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Package Water Treatment Plants

Volume 1. A Performance Evaluation

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PACKAGE WATER TREATMENT PLANTS

Volume 1. A Performance Evaluation

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and interplay among its components require a concentrated and integrated attack on the problem.

Research and development is the first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems (1) to prevent, treat, and manage wastewater, solid and hazardous waste, and pollutant discharges from municipal and community sources, (2) to preserve and treat public drinking water supplies, and (3) to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is a product of that research and is a most vital communications link between the researcher and the user community.

One of the major problems facing the U. S. Environmental Protection Agency in meeting the requirements of the Safe Drinking Water Act is helping small and rural water systems in achieving compliance. This report presents results from a study on the cost and performance characteristics of self contained package water treatment plants. These plants can provide water that will meet the standard at a cost lower than that of conventional treatment. These data should be useful in assisting small and rural systems in providing high quality drinking water.

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ABSTRACT

Many small and rural water systems have both cost and quality problems. Their unit costs tend to be higher because of the small number of connections they service. As shown by the Community Water Supply Survey of 1969 many small systems have trouble meeting minimal drinking water standards. Their problems are likely to be compounded in the future as drinking water standards are raised. The cost of building a conventional water treatment plant to provide higher quality water for a small community may be prohibitive. Package water treatment plants are a possible alternative to conventional water treatment. These plants are self contained units that can be installed for minimum cost.

Results from a study of 36 package plants in Kentucky, West Virginia and Tennessee show that these treatment plants can provide water that meets the turbidity limits established under the National Interim Primary Drinking Water Standards. However, as with all treatment plants, proper operation is required. These plants, contrary to some manufacturers' claims, are not totally automatic but require supervision. Nevertheless when properly maintained and operated, they can provide good quality drinking water at minimum cost.

This volume (Volume 1) contains the performance data from the study with minimal cost data. It represents primarily the efforts of investigators from the University of Cincinnati who participated with EPA. Volume 2 is the in-house analysis of the cost data resulting from this project.

This report was submitted in fulfillment of Contract GS-05S-10458. This report covers the period June 1977 to June 1979, and work was completed as of June 1979.

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METRIC CONVERSION TABLE

ENGLISH UNITS	Metric Equivalents
1 foot	0.305 meters
1 mile	1.61 kilometers
1 sq. mi.	2.59 sq. kilometers
1 mil gal.	3.79 thou. cu. meters
1 $/mil. gal.	0.26 $/thou. cu. meters

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INTRODUCTION

Evidence from studies evaluating the cost and performance characteristics of conventional water treatment plants indicate that significant economies of scale exist in their construction as well as in their day-to-day operation.[1] However, the large expenditures required to construct and maintain a conventional treatment plant can place a significant burden on the customers of a utility producing less than one million gallons per day (MGD). A package water treatment plant might provide an alternative, but little is known about their cost and performance characteristics. This report presents the results of a field study designed to evaluate the cost effectiveness of existing package treatment plants.

THE SMALL SYSTEM PROBLEM

Many small and rural water systems have a built-in cost problem; they cannot benefit from economies of scale as do large urban systems because they are small in terms of the number of connections served. Certain types of support must be provided in a water system whatever the number of connections -- maintaining a chlorinator, for example -- but if connections are few, enough revenue cannot be collected to pay for the support. Many small systems cannot afford full-time operators and even have difficulty paying for part-time operators. The unit cost of nearly every support item rises as the number of connections being serviced decreases.

Most of the water systems in the U. S. serve less than 10,000 people. Table 1 shows a tabulation of utilities by population served.[2] As can be seen from the table, 90% of the systems serve 10,000 people or less and account for only 21% of the population served by community systems. There may be as many as 200,000 non-community water supply systems in the U. S.

Table 1. DISTRIBUTION OF POPULATION SERVED BY COMMUNITY WATER SYSTEMS[2]

Systems Size (persons served)	Number of Water Systems	Percent of Systems	Total Population Served (in thousands)	Percent of Total Population Served
25 to 99	7,008	18	420	0.2
100 to 9,999	30,150	75	36,816	20.8
10,000 to 99,999	2,599	6	61,423	34.6
100,000 and over	243	1	78,800	44.4
Total	40,000	100	177,459	100.0

Small systems tend to have more water quality problems and facility deficiencies than do larger systems. For example, Table 2 summarizes results from the Community Water Supply Survey conducted in 1969. Samples were taken in 969 communities. As can be seen from Table 2, 50% of the utilities serving 500 people or less did not meet the Public Health Service drinking water standards.[3] As utility size increased, the percentage of utilities meeting the standards increased.

Table 2. SUMMARY OF WATER QUALITY EVALUATION[3]

	Population Group Served			
	500 or less	501-100,000	Greater than 100,000	All Populations
Number of systems:	446	501	22	969
	Percent of Systems			
Evaluation of systems:				
Met drinking water standards	50	67	73	59
Exceeded recommended limits	26	22	27	25
Exceeded mandatory limits	24	11	0	16
Survey population in each group (in thousands)	88	4,552	13,463	18,103

In addition to cost and quality problems, small systems face another challenge. While the costs of labor, equipment, and materials have been rising due to inflationary pressures, water systems are being asked to meet higher output standards that may require them to use even more labor and materials. Small systems that already have high costs may find it difficult to pay their own bills and still maintain affordable user charges.

Package water treatment plants, consisting of prefabricated and largely preassembled clarification and filtration units, with minimum on-site construction, are commonly used in some sections of the U. S. for small supplies. The design flow for these plants is usually less than 1,500,000 gallons per day. It is possible that small communities, public utility districts, and recreational areas might be able to reduce the cost impact of compliance with the requirements of the Safe Drinking Water Act (PL 93-523) by using package water treatment plants.

These pressures have resulted in increased interest in small system problems. One type of technological system that holds some promise for minimizing the cost of water treatment is the package water treatment plant. In order to document the cost and performance characteristics of package water treatment plants, the University of Cincinnati and the Environmental Protection Agency initiated a field study. Results from this study are presented in two volumes. The first volume presents the performance data together with some minimal cost data. The second volume presents an in-depth analysis of the economic and cost data obtained during the study.

SCOPE OF THE STUDY

Prior to the study described in this report, there has been no systematic study of the effectiveness of operating package water treatment plants. In order to fill in this information gap, a field study of operating package plants in Kentucky, West Virginia, and Tennessee was initiated. Visits were made to 36 plants in these states and grab samples of untreated and treated water were taken at each site that had a plant in operation. Samples were analyzed for the nonradioactive contaminants listed in the National Interim Primary Drinking Water Regulations, for trihalomethanes as listed in EPA's proposed regulations for organic chemicals, and for typical water treatment plant operating parameters.[4]

Table 3 lists the manufacturers and capacities of the plants visited. Most of the plants were Neptune Microfloc systems. The package plants investigated were categorized as either municipal or recreational, according to their primary utilization. Municipal plants generally serve a stable population and are operated year-round, while recreational plants serve largely a transient population and may be in operation only sporadically. Table 4 lists the location of the package plants categorized by use.

Table 3. TYPES OF PLANTS STUDIED

Sites	Manufacturer	Model	Capacity
5	Neptune Microfloc	WB-27	20 gpm
1	Permutit		48 gpm
6	Neptune Microfloc	WB-82	60 gpm
1	Intermountain Systems	60TS/PF-IF	60 gpm
3	Neptune Microfloc	WB-133	100 gpm
7	Neptune Microfloc	AQ-40	200 gpm
1	Hungerford & Terry	L-28	200 gpm
1	Permutit		200 gpm
5	Neptune Microfloc	AQ-70	350 gpm
3	Neptune Microfloc	AQ-112	560 gpm
2	Neptune Microfloc	AQ-180	900 gpm
1	Neptune Microfloc	Concrete	1000 gpm

Table 4. LOCATION AND CATEGORY OF PLANTS STUDIED

I. MUNICIPAL PLANTS

Alderson, W. Va.
Anawalt, W. Va.
Bonde Croft Utility District, Sparta, Tenn.
Carrollton Utilities, Carrollton, Ky.
Coal River PSD, Racine, W. Va.
Franklin, W. Va.
Greenup, Ky.
Hambrick PSD, Hendricks, W. Va.
Marrowbone Plant, Regina, Ky.
Mountain Top PSD, Mount Storm, W. Va.
Mowbray Utility Dist., Soddy Daisy, Tenn.
Nettie-Levisay PSD, Nettie, W. Va.
Preston County PSD, Reedsville, W. Va.
Richwood, W. Va.
Russell Springs, Ky.
Stanton, Ky.
Thomas, W. Va.
Union, W. Va.
Winfield, W. Va.

II. RECREATIONAL PLANTS

Apple Valley Resort, Jamestown, Ky. (private)
Big Bone State Park, Union, Ky. (state)
Canaan Valley State Park, Davis, W. Va. (state)
Carr Fork Lake, Irishman Creek Rec. Area, Sassafras, Ky. (USACE)*
Dewey Lake, Prestonburg, Ky. (USACE)
East Lynn Lake, East Fork Rec. Area, East Lynn, W. Va. (USACE)
East Lynn Lake, Utility Bldg., East Lynn, W. Va. (USACE)
Fishtrap Lake, Shelbiana, Ky. (USACE)
Green River Reservoir, Holmes Bend Rec. Area, Campbellsville, Ky. (USACE)
J. Percy Priest Reservoir, Cook Rec. Area, Nashville, Tenn. (USACE)
J. Percy Priest Reservoir, Fate Sanders Rec. Area, Nashville, Tenn. (USACE)
J. Percy Priest Reservoir, Poole Knobs Rec. Area, Nashville, Tenn. (USACE)
J. Percy Priest Reservoir, Seven Points Rec. Area, Nashville, Tenn. (USACE)
Natural Bridge State Park, Slade, Ky. (state)
Norris Dam State Park, Norris, Tenn. (state)
Smith County Rest Area, Interstate 40, Tenn. (state)
Snowshoe Ski Resort, Slaty Fork, W. Va. (private)

*NOTE: USACE is U. S. Army Corps of Engineers

DESIGN AND OPERATING CHARACTERISTICS OF PACKAGE PLANTS

Figure 1 shows a flow diagram typical of plants encountered in this survey.[5] All but one of the package plants visited were constructed in the 1970's, and the oldest plant was 10 years old. The majority of plants consisted of flocculators, followed by tube settlers, and a mixed media filter.

Influent flow in these plants is usually maintained at a constant rate. Equipment for adding coagulation chemicals is usually of the dry-feed type except that any polyelectrolytes are usually added in solution. Three of the four plants adding fluoride used sodium fluoride (NaF) and the fourth used hydro-silicic acid (H_2SiF_6). A few plants disinfected by adding purchased chlorine solutions. Others disinfected by adding dry chlorine mixed in solution, or by solution feed gas chlorinators.

Influent water to which coagulation and disinfection chemicals are added, flows to a mechanical flocculator. Flocculation detention times in the plants surveyed usually ranged between 7 and 30 minutes. After mixing and coagulation takes place, water flows to tube settlers. These shallow depth (1 inch deep) nested plates, 39 inches long, inclined at 7-1/2^o, allow economies in the space required for sedimentation. Overflow rates ranged from 120 to 375 gpd per ft^2 and detention times from 8 to 25 minutes. Clarified water passed over an outlet weir onto the filters. The multi-media filters encountered during the survey were composed of three materials, each of different size and density: a top layer generally consisted of 18 inches of anthracite coal, with a specific gravity of 1.5, and an effective size of 1.0-1.2 mm; below that 9 inches of silica sand with a specific gravity of 2.6, and an effective size of 0.45-0.55 mm; and a bottom layer of 3 inches of garnet sand, specific gravity 4.2, with an effective size of 0.25-0.35 mm. A few plants had filters of these same materials, but with different depths. The filters were supported by 18 inches of gravel. Filters examined during the survey operated at surface loading rates of 2.0 to 6.2 gpm/ft^2 with most operating at either 4 or 5 gpm/ft^2. A few plants had filters consisting of two feet of silica sand with an effective size of 0.45 to 0.55 mm, operated at a rate of 2 gpm/ft^2. These filters were preceded by an upflow clarifier rather than by tube settlers.

Filtered water was collected in an underdrain system and then pumped to storage. Filter backwash procedures consisted of draining the settling tubes, with the falling water providing sludge removal, then backwashing the filter. This process can be initiated automatically by head loss controls or can be started manually, but the majority of plant

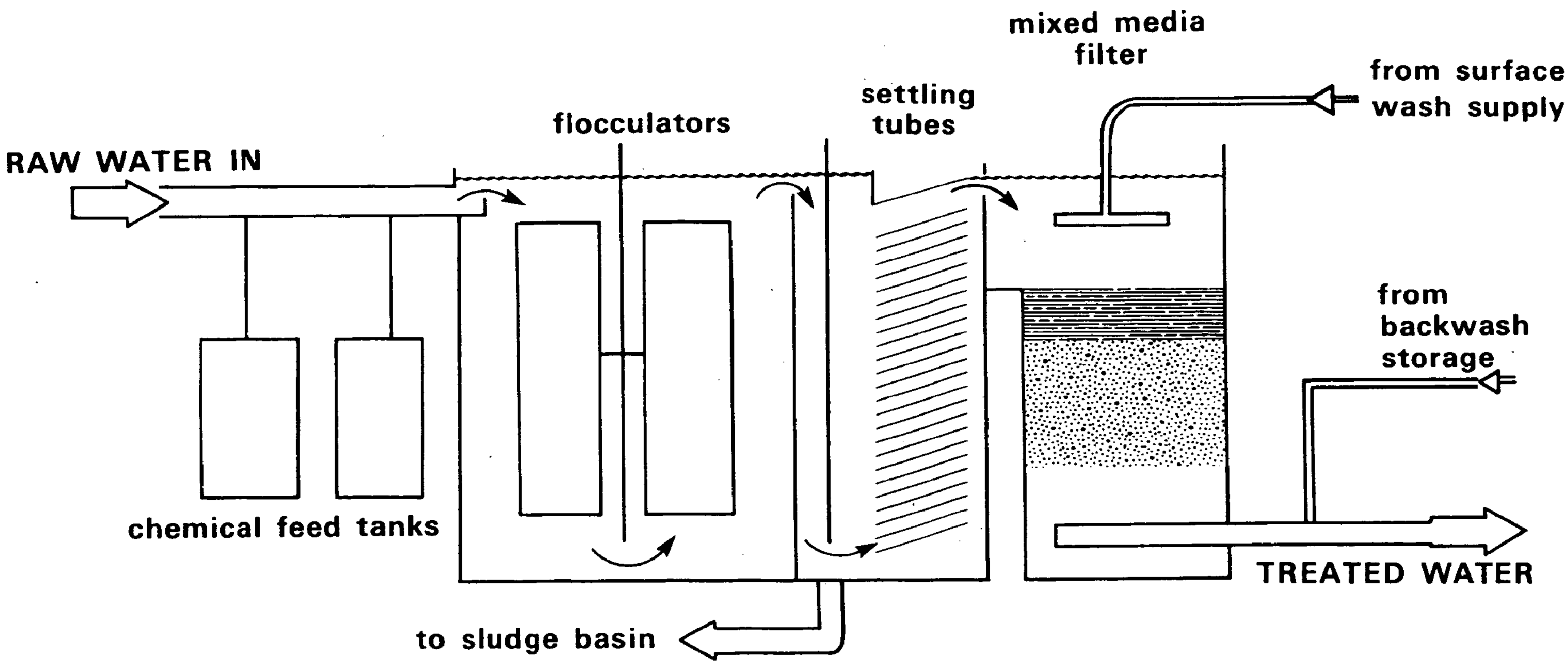

Figure 1. Flow Diagram of Typical Package Plant

operators manually controlled the backwash interval. Although many plants had head loss controls, the operators chose to manually backwash before the maximum head loss was reached. Backwash intervals ranged from twice a day to less than once per week, with the majority of filters backwashed between one and three times weekly. Backwash rates were generally 15-18 gpm/ft^2 for a period of 6 to 10 minutes. The only surface wash devices observed were manual, such as a hand-held hose or a rake used to agitate the filter media.

Almost all of the plants visited had adjacent outside sludge basins designed to receive the backwash water. Water used for backwashing purposes in municipal plants normally accounted for less than 6% of the plant output. Several recreational plants used 20% or even 30% of output water for backwashing because operators routinely backwashed on a time schedule without regard to water demand.

Problems of high iron concentrations from ground water sources were handled several ways. One community, whose source water was natural springs impounded in a reclaimed strip mine pit, used ion exchange media in place of a multi-media filter. The media consisted of a 30-inch bed of manganese green sand zeolite resting on 16 inches of supporting gravel, and operated with a surface loading rate of just over 5 gpm/ft^2. This type of plant involves both filtration and ion exchange, with the iron and manganese in the water being removed by ion exchange. Potassium permanganate was added prior to the filter. As the raw water met the media, the iron and manganese were oxidized into insoluble forms that were removed by mechanical filtering action. The plant had been in operation less than three months when visited in the survey and the operators planned to regenerate the media with a strong potassium permanganate solution when the treatment plant manufacturer could assist.

Another plant with a ground water source had been designed for addition of potassium permanganate for oxidation and precipitation of iron. The manufacturer apparently had computed the chemical requirements and a supply of potassium permanganate had been purchased but never added.

Another plant used aeration by having a cascade in the wet well to oxidize iron prior to entering the treatment plant. This process was not working effectively when the plant was visited in the survey.

Operators of two plants stated that they sometimes added carbon to combat taste and odor problems. At one plant, carbon was added at the multi-media filter and at the other it was added to the settling basin.

One municipal plant that added lime and soda ash to soften ground water also included a recarbonation tank, using a natural gas burner, between the floc tank and the tube settlers.

PERFORMANCE EVALUATION

Samples of untreated water were taken from either the water source near the plant intake or from a raw water tap in the treatment plant or from an influent line into the plant. Finished water samples were taken from treated water taps at each plant. Because a survey goal was to determine how well the treatment plants operated, treated water samples were taken as the water left the plant, rather than at the point of use. Surface water quality is a constantly changing factor, making reliance on a single analysis risky, therefore records kept at each plant were examined to determine the representative nature of the survey grab samples.

The majority of sites visited had personnel who did an adequate job of plant operation. Tennessee state law mandates the presence of an operator at all times that a plant is in operation. In the other states, operators often started up their treatment units and then proceeded to the performance of other duties, such as meter reading and distribution line maintenance.

Occasionally, operators were not performing routine chemical analyses properly. For example, in one case an operator was incorrectly reading a buret, causing all of his titration calculations to be off by a factor of 10. In another example, an operator was not determining turbidity properly.

At one plant, daily jar tests were performed to determine the optimum coagulation chemical dosage but, at most plants, chemicals had been purchased according to the manufacturers' recommendations and were used in the same dosage every day, regardless of raw water quality. Some operators did vary chemical dosages according to visual observation of raw water turbidity. Some treatment operations had not purchased chemicals or had not added chemicals that had been purchased.

At one site, there were so many distribution line leaks that records showed only about 20% of the water treated was reaching consumers. The operator's assigned duties at this plant consisted of starting up the plant when needed, but he had no training in maintaining proper chemical dosages.

Table 5 lists the various water sources utilized by the systems visited during the study.

Table 5. WATER SOURCES

Ground Water	3
Impounded Spring Water	3
Free-flowing Surface Water	7
Impounded Surface Water	18

TURBIDITY, COLIFORMS, HARDNESS, AND ALKALINITY

Turbidity, coliforms, hardness, alkalinity, and pH were measured at each plant. Samples were also mailed to the laboratory of the University of Cincinnati Department of Civil and Environmental Engineering for analysis of trihalomethanes as well as for inorganic contaminants and pesticides. Data on plant type, influent source, chemical additions, and quality information gathered are listed in Appendix A, tables A-1 and A-2.

Table 6. INFLUENT HARDNESS

Hardness of source mg/L	Number of Plants
0-80	15
81-150	9
151-250	4
>250	2

Untreated water pH values ranged between 6.2 and 8.2 except for two plants that had values of 5.2 and 4.7 for the grab samples. Treated water pH values ranged from 6.5 to 8.6. Fluoride levels of water sources were all $\leq$ 0.20 mg/L. Four plants added fluoride with measured levels in the finished waters of 1.66, 1.15, 1.11, and 0.80 mg/L. Only one plant practiced softening. The only two nitrate levels over 1 mg/L (as N) found during the survey were 4.1 and 3.3 mg/L and were from ground water sources.

Coliforms were detected in the finished water of 3 of the 31 plants in operation. At two of these three plants, coliforms were present in only one sample out of two analyzed. The single plant where coliforms were found in significant numbers had no measurable chlorine residual in the treated water. In one plant where coliforms were found in one of the two treated water samples, a sample taken at a residential tap showed a count of 10 per 100 mL. Chlorine residuals at this location were 0.4 mg/L at the treatment plant and less than 0.1 mg/L at the tap sampling point.

Only one plant did its own microbiological testing, and it was possible to collect state bacteriological records from only seven plants. Table 7 contains these state bacteriological results.

Table 7. BACTERIOLOGICAL RESULTS

Plant	Number of + Samples	Number of - Samples
A	0	18
B	2	12
C	0	18
D	1	9
E	1*	5
F	0	10
G	0	48
Total	4	120

*Note on state report that positive sample was probably caused by "poor sampling technique or handling at lab."

Of 31 plants for which turbidity measurements were made, eight did not meet the federal standard of 1 NTU. The survey was made during the months of September and October which should be the time of lowest river water turbidities. Table 8 summarizes the types of coagulation chemicals used by the plants.

Table 8. COAGULATION CHEMICALS

Coagulation Chemicals Used	Number of Plants
Only alum	12
Alum + polyelectrolyte	16
Alum + polyelectrolyte + lime	1
Ferric sulfate + polyelectrolyte	1
Sodium hydroxide + potassium permanganate	1
No chemicals used	1

Table 9 lists the number of plants meeting the turbidity standard for different ranges of raw water turbidity. One plant not meeting the standard used no chemical coagulants at all, and is therefore not included in Table 9. Of the plants not meeting the turbidity standard, only one averaged more than four hours per day in operation.

Table 9. PLANTS MEETING TURBIDITY STANDARD

Turbidity of Source NTU	Plants	Finished Water <1 NTU	<1 NTU
< 5	14	11	3
6-15	8	8	0
16-50	6	2	4
51-100	0	0	0
> 100	2	2	0

Examination of past plant turbidity records at one site, with a turbidity reading of less than one during the survey, showed the standard was exceeded 9 days out of 31 (33% of the time). Of those nine failures, three failures followed influent values of 110 and 100 NTU on successive days and three other unacceptable values followed an influent value of 120. This plant satisfactorily treated influent values of 65, 50, 40 NTU and lower.

A state report on another plant said "turbidity constantly in excess of accepted limits." In this case alum was added but the dosage was not varied according to raw water quality.

One cannot make definite statements regarding these data because they were obtained from grab samples taken during periods of low flow with corresponding low turbidities. Continuous observation over an extended period of time, with monitoring of seasonal fluctuations in raw water quality, is necessary to draw more definitive conclusions with regard to operating efficiencies possible from package plants. However some tentative conclusions may be drawn from these data. The combinations of proper disinfection together with clarification can achieve satisfactory bacteriological results. Although a significant number of the plants failed to meet turbidity standards their failure was not necessarily related to raw water turbidity levels. Examination of Table 9 reveals the fact that the two plants treating raw water with the highest turbidity were able to meet the finished water turbidity limit. Of the fourteen plants treating source water with the lowest turbidities, three failed to meet the finished water turbidity limit. Intermittent operation seems to have a greater affect on failure to meet turbidity standards then does raw water turbidity. Of the seven plants not meeting the turbidity standards, six were averaging less then four hours a day in operation. Based on these data and the authors' observations it was concluded that package plants are capable when operated properly of meeting finished water turbidity levels. More carefully constructed studies need to be made to support this conclusion.

TRIHALOMETHANE FORMATION

For the samples analyzed for trihalomethanes, no attempt was made to neutralize chlorine in the grab samples, and samples were handled so as to allow contact times for maximum THM formation. Chloroform was the only trihalomethane found in the survey, with one exception, where dichlorobromomethane was also detected. No trihalomethanes were detectable in any raw water, except at one location where the survey sampling point probably included mixing with "backed-up" treated water.

No trihalomethanes were detected in finished water from the three plants treating well water. Calculated chlorine dosages in these instances ranged from 1.0 to 1.5 mg/L with measured free residuals of 1.0 mg/L and less.

Finished water from the three plants treating impounded spring waters contained chloroform with levels ranging from 5 to 34 μg/L. Calculated chlorine dosages for these plants were 1.3 to 5.2 mg/L and measured free residuals were 0.4 to 3.0 mg/L.

Of seven plants treating water from free-flowing rivers or creeks, all contained trihalomethanes in their effluents and two exceeded the EPA proposed standard of 100 μg/L. Free chlorine residuals measured were all 2.5 mg/L.

Eighteen plants treated water from surface impoundments. Seventeen of these produced trihalomethanes. Finished water from three of these exceeded 100 μg/L with the highest being 376 μg/L. Other chloroform values from this group of plants ranged from 5 to 98 μg/L with seven of the 14 values between 43 and 59 μg/L. Free chlorine residuals of 2.5 to 3.9 μg/L were measured.

In total, five of the 31 sampled finished waters exceeded 100 μg/L trihalomethanes. All five derived their raw water from surface sources. Most of the plants surveyed, practiced pre-chlorination and had free chlorine residuals of more than 0.4 mg/L. These results are consistent with findings from the National Organic Reconnaissance Survey for Halogenated Organics (NORS), which found higher concentrations of THM when surface waters were the source for treatment.[6] These two factors were also found by the NORS to contribute to higher concentrations of THM. Another factor found by the NORS to accompany high THM was finished waters with high pH values, but this relationship was not apparent in the package plant survey.

GENERAL ORGANICS

Determinations were made for the organic chemicals listed in the National Interim Primary Drinking Water Regulations, endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4-5-TP Silvex. None of these chemicals were found in the untreated or finished waters of any of the treatment plants.

INORGANIC ANALYSIS

Determinations were made for the following inorganic chemicals listed in the National Interim Primary Regulations: arsenic, barium, cadmium, chromium, lead, selenium, silver, and mercury.

Cadmium was found at one municipal plant in the influent water at a concentration of 0.06 mg/L, but was not found in the finished water.

Silver was found in the treated waters of one municipal plant and one recreational plant at a concentration of 0.05 mg/L.

Mercury was detected in several plants at concentrations of less than 1 μg/L. At one recreational plant the influent concentration of 4.8 μg/L was reduced to 1.0 μg/L in the treated water, a level less than the maximum contaminant level listed in the Regulations. At one municipal plant, a treated water concentration of 19.6 μg/L approached 10 times the maximum contaminant level allowed for community water system.

No other inorganic chemicals listed in the Regulations were found.

COST EVALUATION

Cost information was collected for the individual package plants studied and for the utility itself (Appendix B, Tables B-1 and B-2).

UTILITY COSTS

Utility operating and maintenance costs were broken into four major components: support services, acquisition, treatment, and distribution. The last three components represent functional areas related to the physical operation of the plant. Acquisition includes all operating costs incurred in collecting water for delivery to the treatment plant. Treatment costs include the operating costs associated with the purification of source water by the package plant, and distribution expenditures involve all operating costs incurred in delivery of the finished or treated water to the consumer. The fourth component, support services, is related to the overall utility management function. Support services costs include activities, such as billing, supervision, accounting, and general items not directly related to any of the other three components. In addition, subelement operating costs (chemical, payroll, and power) were collected for each component. These are isolated for analysis as to their individual impact on operating expenditures as well as for their productive input into the operation of a utility.

Capital costs for the utility were subdivided into the above mentioned categories and into interest and depreciation. Total capital costs are then contrasted against total operating and maintenance costs.

TREATMENT COSTS

In addition to these overall utility expenditures, specific package water plant costs were gathered in order to examine the treatment process in isolation. The costs of each subelement (chemical, payroll, and power) were collected for treatment operating costs, while capital costs were categorized according to installation, building, and the package plant itself. None of the utilities visited had their costs aggregated in such a way that easy comparisons could be made between systems. This lack of comparability was particularly evident among capital costs. Therefore capital costs were estimated from original construction costs assuming a 20-year life and a 5% interest rate. An interest rate of 5% was chosen to reflect historical rates and not current or incremental rates. Installation capital expense includes the depreciation and interest spent to make the plant operational; building capital expense involves the annualized construction cost of a building to house the package plant; and package plant capital is the annualized purchase price of the plant itself. Also, data on total capital cost including interest for the treatment as well as total construction cost of the plant and utility were collected.

DESCRIPTIVE ANALYSIS

In the following discussion, the analysis is divided into two sections. The first section deals with total utility data, and the second section contains a more detailed analysis of the package treatment plants alone. An extensive analysis of these data is contained in Volume II.

Analysis of Utility Data

Figure 2 contrasts total operating and maintenance costs, depreciation, and interest expenses for all the utilities (both recreational and municipal). Figure 3 shows just the operating and maintenace cost components. This analysis for the current years is based on average total expenditures and percent of expenditures. These utilities (treating an average flow rate of 0.115 MGD) possess a great deal of capital intensity on an annualized expenditure basis. Figure 4 shows chemical, power, and labor costs. As can be seen, labor cost is the most predominant operating and maintenance cost, ranging from 67% to 71% of the total cost of the three components.

Figure 5 shows the capital costs allocated to each of the four cost components. As can be seen, distribution costs tend to dominate total utility costs.

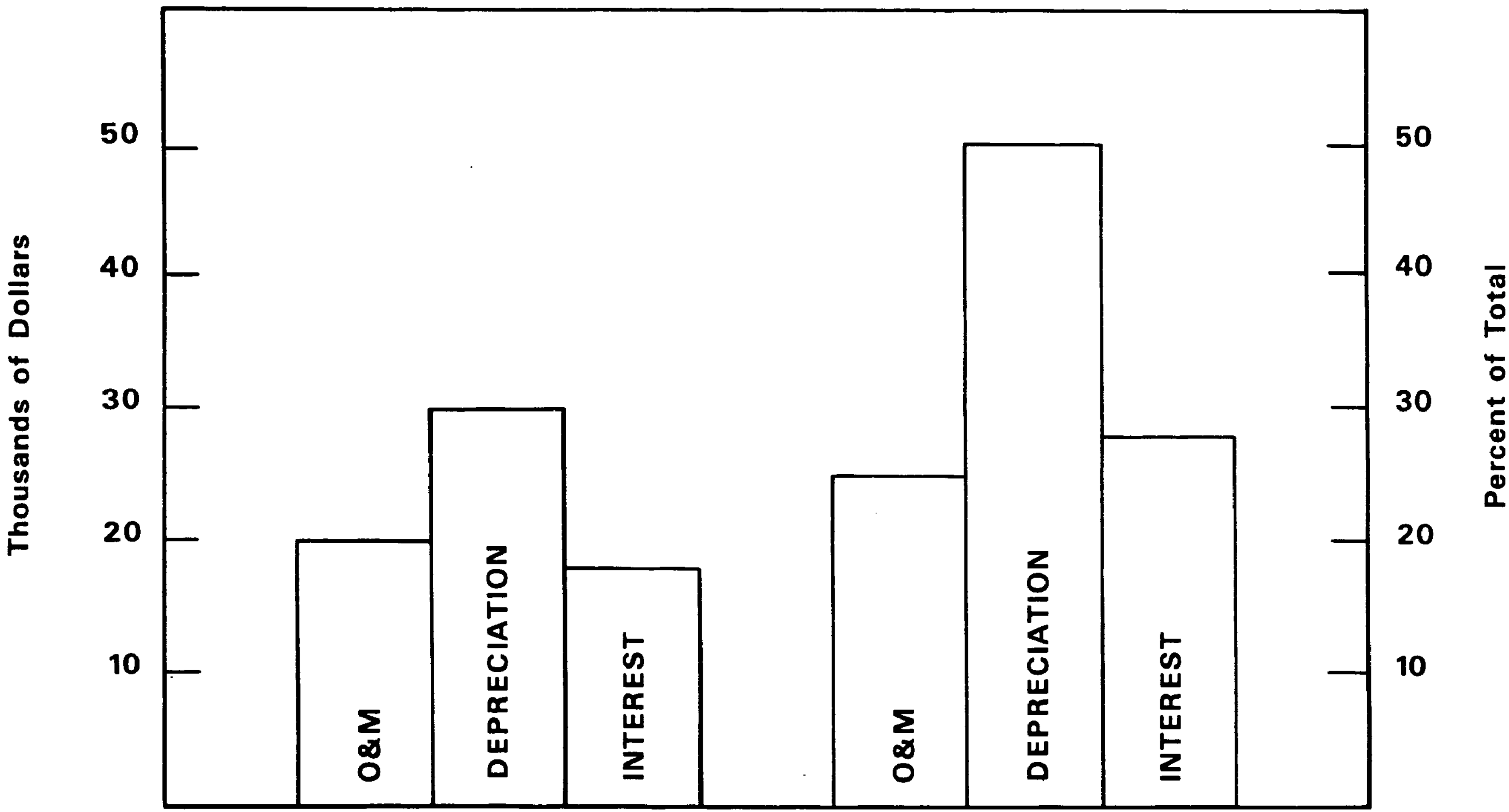

Figure 2. Operating and Capital Costs for Municipal and Recreational Utilities

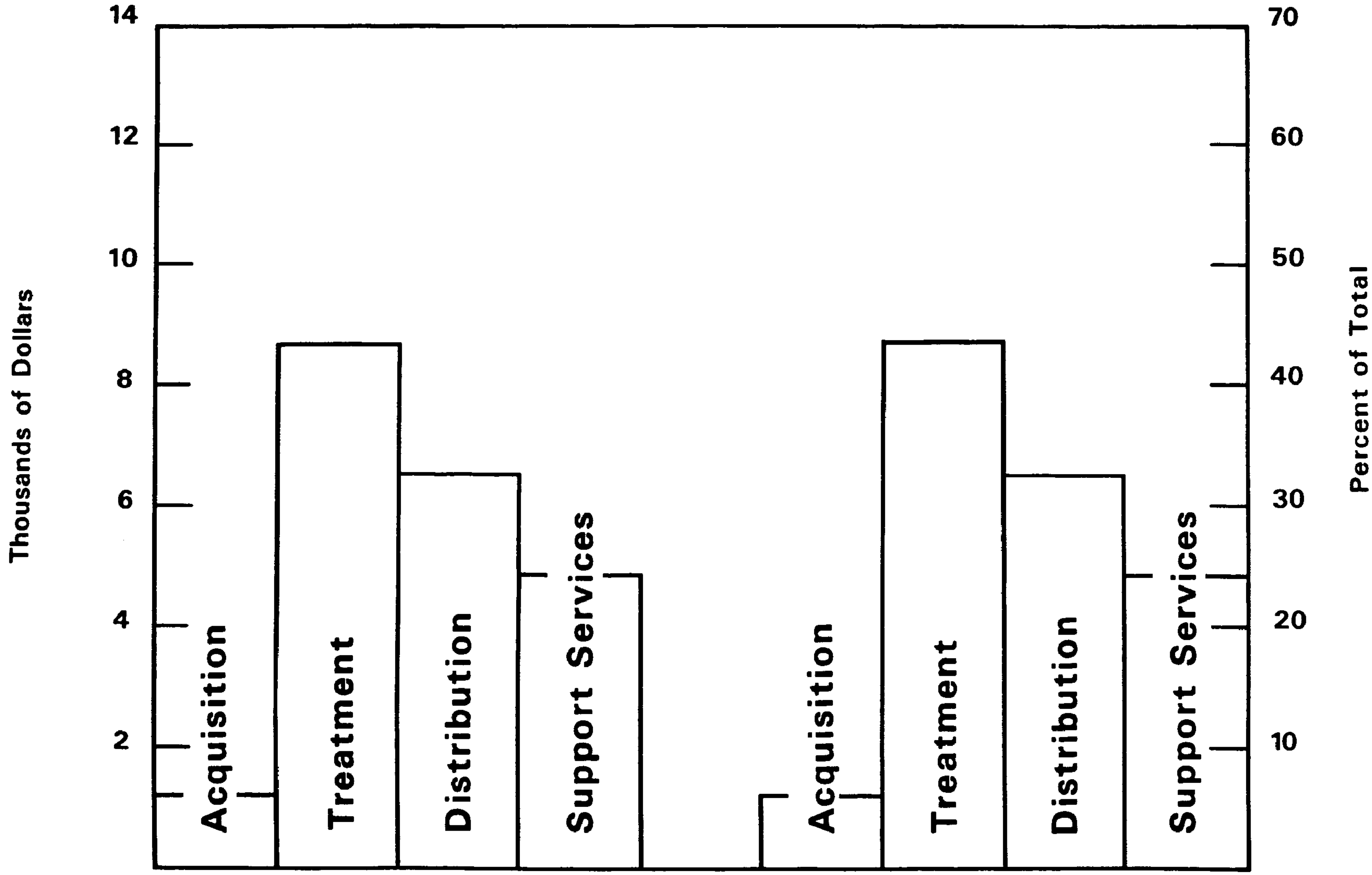

Figure 3. Operating Costs for Municipal and Recreational Utilities

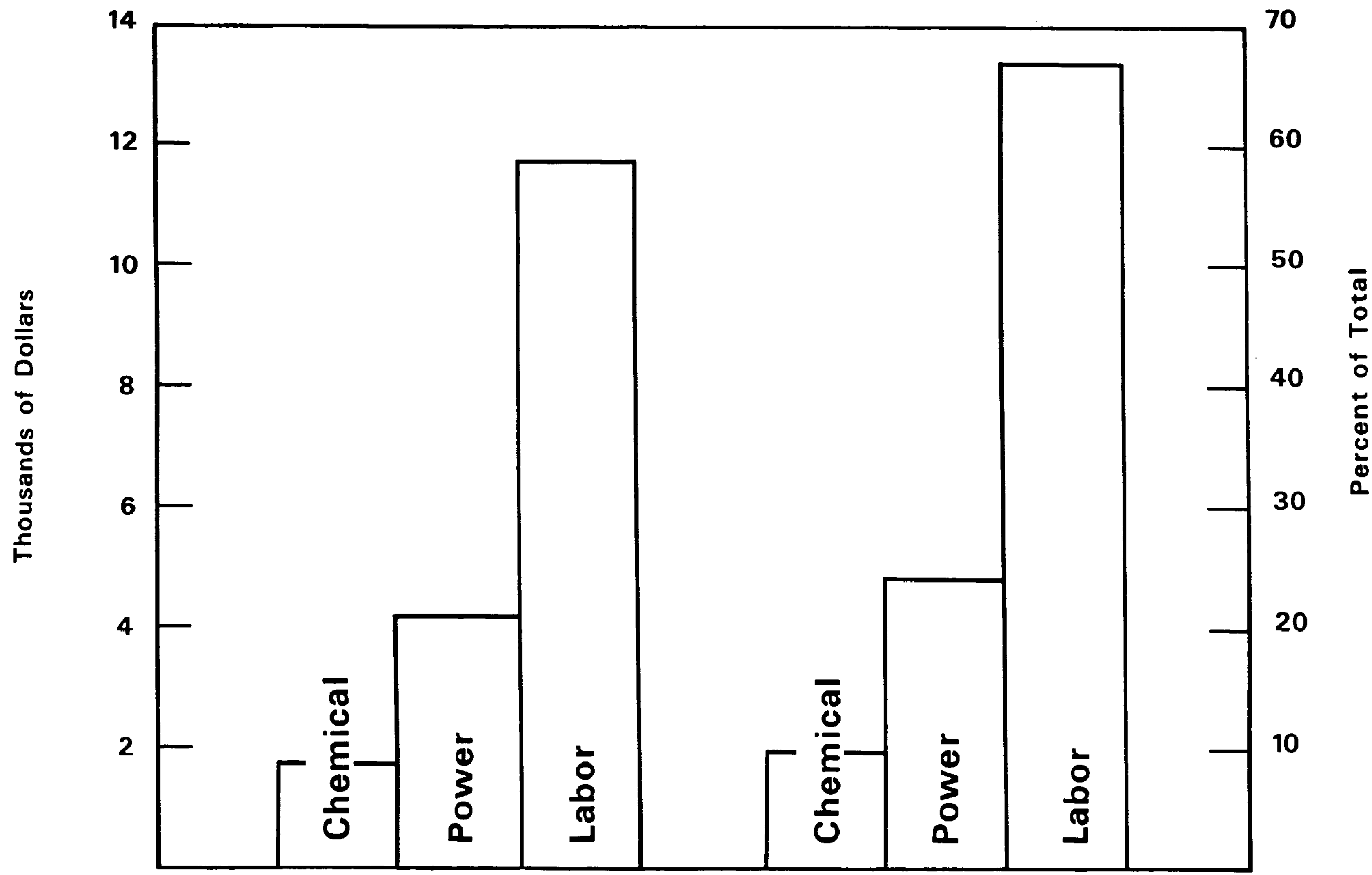

Figure 4. Principle Operating Cost Components for Municipal and Recreational Utilities

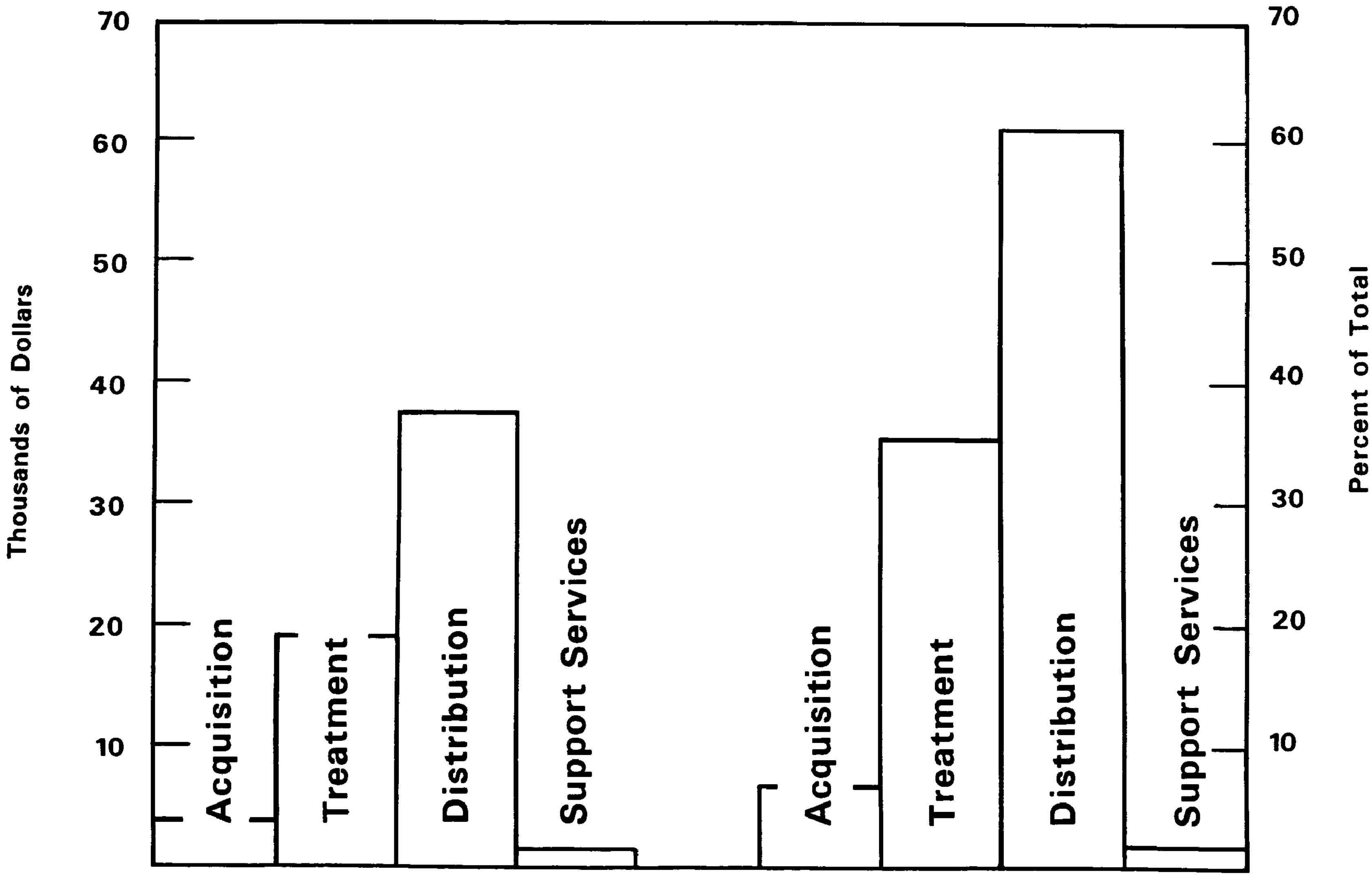

Figure 5. Capital Cost for Municipal and Recreational Utilities

In general, capital costs for the treatment and distribution functions, operating costs for treatment, and labor costs are the major factors influencing the cost of water supply in the selected utilities.

Analysis of Package Plant Data

Figure 6 depicts the average operating and maintenance, depreciation, and interest cost for the package treatment process alone. Capital costs for the treatment process are broken into three parts, including average construction costs for the plant itself, the building to house the plant, and the installation cost (Figure 7). As is evident from the figures, the housing cost factor is over 40% of the treatment plant construction cost. Although the purchase price of a prefabricated building is large, it is also the item which can be affected most by decisions of the utility manager. If the housing is constructed by the utility, significant costs savings might be realized.

Figure 8 shows the principal operating cost elements for the treatment operation. Labor costs again dominate, representing 65% to 75% of the total chemical, power, and payroll expense. Treatment labor accounts for nearly 50% of the utilities payroll. The number of labor hours apportioned to the treatment function can affect the level of quality. This relationship is analyzed more closely in the empirical work to follow.

In summary, it appears that capital cost of the treatment housing and labor operating costs constitute the most significant portion of the treatment operation.

EMPIRICAL RESULTS

In this section, empirical relationships for the economic data are developed. The logarithmic form of the equation (multiplicative model $Y = AX^b$) was used because the data become more readily normalized after logarithmic transformation. Each equation represents results of a combined analysis (municipal and recreational). Three types of relationships have been developed. The first presents the results for predictive type relationships; the second portion provides the empirical results for the production equations; and, the third reports the results from the structural model. Data used in the analyses are contained in Appendix B.

Predictive Relationships

Table 10 provides individual cost equations for each operating and maintenance cost component in the water utility -- acquisition, treatment, distribution, and support services -- estimated as a function of revenue-producing water. These results indicate that operating economies exist in all components as well as for total O&M for these utilities.

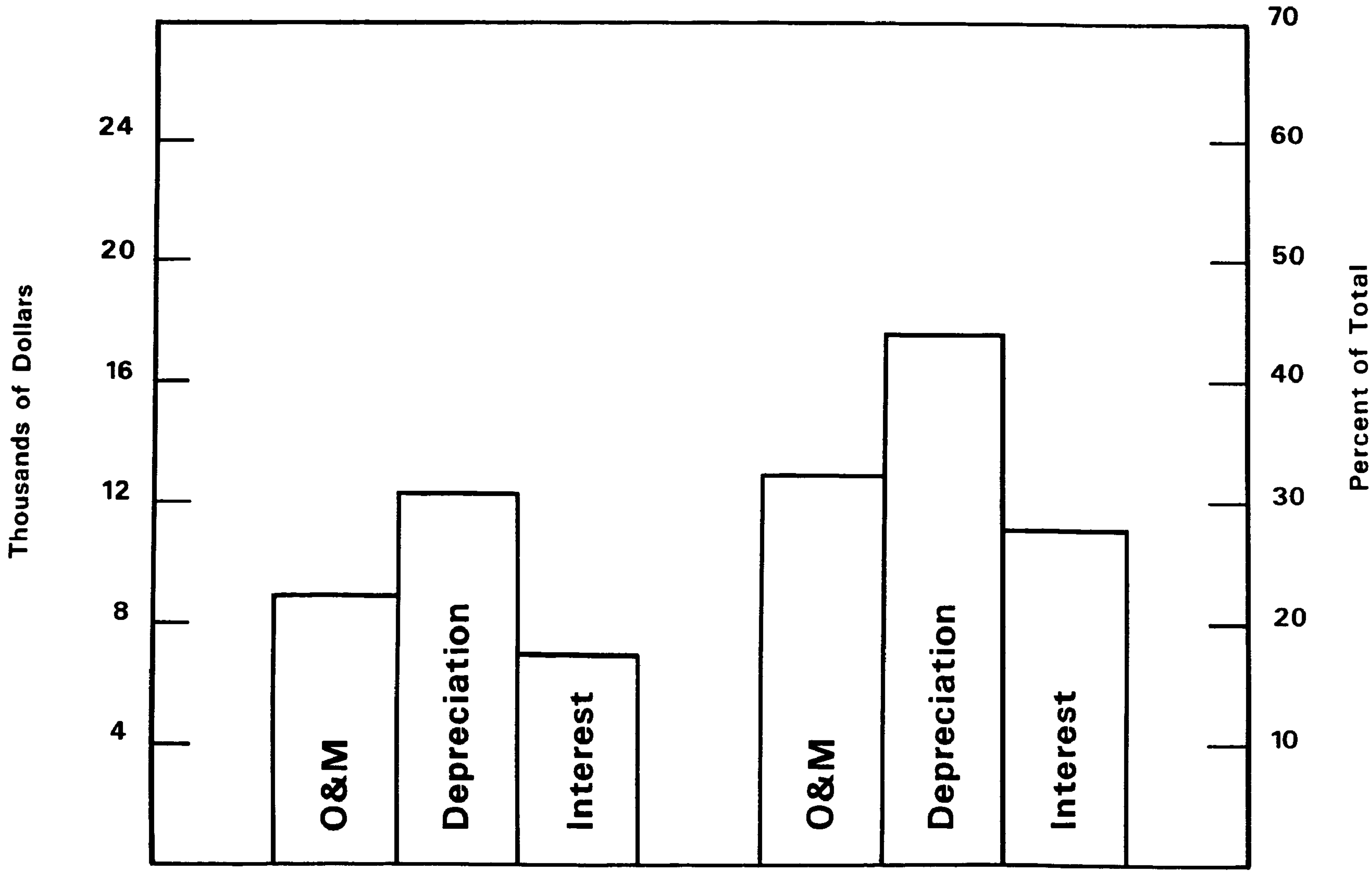

Figure 6 Operating and Capital Cost Components for Municipal and Recreational Package Treatment Plants

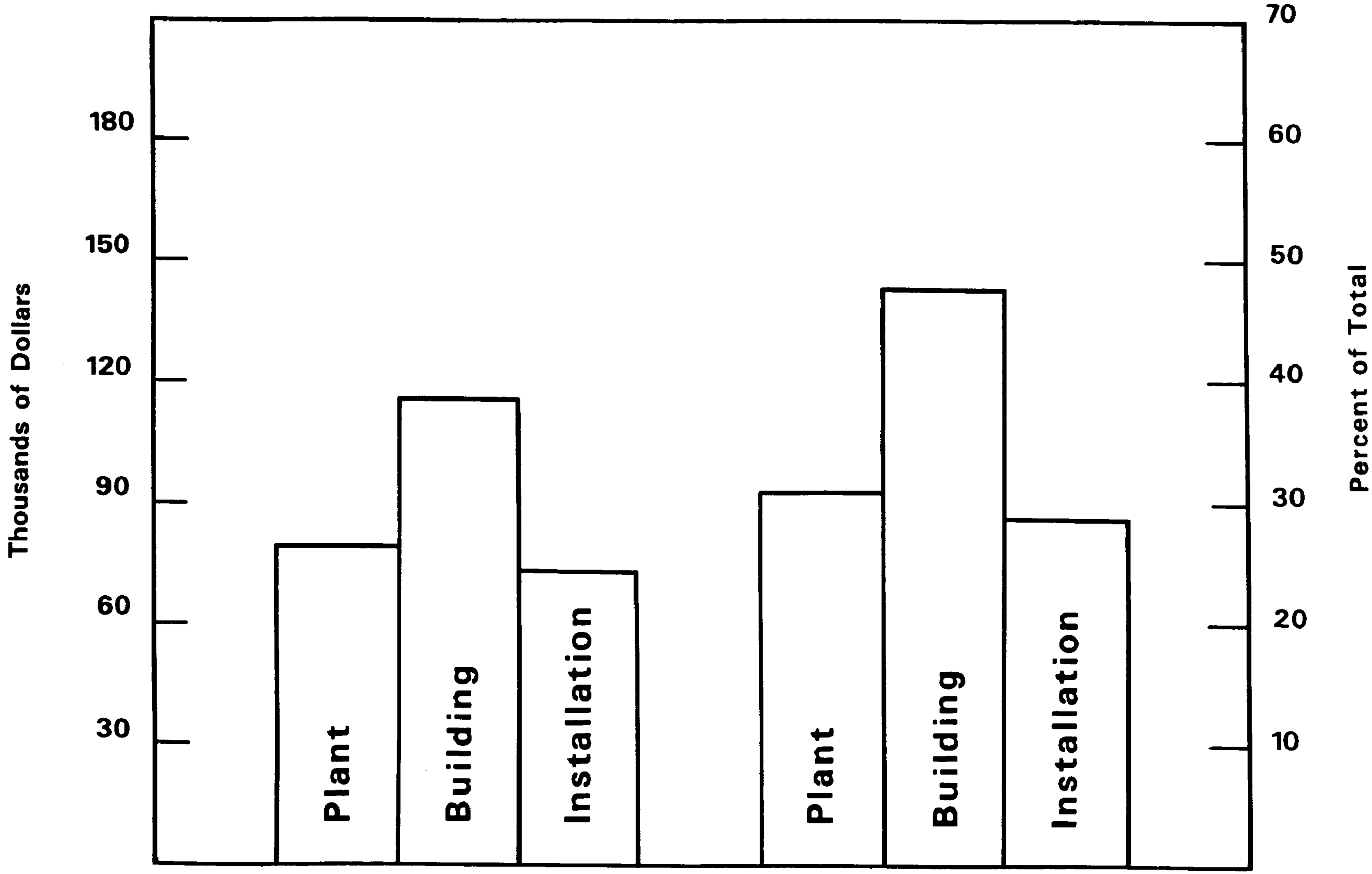

Figure 7. Treatment Plant Construction Cost Components for Municipal and Recreational Utilities

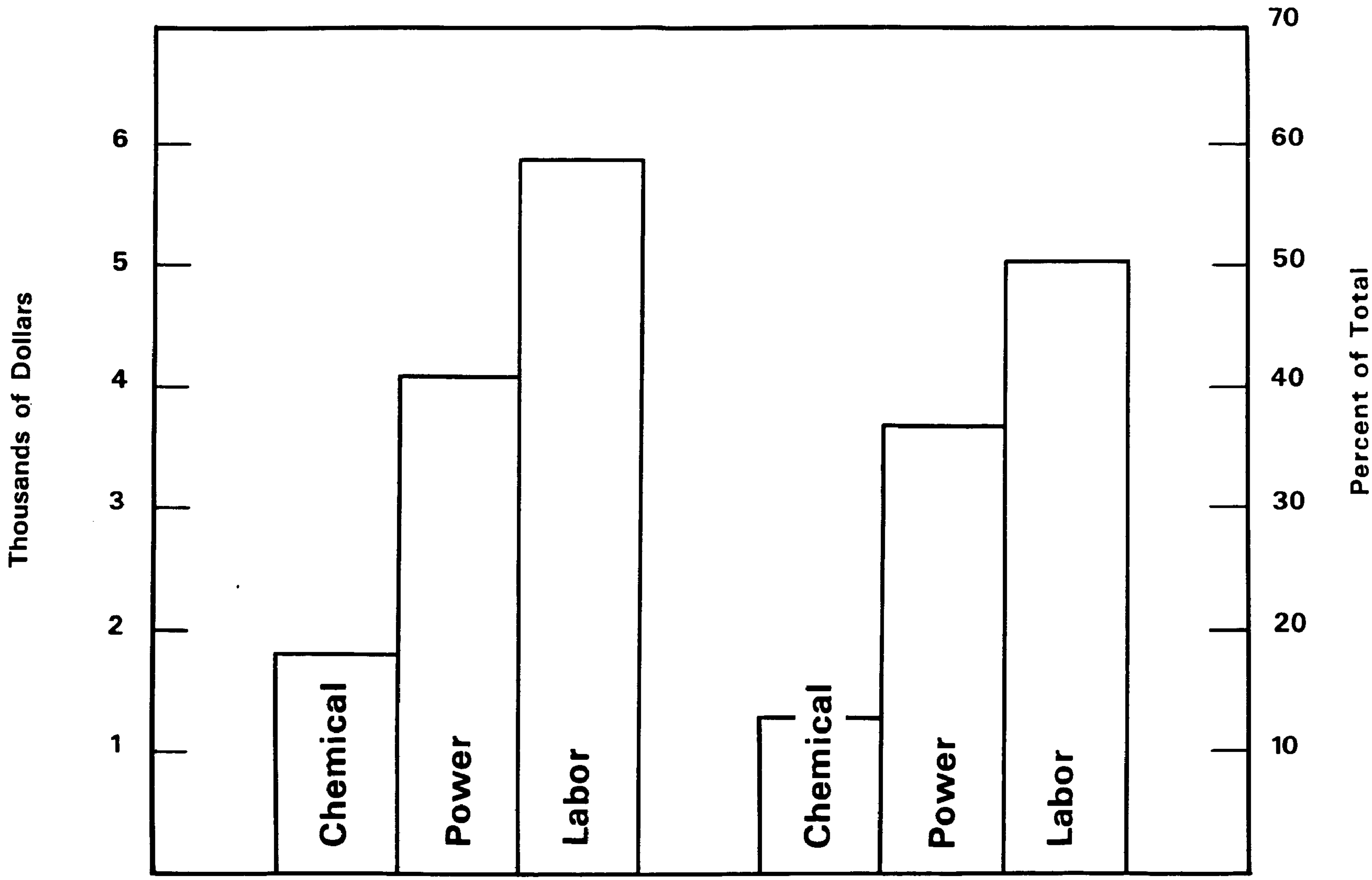

Figure 8. Package Treatment Plant Operating Cost Elements for Municipal and Recreational Utilities

Table 10. OPERATING AND MAINTENANCE COST EQUATIONS FOR MUNICIPAL AND RECREATIONAL UTILITIES

	Form $C = aQ^{b}$ +		
	a	b^{*}	R^2
Acquisition	209.863	.399 (.103)	.350
Treatment	2044.530	.394 (.054)	.646
Distribution	425.354	.724 (.116)	.583
Support Services	329.308	.614 (.134)	.430
Total O&M	3661.697	.475 (.059)	.696

* Values in parentheses are standard errors.

NS-Not significant.

\+ C = dollars per year; Q = mil gal per year of revenue producing water.

Table 11 provides results for the total cost including capital for each component and total system costs as well. The results in these tables indicate that significant economies also prevail for total operating cost, depreciation, and interest, and total annual cost as a function of revenue-producing water.

Table 12 shows construction cost equations for total utility and treatment costs, versus water treated. The treatment cost includes equipment, building, and installation cost. As can be seen from the table, significant scale economies also exist in construction.

Quasi-Production Relationships

Specific operating and maintenance cost trade-offs inherent in package treatment use were examined. The estimated treatment operating and maintenance cost equation is:

$$TOC = 3.561 \underset{(.038}{Q^{.980}} \quad \underset{(.038)}{L^{.612}} \quad \underset{(.025)}{C^{.160}} \quad \underset{(.049)}{E^{.179}} \qquad (R^2 = 0.994) \qquad (1)$$

where:

TOC = Total annual treatment operating cost in $/yr;

Q = Revenue-producing water, million gallons/years;

L = Payroll expense per million gallons;

C = Chemical expense per million gallons; and

E = Power expense per million gallons.

For this equation, it is obvious the payroll costs are a significant factor in operationg the package plant.

Chemical Costs

An estimate was made of chemical cost as follows:

$$CH = 55.037\ Q^{.661}\ AL^{.349} \qquad (R^2 = .860) \qquad (2)$$

where:

CH = Annual chemical cost, $/year;

Q = Revenue-producing water, million gallons/year; and

AL = Alum, mg/L

Table 11. TOTAL COST EQUATION (CAPITAL AND OPERATING) FOR MUNICIPAL AND RECREATIONAL UTILITIES

Form $C = aQ^{b}$ +			
	a	b*	R^2
Acquisition	1460.734	.213 (.102)	.143
Treatment	9556.807	.278 (.043)	.639
Distribution	4817.522	.537 (.094)	.575
Support Services	342.561	.627 (.132)	.520
Total O&M	3661.697	.475 (.059)	.696
Total Capital	16006.113	.329 (.064)	.443
Total Cost	17753.803	.408 (.057)	.653

* Values in parentheses are standard errors.

\+ C = dollars per year; Q = mil gal per year in revenue producing water.

Table 12. CONSTRUCTION COST EQUATIONS FOR TOTAL UTILITY INVESTMENT AND TREATMENT ALONE

Form $C = aQ^b$ +			
	a	b*	R^2
Municipal			
Total	35018.788	.610 (.256)	.251
Treatment	12890.141	.616 (.150)	.498
Recreational			
Total	17835.462	.684 (.165)	.552
Treatment	8470.095	.730 (.194)	.520
Combined			
Total	14289.31	.773 (.090)	.692
Treatment	10739.717	.653 (.064)	.762

* Values in parentheses are standard errors.

\+ C = dollars per year; Q = total water treated in mil gallons per year.

Relationships were developed between chemical cost, total treatment operating cost and selected variables representing source type, turbidity standards and overall drinking water standards.

The following relationships resulted:

$$CH = 105.109 \underset{(.075)}{Q^{.660}} \; 1.458^{X} \qquad (R^2 = .754) \qquad (3)$$

$$CH = 125.336 \underset{(.042)}{Q^{.589}} \; 1.486^{T} \qquad (R^2 = .756) \qquad (4)$$

$$TOM = 1939.140 \underset{(.042)}{Q^{.402}} \; 1.203^{S} \qquad (R^2 = .781) \qquad (5)$$

where:

TOM = Total treatment O&M in $/year

X = { 1 if the utility derives water from an unprotected raw water source; 0 if the utility derives water from a protected raw water source

T = { 1 if the turbidity standared is met; 0 if the turbidity standard is not met

S = { 1 if all the drinking water MCL's are met; 0 if all the drinking water MCL's are not met;

CH = Annual chemical cost, $/year

Obviously meeting the standards when the utility has to treat water from an unprotected source costs more than failing the standards and/or treating water from a protected source.

From equations (4) and (5) it can be seen that it costs more to meet the drinking water standards then it does not to meet them. From equation (1) it can be seen that labor plays an important role as a component of total treatment costs.

Comparative Cost Analysis

Figure 9 shows total construction cost for the system and for the package plant alone (combined data set) versus plant capacity in mgd. Figure 10 shows the annual treatment cost and annual system cost versus system size in revenue producing water (mgd). The cost of package plant technology can be compared against that for conventional treatment although data on the cost of conventional treatment plants are not generally available for plants of less than one MGD. This prohibits extrapolation of cost estimates for conventional treatment into that range. It is also difficult to obtain cost data for package plants greater than one MGD. But, both types of systems may be estimated at the one MGD level.

The construction cost for 1 MGD plant with settling has been estimated at $1,124,000. Total construction cost for a 1 MGD package plant (including plant, housing, and installation), using the equation from Table 12, is $488,236. Therefore, based on construction cost alone, a package plant is significantly less expensive then conventional treatment.

Total operation and maintenance cost for both systems types can also be estimated. The annual treatment O&M cost is estimated as $62,571.42 for conventional treatment. Using the equation in Table 12 for municipal treatment plants, annual operating costs for package plants may be estimated at $40,408.55. (Both systems based on 20-yr life).

Table 13. COMPARATIVE COST ANALYSIS FOR 1 MGD PLANT

Cost Estimate	Conventional	Package
Construction cost	$1,124,000.00	$488,236.00
Annual treatment, operation, and maintenance cost	$ 62,571.42	$ 40,408.55

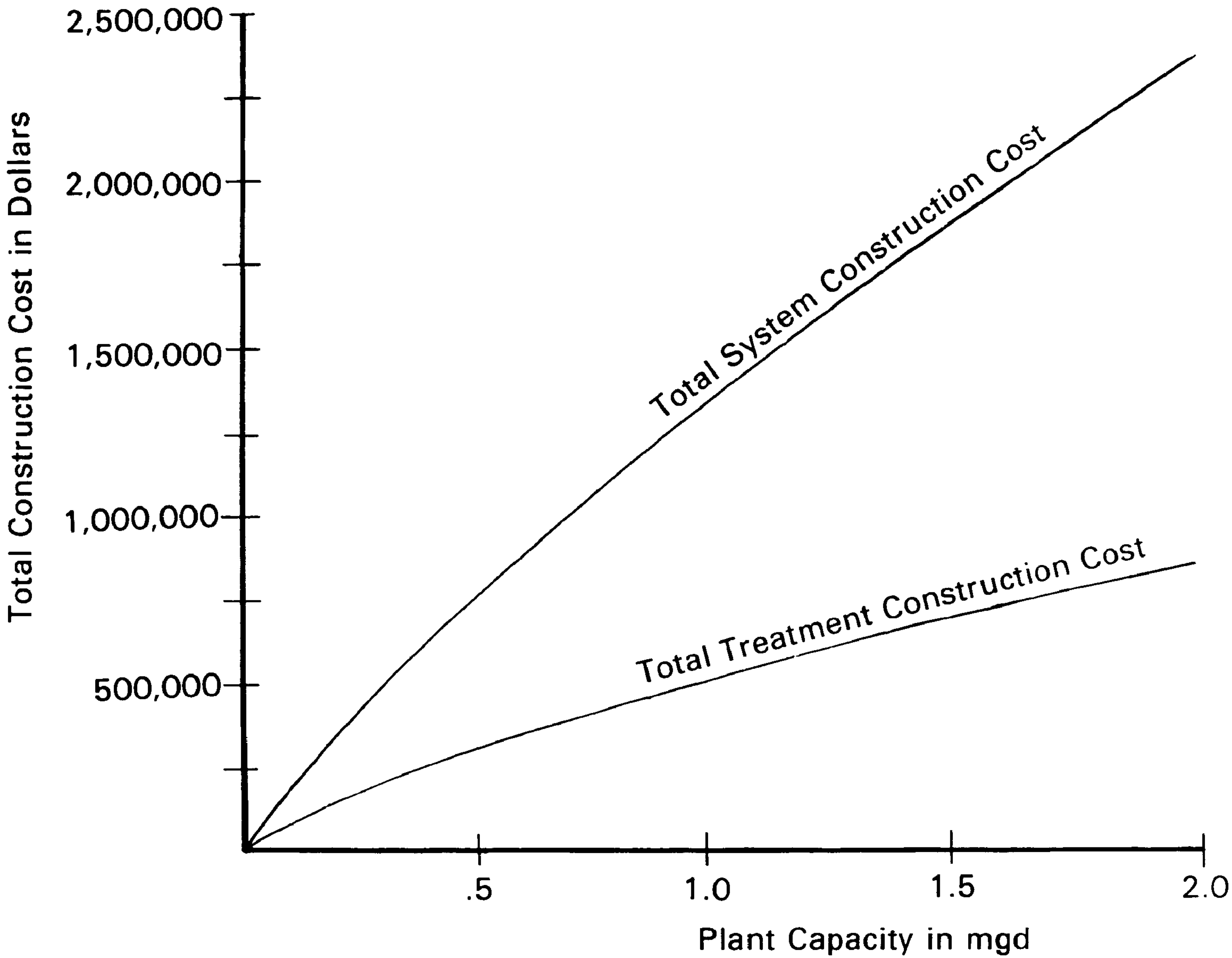

Figure 9. Total Construction Cost Versus Plant Capacity

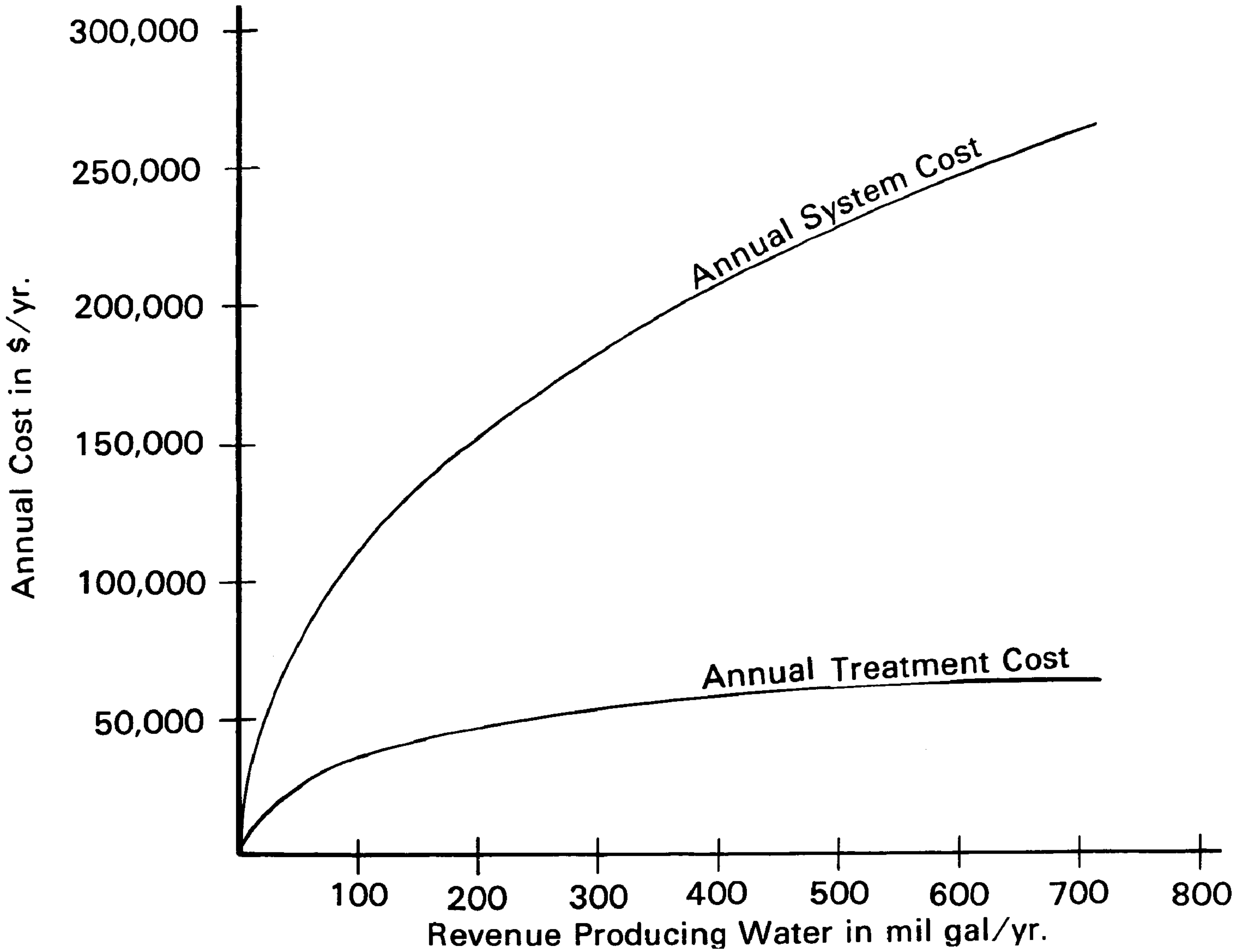

Figure 10. Annual Cost Versus Revenue Producing Water

SUMMARY AND CONCLUSIONS

Compliance with the requirements of the Safe Drinking Water Act may seriously impact the budgets of small communities. But, it is the intent of the Act to provide adequate water quality in small as well in large utilities. This study was conducted to examine the viability of using package treatment plants to meet the drinking water standards.

The study data demonstrates that package plants can meet traditional goals with regard to bacteriology and turbidity. Plants that were not meeting the National Regulations had problems caused by lack of operator attention, e.g., not varying chemical dosage to meet changing raw water quality, or they were not running for lengths of time sufficient to achieve stable operation.

Two conclusions may be drawn from this study. First, the impact of the requirements of the Safe Drinking Water Act significantly raise costs for small utilities unable to achieve scale economies with conventional treatment. As this report indicates, scale economies exist in package treatment plants under 1 MGD.

Secondly, as shown in Table 13, the construction and operating costs are significantly lower for package treatment technology than for the conventional treatment. Utilities can considerably lower their initial construction cost for package systems by performing some of the installation and work themselves. Therefore utility managers have a great deal of flexibility in controlling construction costs.

Based on the results of this study package plants have the potential to provide a cost-effective mechanism for meeting the turbidity and bacteriological requirements of the Safe Drinking Water Act. More extensive research and monitering is required to determine the precise limitation and ultimate potential of package plants for satisfying all of the Acts requirements under widely differing water conditions.

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APPENDIX A

QUALITY DATA

Table A-1. MUNICIPAL PLANTS

Plant No.	Type of Plant	Capacity gpd	Plant Output gpd	Water Source	Alkalinity, mg/ℓ Raw	Alkalinity, mg/ℓ Finished	Hardness, mg/ℓ Raw	Hardness, mg/ℓ Finished	pH Raw	pH Finished	Temperature, °F Raw	Temperature, °F Finished	NO_3(as N), mg/ℓ Finished
1	AQ 40	288,000	97,000	Im	36	70	60	62	7.1	7.8	73	73	< 0.01
2	(2)WB 133	288,000	98,500	Gr	180	180	180	184	7.3	7.3	55	55	0.18
3	AQ 40	288,000	75,000	Gr	257	261	390	400	7.1	7.2	56	57	3.30
4	AQ 70	504,000	147,350	Ff	55	59	78	88	7.9	7.6	70	71	0.40
5	AQ 40	288,000	105,500	Im	100	113	64	62	7.8	7.9	59	59	0.13
6	Concrete	1,440,000	860,000	Ff	4	12	12	10	6.6	7.2	58	60	0.22
7	AQ 180	1,296,000	364,000	Gr	358	159	448	124	7.0	8.5	57	61	4.1
8	AQ 112	806,400	233,000	Ff					7.8	8.2	69	69	0.04
9	AQ 70	504,000	229,000	Ff	34	40	75	126	7.0	8.6	66	66	0.49
10	H-T	288,000	114,000	Sp	16	15	236	230	7.1	6.5	56	60	0.13
11	AQ 40	288,000	84,300	Im	11	39	18	20	6.5	8.1	52	54	0.09
12	AQ 70	504,000	80,000	Sp	86	82	98	94	7.4	7.4	50	52	0.20
13	WB 133	144,000	70,000	Im	1	6	28	30	5.5	6.6	53	54	0.72
14	AQ 40	288,000	70,000	Sp	0	7	10	30	4.7	7.9	57	60	0.02
15	AQ 112	806,000	43,200	Im	6	16	8	22	6.9	7.5	59	59	0.01
16	AQ 180	1,296,000	450,000	Ff	42	36	106	102	7.3	7.3	59	59	0.60

Water Sources: Gr - Ground water
Sp - Spring
Ff - Free-flowing surface water
Im - Impounded surface water

Table A-1. MUNICIPAL PLANTS (Cont.)

Plant No.	Fluoride, mg/ℓ Finished	Turbidity, NTU Raw	Turbidity, NTU Finished	Average Chemical Doses, mg/ℓ Alum	Polyelectrolyte	Soda Ash	Other	Coliforms/100 mℓ Raw	Coliforms/100 mℓ Finished	Free Chlorine residual, mg/ℓ	Trihalomethanes μg/ℓ
1	0.10	6.4	0.9	31	0.02	37		TNTC	0	2.5	355.0
2	0.18	20.	0.7	13	0.1			38	23,7	< 0.1	< 1.0
3	(0.17 raw) 1.15	7.0	0.5		0.03		ferric sulfate 8 mg/ℓ	780	0	1.0	< 1.0
							fluoride 0.5 mg/ℓ				
							lime 18 mg/ℓ				
4	0.07	5.2	0.5	20	0.3		lime 18 mg/ℓ	TNTC	0	1.5	35.1
5	0.13	1.8	1.6			13		TNTC	0	1.5	57.5
6	(0.05 raw) 0.80	0.6	0.8	9	0.04	17	fluoride 0.6 mg/ℓ	TNTC	0	1.0	68.0
7	(0.14 raw) 1.66	0.04	0.03	22			sodium hydroxide 13 mg/ℓ	4	0	0.6	< 1.0
							fluoride 0.6 mg/ℓ				
							lime 339 mg/ℓ				
8	0.12	7.0	0.2	43	0.5	66		TNTC	0,3	2.5	24.0
9	0.20	520.	1.4	52			lime 23 mg/ℓ		0	1.7	112.0
10	0.12	5.0	0.7				$KMnO_4$ 0.2 mg/ℓ	TNTC	0	3.0	5.1
11	0.02	6.6	0.7	57		52				0.6	46.3
12	(0.05 raw) 1.11	1.1	0.4	11		5	fluoride 1.6 mg/ℓ	TNTC	0,1	0.4	14.8
13	0.07	3.4	0.4	7		9				1.0	41.0
14	0.02	0.8	0.3	37			lime 22 mg/ℓ	TNTC	0	2.5	34.0
15	0.01	5.9	0.7	20	0.4	12	lime 9 mg/ℓ	TNTC	0	1.5	59.0
16	0.07	29.	6.0	14			lime 4 mg/ℓ		0	1.7	10.8

Table A-2. RECREATIONAL PLANTS

Plant No.	Type of Plant	Capacity gpd	Plant Output gpd	Water Source	Alkalinity, mg/ℓ Raw	Alkalinity, mg/ℓ Finished	Hardness, mg/ℓ Raw	Hardness, mg/ℓ Finished	pH Raw	pH Finished	Temperature, °F Raw	Temperature, °F Finished	NO_3(as N), mg/ℓ Finished
1	WB 27	28,800	1,000	Im	16	31	30	30	6.4	7.3	74	73	0.01
2	ISI	86,400	5,200	Im	19	25	30	32	7.0	7.4	72	72	0.06
3	WB 27	28,800	2,700	Im	65	72	215	219	7.1	7.3	68	72	0.38
4	WB 82	86,400	3,250	Im	98	102	114	106	7.9	7.7	75	81	0.07
5	WB 82	86,400	4,700	Im	90	97	115	120	8.0	8.3	81	84	< 0.01
6	WB 27	28,800	1,150	Im	108	110	118	118	7.4	7.6	79	79	0.04
7	Per. 48	69,120	6,000	Im	92	96	114	116	8.2	7.9	82	82	
8	Per.200	288,000	50,000	Ff	12	88	24	26	6.2	8.4	48	52	0.03
9	WB 82	86,400	1,250	Im	50	46	62	72	7.9	7.2	55	61	0.17
10	WB 82	86,400	6,300	Im	40	52	63	65	7.3	7.4	64	64	0.31
11	AQ 40	288,000	12,000	Im	80	75	110	112	7.2	7.0	58	58	0.21
12	WB 27	28,800	13,000	Ff	73	80	100	94	6.9	7.5	59	59	0.26
13	WB 27	28,800	3,000	Im	38	57	159	180	6.9	7.1	64	63	0.27
14	WB 82	86,400	3,600	Im	56	58	98	115	7.6	7.6	59	61	0.20
15	WB 133	144,000	33,400	Im	36	57	43	48	7.8	8.3	57	59	< 0.01

Water sources: Im - impounded surface water
Ff - free-flowing surface water

Table A-2. RECREATIONAL PLANTS (Cont.)

Plant No.	Fluoride, mg/ℓ Finished	Turbidity, NTU		Average Chemical Doses, mg/ℓ				Coliforms/100 mℓ		Free Chlorine residual, mg/ℓ	Trihalomethanes μg/ℓ
		Raw	Finished	Alum	Polyelectrolyte	Soda Ash	Other	Raw	Finished		
1	0.01	7.4	0.3	62	0.9	108		TNTC	0	0.4	95.0
2	0.02	6.0	0.4	30	0.7	31		TNTC	0	2.5 - 3.0	26.0
3	0.07	38.	0.4	48				166	0	1.0	4.7
4	0.12	2.6	2.1	10	1.2			4	0	1.0	98.0
5	0.11	28.	2.0	2	0.3			0	0	0.7	55.0
6	0.12	4.8	2.7	3	0.5			1	0	0.1 - 0.4	45.0
7	0.13	22.	2.5	2	0.5			0	0	2.0	70.3
8	0.01	2.8	0.5	83		88		TNTC	0	1.5	185.0
9	0.02	11.	1.0	680	0.9			0	0	0.2	23.6
10	0.06	5.0	2.5	10	2.8	9		25	0	1.8	45.0
11	0.03	2.5	0.5	33				TNTC	0	1.5	42.8
12	0.12	1.4	0.7	15				TNTC	0	2.0	64.0
13	0.20	> 100.	1.4	8	2.0			0	0	> 3.0	376.0
14	0.14	31.	12.	19	0.4			0	0	6.1	< 1.0
15	0.03	1.7	0.7	8		16		32	0	3.9	132.0

APPENDIX B

COST DATA FOR PACKAGE PLANTS

Table B-1. MUNICIPAL PLANTS

I.D.	Design	Treatment Operation Rate	Acquisition O&M	Treatment O&M	Chemical O&M	Distribution O&M	Support Services O&M	Total O&M	Power	Acquisition KI
1	288000.	97400.	456.	6752.	1970.	4981.	2069.	14258.	2113.	173040.
2	288000.	98500.	1250.	4184.	1200.	4420.	1053.	10907.	4282.	- 2.
3	288000.	75000.	1063.	4364.	607.	4076.	1028.	10531.	5314.	23359.
4	504000	147350.	1241.	10905.	1000.	10278.	5039.	27463.	6204.	17124.
5	288000.	105500.	2183.	11614.	505.	12766.	6301.	32864.	9406.	112895.
6	1440000.	860000.	4447.	33323.	6076.	31335.	11550.	80655.	18474.	93001.
7	1296000.	364000.	2158.	29947.	8732.	24173.	33193.	89471.	7994.	10500.
8.	806400.	233000.	3750.	23716.	7940.	19500.	9202.	56168.	18228.	15000.
9	504000.	229000.	2000.	23795.	3666.	28829.	14181.	68805.	8286.	81865.
10.	288000	114000.	1133.	9060.	300.	9100.	3473.	22766.	5666.	10000.
11.	288000	84300.	822.	6877.	2832.	4292.	9072.	21063.	4109.	0.
12.	504000.	80000.	411.	6265.	2174.	3690.	5024.	15420.	2639.	57192.
13	144000.	70000.	778.	1015.	-2.	1555.	58.	3406.	3348.	0.
14	288000.	70000.	604.	8068.	1648.	6601.	11450.	26723.	3021.	38410.
15	806400.	43200.	936.	6586.	767.	6100.	7376.	20998.	4681.	21221.
16	1008000.	450000.	-2.	22220.	3636.	-2.	-2.	-2.	-2.	12200.
17	288000	-2.	-2.	-2.	-2.	-2.	-2.	-2.	-2.	25332.
18	806400	-2.	-2.	-2.	-2.	-2.	-2.	-2.	-2.	50000.
19	504000.	-2.	-2.	-2.	-2.	-2.	-2.	-2.	-2.	4209.
Ave.	559326.3	195081.1	1550.8	13043.2	2870.2	11446.4	8004.6	33433.2	6917.7	41408.2

Table B-1. MUNICIPAL PLANTS (Cont.)

I.D.	Total Treatment KI	Plant Equipment KI	Treatment Building KI	Treatment Installation KI	Distribution Storage KI	Overhead KI	Interest	Total KI	Payroll O&M	Treatment Labor $
1	272593.	106593.	93737.	72264.	295295.	0.	25994.	740928.	10175.	4070.
2	196645.	122652.	25384.	48609.	16520.	0.	5003.	213165.	5425.	1920.
3	165031.	54180.	69795.	41056.	12317.	0.	7502.	200707.	4610.	1844.
4	199347.	88565.	64263.	46520.	438589.	11340.	23379.	666400.	19180.	7672.
5	225785.	58700.	111391.	55694.	2264095.	0.	26106.	2602775.	21000.	8400.
6	923415.	161203.	479911.	282301.	1610674.	123131.	69697.	2750222.	56105.	22442.
7	244841.	219533.	9047.	16261.	1551985.	-2.	11820.	1807326.	49640.	19856.
8	413850.	135000.	137250.	141600.	2110706.	-2.	33936.	2539556.	30000.	12000.
9	571440.	183201.	257428.	130811.	-2.	-2.	87619.	653304.	43080.	17709.
10	322025.	55000.	168127.	98898.	950970.	29670.	28859.	1312665.	16800.	6720.
11	339325.	60893.	185622.	92810.	327816.	0.	3522.	667141.	6415.	2566.
12	342662.	69440.	182688.	90131.	549053.	0.	18967.	948503.	7020.	2808.
13	97710.	43970.	24428.	29313.	445292.	-2.	10050.	543002.	-2.	-2.
14	133600.	53440.	53440.	26720.	542830.	-2.	18075.	714840.	1664.	5332.
15	457995.	124749.	234219.	99027.	986653.	0.	27172.	1265869.	10335.	4134.
16	430996.	93071.	135830.	202094.	153560.	-2.	23584.	596756.	18584.	18584.
17	363934.	69663.	196181.	98090.	710734.	0.	15700.	404966.	-2.	-2.
18	595965.	85000.	340643.	170322.	228712.	-2.	36500.	874677.	-2.	-2.
19	318067.	196881.	87890.	33196.	45716.	1564.	18400.	367992.	-2.	-2.
Ave.	348169.8	104301.7	150382.8	93458.8	724528.7	13808.	25888.7	1045831.4	20002.2	9070.5

Table B-1. MUNICIPAL PLANTS (Cont.)

I.D.	Treatment Energy	Lab Expense	Total Depreciation	CPI O&M	CPI Deprec. & KI
1	712.00	-2.00	37046.40	1.00	1.36
2	1064.00	0.00	10658.00	1.00	1.00
3	1913.00	-2.00	10034.91	1.00	1.29
4	2233.00	-2.00	33320.00	1.00	1.36
5	2709.00	670.00	130138.99	1.00	1.81
6	4805.00	-2.00	137511.23	1.00	1.11
7	1359.00	-2.00	61379.85	1.00	1.05
8	3776.00	-2.00	126978.00	1.00	1.50
9	2420.00	6215.00	32665.42	1.00	1.01
10	2040.00	-2.00	65633.00	1.00	1.00
11	1479.00	-2.00	33356.72	1.00	1.36
12	1283.00	-2.00	47425.28	1.00	2.24
13	1015.00	-2.00	27150.00	1.00	1.50
14	1088.00	-2.00	17114.16	1.00	1.67
15	1685.00	-2.00	63293.44	1.00	1.12
16	-2.00	-2.00	29837.54	1.01	1.22
17	-2.00	-2.00	20248.00	1.00	1.00
18	-2.00	-2.00	43734.00	1.00	1.00
19	-2.00	-2.00	18400.00	1.00	1.00
Ave.	1972.1	2295.0	49785.5		

Table B-2. RECREATIONAL PLANTS

I.D.	Design Flow	Treatment Operation Rate	Acquisition O&M	Treatment O&M	Chemical	Distribution O&M	Support Services O&M	Total O&M	Power	Acquisition KI
1	28800.	1000.	80.	2025.	143.	1906.	1127	5138.	400.	2040.
2	86400.	5200.	147.	3464.	186.	71.	260.	3942.	352.	2040.
3	28800.	2700.	132.	4569.	321.	52.	200.	4953.	244.	13362.
4	86400.	3250.	182.	2486.	68.	1617.	833.	5118.	404.	10500.
5	86400.	4700.	182.	2588.	170.	1617.	833.	5220.	404.	13100.
6	28800.	1150.	182.	2469.	52.	1617.	833.	5102.	404.	16700.
7	69120.	6000.	182.	2632.	214.	1617.	732.	5163.	404.	12200.
8	288000.	50000.	1095.	4317.	1315.	4754.	4090.	14256.	3176.	-2.
9	86400.	1250.	392.	1443.	350.	187.	220.	2242.	932.	97071.
10	86400.	6300.	1800.	2389.	379.	300.	100.	4589.	1800.	59393.
11	288000.	12000.	480.	3722.	170.	3696.	1392.	9290.	2400.	10500.
12	28800.	13000.	396.	5603.	1050.	832.	39.	6870.	1980.	5240.
13	28800.	3000.	146.	924.	122.	307.	255.	1632.	731.	80199.
14	86400.	3600.	353.	1811.	75.	35.	104.	2303.	882.	14443.
15	144000.	144000.	10.	4539.	890.	880.	485.	5914.	1795.	6477.
16	504000.	302400.	-2.	-2.	-2.	-2.	-2.	-2.	-2.	213754.
17	86400.	-2.	-2.	-2.	-2.	-2.	-2.	-2.	-2.	3750.
Ave.	120112.9	34971.9	383.9	2998.8	366.9	1299.2	766.9	5448.7	1087.3	35048.1

Table B-2. RECREATIONAL PLANTS (Cont.)

I.D.	Total Treatment KI	Plant Equipment KI	Treatment Building KI	Treatment Installation KI	Distribution Storage KI	Overhead KI	Interest	Total KI	Payroll O&M	Treatment Labor $
1	56100.	17850.	20400.	17850.	2040.	0.	2111.	60180.	4095.	1738.
2	74800.	34000.	6800.	34000.	-2.	0.	2696.	76840.	3151.	3151.
3	47237.	17063.	12873.	17301.	40898.	0.	3697.	101497.	4136.	4120.
4	136500.	20370.	77420.	38710.	79800.	0.	10617.	226800.	4545.	2273.
5	72050.	20174.	34584.	17292.	55020.	0.	5105.	140170.	4545.	2273.
6	66800.	25050.	41750.	0.	58450.	0.	3963.	141950.	4444.	2273.
7	79300.	19520.	42700.	17080.	75640.	0.	6605.	167140.	3829.	2273.
8	-2.	-2.	-2.	-2.	-2.	-2.	-2.	-2.	6135.	2454.
9	106405	53992.	38062.	14351.	236617.	0.	16029.	440093.	758.	758.
10	90525.	38823.	37581.	14121.	41111.	0.	8942.	191029.	2410.	1410.
11	454230.	50820.	268940.	134470.	-2.	0.	21754.	464730.	6720.	2688.
12	22139.	8450.	5240.	8450.	29344.	0.	1940.	56723.	3840.	3840.
13	115289.	59920.	40249.	15120.	16100.	0.	9199.	211588.	539.	539.
14	161600.	30805.	87196.	43599.	27427.	0.	9990.	203470.	1260.	1260.
15	151225.	58670.	51467.	41089.	112885.	-2.	12668.	270617.	2779.	2779.
16	99431.	-2.	-2.	-2.	567035.	1029.	35423.	880219.	-2.	-2.
17	40866	21000.	13244.	6622.	27892.	0.	3625.	72508.	-2.	-2.
Ave.	110906.1	31767.	51900.4	28003.7	97875.7	68.6	9647.8	231597.1	3545.7	2255.1

Table B-2. RECREATIONAL PLANTS (Cont.)

I.D.	Treatment Energy	Lab Expense	Total Depreciation	CPI O&M	CPI Deprec. & KI
1	144.00	250.00	3008.32	1.00	1.36
2	127.26	252.50	3842.00	1.01	1.36
3	128.00	100.00	5074.94	1.00	1.31
4	145.44	101.00	11340.00	1.01	1.05
5	145.44	101.00	7008.50	1.01	1.31
6	145.44	101.00	7097.50	1.01	1.67
7	145.44	101.00	8357.00	1.01	1.22
8	548.00	-2.00	-2.00	1.00	1.00
9	335.32	202.00	22004.07	1.01	1.31
10	600.00	0.00	9551.85	1.00	1.05
11	864.00	-2.00	23236.50	1.00	1.05
12	713.00	0.00	2836.15	1.00	1.31
13	263.00	0.00	10579.52	1.00	1.12
14	476.00	0.00	10173.73	1.00	1.01
15	870.00	0.00	13530.30	1.00	1.05
16	-2.00	-2.00	29911.20	1.00	1.21
17	-2.00	-2.00	3625.00	1.00	1.00
Ave.	376.7	92.9	10698.5		

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

Many small and rural water systems have both cost and quality problems. Their unit costs tend to be higher because of the small number of connections they service. As shown by the Community Water Supply Survey of 1969 many small systems have trouble meeting minimal drinking water standards. Their problems are likely to be compounded in the future as drinking water standards are raised. The cost of building a conventional water treatment plant to provide higher quality water for a small community may be prohibitive. Package water treatment plants are a possible alternative to conventional water treatment. These plants are self-contained units that can be installed for minimum cost.

Results from a study of 36 package plants in Kentucky, West Virginia and Tennessee show that these treatment plants can provide water that meets the turbidity limits established under the National Interim Primary Drinking Water Standards. However, as with all treatment plants, proper operation is required. These plants, contrary to some manufacturers' claims, are not totally automatic but require supervision. Nevertheless when properly maintained and operated, they can provide good quality drinking water at minimum cost.

This volume (Volume 1) contains performance data from the study with minimal cost data and represents primarily the efforts of investigators from the University of Cinti who participated with EPA. Volume 2 is the in-house analysis of the cost data resulting from the project.

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