sidestep

A very small proportion of manufacturers are begging the question altogether, by either tying in to a public treatment facility, or by hiring a private contractor to handle their waste. This may be practicable from the polluter's standpoint and desirable from society's standpoint, but nonetheless must be recognized as an avenue available to avoid the adoption of current available pollution-control technology.

APPENDIX B

INDUSTRY ATTITUDES TOWARD MINIMUM DISCHARGE

Some general observations concerning industry's attitude toward minimum discharge can be made on the basis of interviews and discussions with representatives of industry, consultants, and equipment vendors.

It has been tacitly assumed by many people that if and when the effluent quality required for discharge from an industrial operation is equal to or better than the previously used water supply or the quality of water required for that industry operation, reuse of the effluent would follow almost automatically. The interviews that have been held and the progress of current litigation in Illinois indicate that this is far from the case.

The first principal reason for resistance to the concept of minimum discharge, as opposed to terminal treatment, is the claim that no demonstrable benefit can be shown insofar as water quality affecting uses is concerned. This is apparently a sincerely held belief on the part of industry representatives. It is inherent in the water quality standard concept which implicitly says that the assimilative capacity of the surface waters, up to the tolerable limits of any contaminant for specific uses, should be available to the discharger of waste water effluents.

Litigation in Illinois has been based on the State's contention that nothing less than minimum discharge, i.e., recirculation and blowdown treatment, is acceptable. In most of these cases, the average quality of the process waste water effluent would be as good or better than that of the intake water or equal to or better than the water quality required for use when agreed-upon treatment is installed. Pumping and distribution facilities would have to be added and cooling would generally be required for reuse. The Plaintiffs here are not seeking any restrictions on the once-through use of indirect cooling water. The Defendents have taken the position that only a court order will force them to recycle the treated process waste water and this attitude is apparently based upon the additional costs involved. There has been no argument that reuse is not technologically feasible. A very likely additional motive, however, is the fear that a precedent set here will be noted in other plants where present treatment is not nearly as good. That other comparable industrial plants in the Lower Lake Michigan region have instituted measures similar to those demanded by the Plaintiffs apparently has no significance insofar as these Defendents are concerned.

In nearly all cases, the age of the plant seems to be the second most important point. It is maintained that the cost of instituting reuse systems in old plants is prohibitive due to lack of space and the complexities of pumping and piping changes; and that had reuse systems been mandated prior to the construction of terminal treatment facilities, construction layouts would have been different and presumably less extensive treatment systems installed. An additional factor of importance is undoubtedly the reluctance of those responsible for the design and installation of present facilities to go again to management and say that more money must be spent; this seems to be akin to saying that there was no foresight of increasingly stringent regulations. There is little indication of militant resistance to minimum discharge facilities in plants under construction.

The consent decree in the case of Illinois vs. U. S. Steel, South Chicago Works indicates that the change to minimum discharge in old plants with terminal treatment is neither impossible nor impractical. Not only is this particular plant old and large, but the required construction was in a sandy soil on the lakeshore and involved extensive tunneling.

In the opinions of some consultants, resistance to any change, the unwillingness to assume any additional real or imagined problems or to do anything that might conceivably interfere with production, the lack of knowledge of alternative technology, and the costs involved are the reasons why once-through use with terminal treatment is so stubbornly advocated by industry. The engineering profession seems to be at least partially guilty of perpetuating terminal treatment systems, i.e., recommending and designing systems on the basis of past, tried-and-true, similar systems. This may be as much due to the lack of knowledge of the alternative technology as to the specification of terminal treatment by the client in the opinion of many.

The installation of reuse systems is frequently blamed for production problems. A "new" factor such as this undoubtedly provides a convenient scapegoat for plant operators who must always explain any production problems to their superiors. Many reported "failures" of reuse systems can be traced to this sort of situation. There is also the at least implied resentment of "changing the rules in the middle of the game." It is perhaps a moot question as to whom is most guilty of the lack of foresight: Industry or those responsible for regulations. Industry, at its own insistence, has been part of the business of formulating regulations; it is hardly credible to now maintain that it had no foreknowledge of things to come.

Several consultants and equipment vendors felt that pollution control measures costing more than 20% of profits would be regarded as prohibitive; investment of 10% of profits would be considered normal. The concept of minimum discharge would find greater acceptance if blowdown of 5-20% of the recirculation rate could go to municipal sewers. Capital costs and the reluctance to change are the primary objections to reuse systems. The availability of loans that would not reduce borrowing power for production facilities would greatly accelerate reuse systems acceptability.

Interviews with loan officers at three major Pittsburgh banks indicate that loans for pollution control facilities are generally available to good credit risks and such loans are based upon general financial position as are any other loans. Such equipment is useless as collateral, except for some package-type plants which can be easily removed and sold. The largest commercial bank regards pre-treatment facilities and post-treatment facilities in much the same way, i.e., as overhead costs which reduce profitability. This bank, however, frequently will loan money for such purposes as a community service gesture when the project, considered on its own, is not regarded as a good risk. The other two banks regard pre-treatment facilities as production equipment and will lend money as for any production facility. Generally, good credit risks can borrow money for any purpose; marginal risks generally have to justify loans on the basis of expected return and can only borrow a portion of the cost.

Personnel interviewed at the American Petroleum Institute were able to offer certain generalizations regarding the practical application of various water pollution control techniques by the refining industry that seemed to offer insight into the factors influencing management attitudes toward minimum waste water discharge.

The first, and most basic, of these is consideration of the difference in economic aspects of pollution control in the petroleum industry as between the integrated and non-integrated producing and refining companies.

In the petroleum industry an integrated company is one that owns its own production, transportation, refining and, usually, marketing facilities. In the case of refineries, the non-integrated unit is usually the independent refiner who owns only the refinery and purchases his feedstock from the producing companies at competitive prices. He may, or may not, have marketing facilities at the consumer level.

These two categories of companies are in very different positions regarding large capital and/or operating expenditures. Thus, while a given pollution control process may be technically feasible for all refineries, it may also be economically difficult for a great many presently operating, non-integrated refineries.

The differences in these two categories of petroleum operations also shows up in the organization of responsibility for originating and implementing pollution control measures. In general, the integrated companies make all major final decisions at the corporate management level. Each integrated company, of which there are approximately 30 in the United States, now has a management environmental control group operating at corporate headquarters and reviewing and supervising the installation and operation of pollution control facilities at the corporation's individual refineries. The non-integrated (approximately 1,500) refineries generally have key decisions regarding such facilities made by the plant owner or manager. In both cases, however, the practice of using consultants for final design and installation of any pollution control system is nearly universal. The reason for this practice is primarily political, i.e., it puts a neutral and presumably, objective, third party between the refinery and the various regulatory bodies.

There are significant differences in management's willingness to install pollution control in new plants as opposed to older, existing plants. When designing new refineries, the pollution control facilities, in general, are designed to the maximum limits of current technology, irrespective of existing treatment standards or limitations prescribed by law. In older refineries the installation of such facilities is usually geared to minimum, short-range compliance. The complexities of piping systems in refinery processes usually makes any modification in existing fluid-flow systems expensive. The technology for high-level treatment, or closed-systems design, may also be expensive. Since the rate of obsolescence is usually high in refining installation, the management of older refineries often finds that high-level or reuse treatment systems require capital expenditures involved that will require, say twenty years to recover when the refinery itself may only have a projected remaining life of ten years. In such cases, both the initial cost of the system and the operating costs may be critical to the decision-making process.

Due to the intensive level of competition between petroleum product producers at the level of the ultimate consumer, it becomes almost impossible for the non-integrated refiner to pass along these increased costs, in the form of price increases, to the consumer. Furthermore, the small refiner is unable to purchase his feedstock at any significantly lower price to compensate for the increased cost. On the other hand, the integrated company often can: (1) balance increased cost at one particular facility against other higher profitability operations (2) has some control over the actual cost of his feedstock supply, and (3) can often influence the overall market sufficiently to pass his increased costs on in the form of product price increases. In consideration of the foregoing marketing and economic factors, it is the opinion of people in the petroleum industry that pollution control requirements will lead to the disappearance of the non-integrated refiners in the next few years. This will probably occur through mergers and acquisitions between the two categories, rather than by individual plant shutdowns caused by financial stress, thus hopefully avoiding serious employment dislocation during the period. This situation will, of course, be accelerated by the addition of new environment restrictions on lead and sulfur in the finished product. These restrictions will add a great deal to the total cost of rennovating old plants to meet all the new environmental restrictions. Given the relatively narrow profit margins of the independent refiner, it does appear as though the combination of the factors cited will probably, in the near future, result in a considerable realignment of the traditional processing and marketing phases of the petroleum industry.

The industry is currently spending about 20 to 25% of new plant cost on various pollution control systems. One case has shown a system cost of 36% of new plant cost but this was exceptional. The relation between pollution control costs and plant cost varies widely in the case of older plants. And it will usually appear as an excessive percentage if current equipment costs are applied to original plant costs.

A more practical relationship, in the case of these older plants, is to calculate the cost of pollution control systems against the percentage of profitability that has been established by past plant operation. This is the approach most plant managers are using either, consciously or subconsciously, and it does appear to give them a more realistic base from which to estimate funds available for installation and operation of control facilities.

In general one might say that, for new plants, an investment over 10% of plant cost would be considered significant, an investment of 20 to 25% would be normal, and in investment in excess of 35% would be considered excessive or prohibitive by most corporate managers.

However, for older plants the percentage figures will vary widely, in attempting to relate pollution control facilities cost to plant cost. The determining factor being, of course, the particular numbers used to represent "plant cost". Obviously, in most cases, relating current pollution control system cost to old plant original cost will make the pollution system cost up as an excessive percentage figure of "plant cost".

In relating pollution control cost to profitability one gets a little better picture of the relationship between system cost and the old plant management's "ability to pay" for the system. In general, the "old plant" profit per gallon of finished product will average between .05 cents and .075 cents across the total product line producer per year. Thus, if total pollution control system initial cost and operating cost run over about 5% of this figure, for very long, the older non-integrated plant will be in serious trouble.

Furthermore, this problem does not appear to be greatly helped by low-cost, long-term loan availability in many such cases. If we assume a period of 10 to 12 years as the breakdown point between new and old plants and an average refinery life of 25 years, it follows that a 20-year loan, for example, would be of little use to management for the construction of pollution control facilities in a non-integrated 12 year old plant.

For this reason, the non-integrated older refineries would frequently not be able to avail themselves of such loans. On the other hand, the larger integrated companies would probably make use of such loans but, in most cases, do not really need them to survive.

Insofar as the A.P.I. is concerned, an effective environmental protection program for the petroleum refining industry must balance several important factors in order to achieve optimal overall social benefit. Among these are:

1. Maximum protection of the natural environment.
2. Maximum protection of total current refinery capacity in the U. S. ("a country that runs on oil cannot afford to run out.")
3. Minimum economic dislocation in terms of unemployment or increase of product prices.
4. Maintenance of availability of adequate water supply.

The views of industry representatives to the National Council of the Paper Industry for Air and Stream Improvement were sought at a meeting of this group in New York. The opinion was expressed that the problems of the pulp and paper industry are primarily due to the fact that it is an extractive industry whose technology is heavily dependent upon water as the extractive medium. Additionally, various segments of the industry are really quite different in water use, potential contaminant loads, process water requirements, and financial positions.

The contaminants in the industry's waste waters fall into three categories: suspended solids, soluble organics, and esthetically objectionable characteristics such as color. Insofar as the reuse of paper is concerned, it can be reused in its own grade or down-graded to a lower grade, but cannot be reused to produce a higher grade or class. These grades can be classified as follows from the highest to lowest grades:

1. Tissue and bond paper
2. Magazine and coated paper
3. Newsprint and paperboard
4. Roofing felt

The production of de-inked pulp creates by far the most severe pollution problem in the pulp and paper industry.

For every one-hundred pounds of waste paper entering a de-inking plant, seventy-five pounds of de-inked pulp is produced; i.e., twenty-five pounds of broken fibers, ink, and foreign materials must be disposed of. Most of this waste is as a watery sludge which must be thickened and dried prior to incineration. The B.O.D. in the waste from a de-inking plant is 110 pounds per ton of de-inked pulp versus 60 pounds per ton of kraft pulp, the major pulping process in the United States.

Paper can be recycled to such uses as coarse paper, paperboard, carton stock, roofing felt, and building board without de-inking, i.e., without removing inks, binders, coatings, and filters, thus producing less waste per ton of pulp. All reprocessing of papers is limited in the number of cycles through which the basic cellulose fiber can pass. In the higher grades of paper, the loss per cycle is 25 to 30 percent. A maximum overall reuse rate of 60% has been predicted, versus the current 20% in the U. S. and 45% in tree-starved Japan. Polychlorinated biphenyls, an ingredient of some inks and carbonless reproduction paper until recently, is a very stable compound which has been predicted to have adverse environmental effects. Materials such as this in much of the previously accumulated waste paper could be a limiting factor in reuse for, say, food containers.

Of major concern to the pulp and paper industry are the effects on pollution abatement costs in older plants and in those whose operations are marginally profitable. Space problems are of great concern in older plants. Municipal co-treatment offers limited potential in most pulp mills which are not near large cities; most plants near municipal sewage treatment facilities are very large water users as compared to the volume of sewage flows.

Correspondence with a major non-ferrous metals company indicates that their primary concern is that the costs of pollution abatement facilities be measured on the basis of the "opportunity costs" of capital. This company's concern is largely with measures such as "return on investment" or "return on capital employed", since they regard themselves as highly capital intensive. The data on Table 66 show some relationships between investment, sales, and profitability for 8 major U. S. Corporations.

Table 66. Comparative Invested Capital and Profitability
Selected Industry Leaders
Year 1971

Source: Annual Reports (Amounts in Millions of Dollars)

	Alcoa	Du Pont	General Electric	General Motors	IBM	Phelps-Dodge	Standard Oil of New Jersey	U.S. Steel
SECTION I - BASIC DATA								
Net Sales	$1,441	$3,848	$ 9,425	$28,264	$8,274	$704	$20,362	$4,963
Cost of Goods Sold (1)	1,328	3,275	8,688	24,608	6,300	632	17,681	4,734
Invested Capital								
Net Worth (Equity)	1,269	3,095	2,927	10,805	6,642	710	11,593	3,507
Long-Term Debt and Notes, including amounts due within one year	976	236	1,357	616	919	166	3,865	1,498
TOTAL	2,245	3,331	4,284	11,421	7,561	876	15,458	5,005
SECTION II								
Invested Capital/$ of Sales	$ 1.56	$ .87	$ .45	$ .40	$ .91	$1.24	$ .76	$ 1.01
SECTION III								
A markup of 10% on Cost of Goods Sold would result in a return on invested Capital of........	5.9%	9.8%	20.3%	21.5%	8.3%	7.2%	11.4%	9.5%
A markup of 10% on Invested Capital would result in a return on Cost of Goods Sold of	16.9%	10.2%	4.9%	4.6%	12.0%	13.9%	8.7%	10.6%

(1) Excludes interest where identified

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16. Abstract: This study presents order-of-magnitude estimates of the costs of implementing minimum and zero discharge requirements for the manufacturing and electric power industries. The analysis was made, for the most part, at the 2 digit S.I.C. level for the manufacturing industries. The assumed technology was maximum in-plant recirculation and reuse, concentration of the recirculation blowdown by evaporation, and final residual disposal by the applicable least-cost method among incineration, deepwell disposal, solar evaporation, and ocean disposal.

It is concluded that a strict zero discharge requirement would have greatly variable and significant economic consequences, but that less stringent definitions of minimum discharge would be feasible. The limiting factors in applying a strict zero discharge requirement appear to be the availability of physical resources particularly energy, for purposes of effluent concentration.

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