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I am submitting herewith a thesis written by Farhad Forouzesh entitled "A Case Study of Public Water Supplies in the East Tennessee Development District." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Water Resources Development.

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Vice Chancellor
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A CASE STUDY OF PUBLIC WATER SUPPLIES IN THE EAST TENNESSEE DEVELOPMENT DISTRICT

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Farhad Forouzesh

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1356413

DEDICATION

This thesis is dedicated to my parents, Mrs. Homa Forouzesh and Mahmoud Forouzesh, M.D., for their patience and concern.

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ABSTRACT

This paper reviews the deficiencies in small public water supply systems in the East Tennessee Development District. According to the Tennessee Department of Public Health, the deficiencies are categorized into water quality, physical equipment, and operation. The purpose of this study is not to promote comparison of one system with another or to evaluate state inspection programs. Taken as a group, the deficiencies in small public water supply systems are analyzed.

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CHAPTER I

INTRODUCTION

Background

The quality of life and economic well-being of the people in East Tennessee are greatly dependent upon the availability of quality water in adequate quantities. Today Americans use approximately 150 to 200 gallons per capita per day (gpcd) of water (including commercial usage) and domestic use is approximately 60 gpcd.[1]

On the average, over 37 billion gallons of water are consumed daily in this country. Most of it is treated by a public water utility (approximately 70 percent of the water supply systems in the country are publicly owned).[2]

On a production basis, the water supply industry is by far the largest in the United States. It produces more tonnage in less than two days than the entire steel industry produces in a year. In less than eight days it produces more gallons than the annual total of oil industry production. It must operate but seven days to match the yearly

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[1]J. Michael La Nier, Journal of American Water Works Association (AWWA), Vol. 68, No. 4, April 1976, p. 173.

[2]Ibid., p. 173.

tonnage of bituminous coal produced.[3] Water is also transported on a tremendous scale. Water utilities transport over 80 million tons of safe drinking water every day. In less than a month, a greater tonnage of water is transported than all of the tonnage transported by railroads in the United States in one year.[4]

The production of water is important not only because it is the largest industry in production and transportation but also because it is the most essential industry from the standpoint of need. Life is impossible without an ample supply of safe, wholesome water.[5]

No other industry has the responsibility that is inherent in the water supply industry. Every water utility has the life, health, safety, and welfare of the people it serves at stake 24 hours a day; it cannot afford mistakes. Therefore, it must be operated by competent people. Each employee must realize this responsibility and be dedicated to giving his best possible service.[6]

Ideally, water delivered to the consumers should be clear, colorless, odorless, and of good taste. It should

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[3]Garvin H. Dyer, Journal of AWWA, "Manpower: The Important Element in Providing Quality Water Service," Vol. 66, No. 7, July 1974, p. 434.

[4]Ibid., p. 434.

[5]Ibid., p. 434.

[6]Ibid., p. 435.

contain no pathogenic organisms, and it should not contain chemicals that may be physiologically harmful or economically damaging. The water should not be corrosive nor incrusting, and should not leave deposits on water-conveying structures through which it passes or in which it may be retained,[7] including all pipes, tanks, water heaters, and plumbing features. The water should be adequately protected by natural processes, or by treatment processes, which insure consistency in quality.[8]

The purpose of a water treatment plant is to produce a quality of water that will protect and promote the health and well-being of the community. To supply that type of water described by all water utilities would be practically impossible and economically unjustifiable. "For this reason, minimum standards such as the Drinking Water Standards for water quality have been adopted."[9] The "Drinking Water Standards" act was first promulgated in 1914 and was revised in 1925, 1942, 1962, and 1972,[10] and is currently (1977) being revised.

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[7]Public Water Supply Treatment Technology AWWA, "Report on Water Quality Management for Office of Water Resources Research," U.S. Department of the Interior, 1973, p. 159.

[8]Ibid., p. 159.

[9]Ibid., p. 159.

[10]Ibid., p. 159.

Generally, however, economics rather than scientific know-how usually dictate the extent that the utility will go in upgrading the quality of its water above the local, state, and national acceptable standards. The smaller systems (which comprise a large majority of the waterworks in the United States) frequently find it difficult to provide water complying with established standards. In fact, many small public water systems fail to meet all aspects of the quality standards on a continuous basis. Studies have shown that a higher percentage of epidemics occur in the systems supplying under 5,000 persons.[11]

The quality of service from many small public water supply systems is far from satisfactory. The average size supplier has fewer than 2,000 customers. Deficiencies in quality have been shown to be inversely proportional to the size of the water supply systems. Most of the small suppliers do not have the benefit of services of full-time qualified operators, nor do they have high quality engineering in their conception, design, and construction.[12]

The domestic water-supply industry is caught between two strong trends in water quality. On the one hand, domestic and industrial customers are demanding improved quality and greater uniformity in the water delivered to the

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[11]Ibid., p. 15.

[12]Ibid., p. 5.

tap. On the other hand, the sources of raw water have been deteriorating under the impact of modern civilization and may be expected to get worse in future years if the present technological trends continue. The waterworks industry, therefore, must produce a better and more uniform product while drawing upon a poorer and less predictable source of supply.[13]

The Role of the Tennessee Department of Public Health (TDPH)

The water quality specialists from the TDPH, Division of Water Quality, periodically visit and inspect public water systems in the East Tennessee Development District (ETDD). Each public water system is rated according to the TDPH rating form (see Public Water System Rating Form, Division of Sanitary Engineering, TDPH, in Appendix). The rating is categorized into three major categories: water quality (58), physical equipment (21), and operation (21) points. In addition, each category is broken down into minor categories as well as subcategories.

Deficiency points for each item not meeting prescribed standards are added, then subtracted from an optimal score of 100. Any public water system with total scores ranging between 90 and 100 is approved by the TDPH. Any system with points between 64 and 89 is provisionally approved.

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[13]Ibid., p. 1.

Consequently, all systems with total points below 64 are unsatisfactory. Each inspection rating covers the visit, past records, previous rating score, and recommendations on deficiency.

Utility Districts in Tennessee--Organization, Management and Personnel

The Utility District Act of 1937 authorized the formation of special purpose units of government, called utility districts, to provide any of a number of services, including water supply, to residents within its boundaries. The Utility District Act has been amended several times, most recently in 1974.[14]

There is no formal administrative structure or hierarchy found below the level of the board of commissioners in the utility districts of Tennessee. Below the level of the board of commissioners, one may find either a part- or full-time employee as well as a number of subordinate personnel assigned to functions such as bookkeeping, plant operation, maintenance, and meter reading. This pattern of functional organization is reflected in Figure 1. The commissioners receive no formal salary for the services but are compensated for any expense they may incur in performing their duties. The board makes all rules and regulations

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[14]M. Robinson Nelson and John R. Petty, Public Utility Services in Tennessee, A Study Subcommittee of the Tennessee Legislative Council Committee, p. 23, 1966.

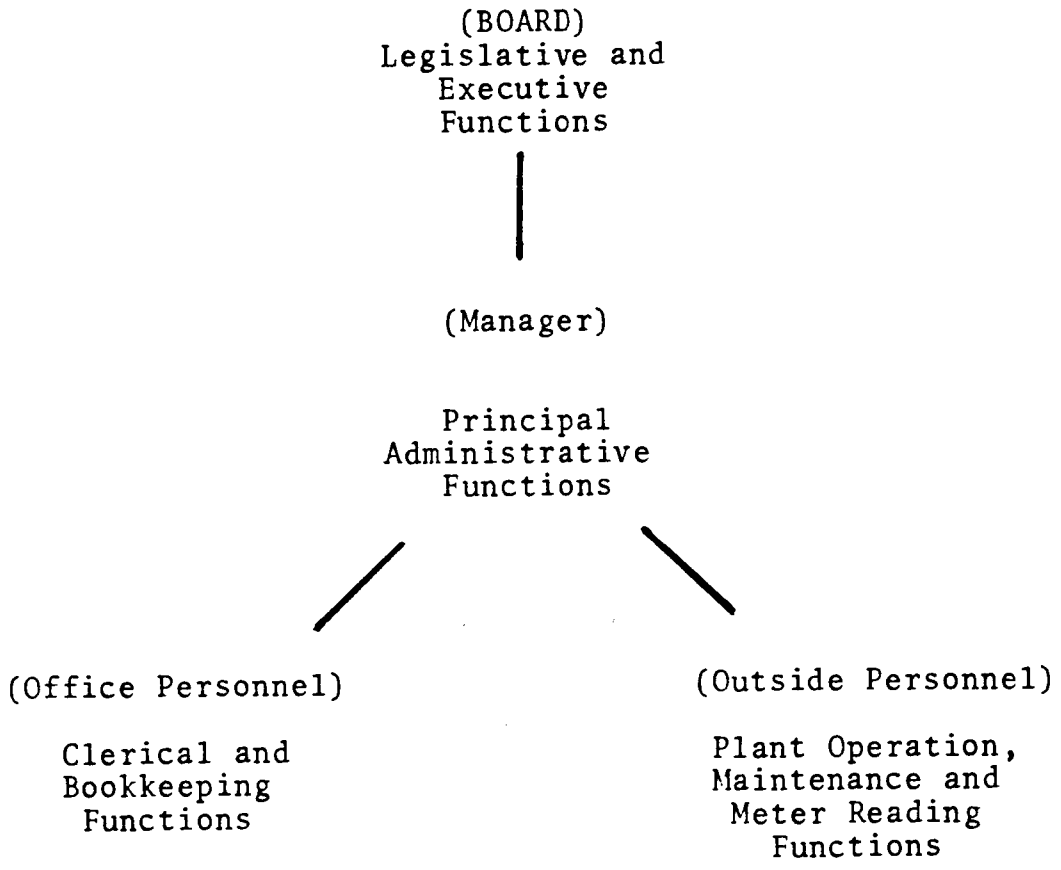

Figure 1. Organizational distribution of function in a typical Tennessee Utility District.

Source: Public Utility Services in Tennessee, a Study for Subcommittee I of the Tennessee Legislative Council Committee, p. 8C, 1966.

necessary for the management of the district, including the determination of salaries of the district officers.[15]

Tennessee utility districts are not required to inform any state agency as to the fact of their existence. Neither their conduct nor their rates are subject to regulation by the public service commission. The only agency to which they are answerable in any way is TDPH. The general law does not provide for the termination or dissolution of utility districts which have failed to render assigned services or outlined their usefulness. However, it is in the area of public control where utility districts are most deficient. It does not appear that they are controlled or supervised in a democratic manner for a corporation which performs a public service.

The principle of self-support should be sufficient for a financial base in the utility districts which are witnessing a good deal of growth and have a sizeable service area. However, in areas which are not experiencing growth, an inability to generate additional revenue through new customers makes self-support difficult to maintain.

"In more than half of these districts, however, a nearby municipality or larger utility district is the source from which the district obtains its water, and these larger utilities perform many of the key operational functions

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[15]Ibid., p. 77a.

associated with the provision of water service."[16] In the smaller districts, the board of commissioners will often perform the managerial function. In many of the larger districts, the manager will formulate policy and recommendations for the consideration of the board.

Generally, the more elaborate plant and organizational structures are associated with utility districts which are relatively large, in terms of number of customers and service area.

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[16]Ibid., p. 83.

CHAPTER II

OBJECTIVES

The objectives of this study are:

1. To present the deficiencies in water quality, physical equipment, and operation of 146 public water supplies in ETDD.

2. To report the public water supply systems classification according to the TDPH standards as follows:

   a. The systems that meet the TDPH approved standards.

   b. The systems that do not meet the TDPH approved standards.

   c. The systems that have not been rated.

3. To focus attention on the public water supplies which are rated below the TDPH approved standards.

CHAPTER III

PROCEDURE

In determining the deficiencies in the public water supplies, it is necessary to obtain information on water quality, physical equipment, and operation. The three categories determine existing standards for the public water supplies in the ETDD. The physical equipment and operation categories have indirect effects on water quality.

The water quality specialists of the TDPH in Knoxville periodically inspect public water supplies to insure that the system is operating and meeting all standards required by the TDPH. The visits of water quality specialists consist of examining past records, pointing out deficiencies, and making recommendations.

Ten selected public water supplies in ETDD were visited to obtain information concerning the deficiencies in water quality, physical equipment, and operation. In addition, 20 public water supplies were visited for interview. Small as well as large systems were studied in order to provide information on existing deficiencies.

Two visits to the TDPH in Nashville provided information on utility district problems. The visits also provided the interviews with five TDPH officials concerning operational deficiencies and the different alternatives to eliminate such deficiencies in Tennessee.

CHAPTER IV

RESULTS

Chapter IV includes a statistical analysis of the public water supplies in ETDD serving an approximate population of 507,560 (total population of ETDD, 758,900).

It was found that 45 public water supplies (serving a population over 100,000) were rated below the TDPH approved standards (Table I).

This analysis indicates that only a minority of systems (39) are presently meeting the TDPH approved standards; they serve a total population of 400,000 (Table II) based upon data from TDPH.

Sixty-two public water supplies that have not been rated by TDPH now serve a population of 6,000. These systems are so small that each serves 500 or less customers.

Based upon the TDPH data, the total of 33 utility districts were rated and only 51 percent approved (see Table III).

Among these 45 public water supplies which do not meet TDPH approved standards, certain deficiencies are evident. The following chapter observes the extent and type of these deficiencies and the problems they cause in public water systems.

TABLE I

146 PUBLIC WATER SUPPLIES IN THE ETDD, 1977

County	Number of Water Supplies	Under 5,000*	Rated Above 90	Rated Below 90	Number of Water Systems**
Anderson	8	7	3	4	1
Blount	14	11	4	5	5
Campbell	8	7	3	0	5
Claiborne	11	11	3	0	8
Cocke	11	10	2	1	8
Grainger	3	3	1	1	1
Hamblen	7	4	3	1	3
Jefferson	11	10	4	4	3
Knox	12	6	7	2	3
Loudon	8	6	2	3	3
Monroe	9	8	2	4	3
Morgan	4	4	1	2	1
Roane	15	13	2	8	5
Scott	2	2	0	2	0
Sevier	18	17	2	6	10
Union	5	5	0	2	3
Totals	146	124	39	45	62

* = Population served.

** = Not rated.

Source: Tennessee Department of Public Health, Community Water Systems in Tennessee, July 1977.

TABLE II

APPROVAL OF PUBLIC WATER SUPPLIES IN THE ETDD, 1977[a]
(COMMUNITY WATER SYSTEMS)

Number of Public Water Supply Customers	Community Water Systems in ETDD		
	Number Rated	Number Approved	Percent Approved
500 or less	14	3	21
501 - 1000	8	2	25
1001 - 2000	16	4	25
2001 - 5000	24	14	58
5000+	22	16	73
Totals	84	39	46

[a]A rating of 90 is required for an approved water system.

Source: Tennessee Department of Public Health, Community Water Systems in Tennessee, July 1977.

TABLE III

APPROVAL OF PUBLIC WATER SUPPLIES IN THE ETDD, 1977[a]
(UTILITY DISTRICTS)

Number of Public Water Supply Customers	Utility Districts		
	Number Rated	Number Approved	Percent Approved
500 or less	4	0	0
501 - 1000	2	1	50
1001 - 2000	5	1	20
2001 - 5000	15	9	60
5000+	9	6	67
Totals	33	17	51

[a]A rating of 90 is required for an approved water system.

Source: Tennessee Department of Public Health, Community Water Systems in Tennessee, July 1977.

CHAPTER V

DISCUSSION

The analysis of 31 public water supplies below the TDPH approved standards indicated that the water systems operation was shown to be deficient in the ETDD.

The deficiencies were categorized into water quality, physical equipment, and operation. It is not the purpose of the data to promote comparison of one system with another or evaluate state inspection programs. Taken as a group, the public water supplies showed significant deficiencies (see Appendix).

A related deficiency common to water quality problems involved the distribution system, reservoirs and tanks, cross connection, management and training, and bacteriological quality (Table IV).

Water Quality Problems in Distribution System, Reservoirs and Tanks

The water quality problems in the distribution system are predominantly those of non-harmful nature. Unpleasant taste and odor and colored water at the consumer's tap are the largest source of complaints for most public water supplies. These problems of quality deterioration are probably caused by any of a number of factors, such as poor quality water put into the distribution system. Chemical interaction of water with pipe material, biological

TABLE IV

THIRTY-ONE PUBLIC WATER SUPPLIES BELOW THE TDPH APPROVED STANDARDS, 1977 (WATER QUALITY, PHYSICAL EQUIPMENT AND OPERATION DEFICIENCY)

Description	Percent with Deficiencies
Chemical Characteristics	61
Bacteriological Quality	68
Source of Supply	42
Cross Connections	90
Distribution System, Reservoirs, and Tanks	84
Laboratory Control of Treatment	42
Equipment, Buildings, and Grounds	52
Treatment Facilities	68
Laboratory Facilities	29
Distribution System Piping	52
Certified Operator	49
Maintenance of Equipment, Buildings, and Grounds	26
Cooperation with Department	77

Source: Tennessee Department of Public Health, Public Water Supplies, 1977.

degradation, cross connections, inadequate disinfection procedures, defects in design and construction of different components of the distribution system, poor operation and maintenance.

The design of the distribution system, its layout, selection of proper pipe size and material, installation practices, system valving, operating and maintenance procedures are very important in maintaining water quality in the distribution system.

A properly designed distribution system is an integral part of the quality control program. Lack of proper circulation in the system and dead ends tends to cause a deterioration of the quality of the water with time. Improper location of hydrants and blowoffs may fail to adequately aid in the flushing program.

Improper selection of pipe size and its material has had a marked effect on the hydraulic adequacy and the degradation of the water quality. A total of 29 percent had problems with the kind, size, and location of mains. Careful consideration must be given to the types and volumes of water to be transported, the turnover rate of water in the pipe, and the environment of soils in which the pipe is laid. Unlined or unprotected cast iron and steel pipes are subject to corrosion.

Negative pressures in the distribution system can contribute to water quality problems by allowing infiltration

or back-flow of undesirable materials. Negative or low pressures occur in the distribution system from several primary causes, such as insufficient hydraulic capacity, main breaks, planned or unplanned shutdowns, excessive leakage from the distribution system, and many others.

In practice, every public water supply should inspect the system continuously and locate low and negative pressures and determine the cause. Solutions to such problems include a pipe replacement program, development of a more adequate supply system, addition of major feeders in the transmission system, addition of more frequent and better located valving systems and installation of booster pumping stations or increased pumping facilities in existing stations.

Good operating practices require making surveys to prevent leakage. The value of surveys is to avoid the burden created by added costs of pumping to maintain desirable pressure levels. The control of leakage reduces capital expenditures to provide additional plant capacity due to inefficient utilization of existing facilities, the shortened useful life of the facilities and the increased maximum hour demands.

Failure to maintain a chlorine residual throughout the distribution system was a common operational failure (32 percent).

Many reservoir tanks now in use have created problems because of material and construction design. Studies indicate that 29 percent failed to have maintenance of reservoirs or tanks.

Cross Connection Problems

Of all the problems of contamination in the distribution system, probably the most serious are caused by cross connections. The potential effects of cross connections are so serious that immediate discontinuation of potable water service may be affected if appropriate protection is not provided to the customer.

The two main categories of cross connections are backflow and backsiphonage. Backflow is the flow of liquids, mixtures, or substances into the distribution system of a potable water supply from a source other than the intended source. Backsiphonage is the flowing back of used, contaminated or polluted water from a plumbing fixture or vessel or other sources into the distribution system due to a negative pressure in such a pipe.

Generally, the responsibility for the cross connection control program is divided among the health agency, the plumbing inspector, the water purveyor and the consumer.

The health agency is responsible for enforcing the laws and regulations necessary to insure that the public water system is free of unprotected cross connections. A common practice is to have a plumbing inspection department enforce proper practices for installing, modifying, or adding, to any piping system that is connected to a potable water system.

The water purveyor has the overall responsibility of

protecting the public water distribution system from contamination. It is the responsibility of the health agency, the plumbing inspector, and the purveyor, as well as the consumer, to determine the extent of a hazard to the public potable supply and see that any hazard that might contaminate the public potable supply is eliminated. The purveyor has the authority to discontinue service to any user who does not comply with cross connection rules. The customer has the primary responsibility of preventing contaminants from entering the potable water system. A total of 90 percent public water supplies failed to have cross-connection deficiency.

Management and Training Problems

It is rather difficult to discuss the quality aspects of the distribution system without looking at the overall picture including all parts of the public water supply system and the personnel associated with the water quality. For the public water supplies to be successful in meeting its overall obligations, including quality aspects of its distribution system, management should be customer-oriented, future-oriented, profit-oriented, and board-oriented. The public water supplies must continue to recruit ever more qualified people, and encourage continued training to develop and keep up with the new technology. They must develop the means to attract

qualified personnel. Training and certification of operators have had a great impact on public water supplies. Studies indicate that those trained and certified operate better (although not necessarily faultlessly) water systems. However, a great deal has to be done in order to upgrade the training and reach the remaining 49 percent who are not certified. However, studies indicate that 77 percent of public water supplies failed to cooperate with the TDPH. The public water supply manager has the responsibility to submit operation reports to the state agency for the evaluation of overall operations in determining the reliability of the system.

The Bacteriological Quality

Bacteria of one form or another are, in all probability, not present in the water as it enters a distribution system. As potable water moves through a distribution system, it is possible that bacteria, or other contaminants, can enter the system. However, those of concern are the pathogenic or disease-causing organisms which can inhabit the intestinal tract of man and are excreted in the feces, thus entering sources of water supplies through domestic wastes. "Coliform" bacteria, although they are not pathogenic in most cases, are the most common inhabitant of the intestinal tract of man. They are excreted in great numbers along with any pathogens which may be present and thus can be indicators of possible harmful fecal contamination.

Bacteriological quality of public water systems was judged by comparing the bacteriological sampling record compiled during the previous twelve months against the Drinking Water Standards. Only samples collected from varying points through the distribution system should be counted as official samples. The minimum number of samples to be collected each month should be in accordance with population served. When a sample is positive, daily samples from the same sampling point should be collected promptly and examined until the results obtained from at least two consecutive samples indicate the water to be of satisfactory quality. Any system failing to meet the bacteriological limits during one or more of these months was considered to have failed the bacteriological standards. The bacteriological samples submitted on a monthly basis appear to demonstrate a significant deficiency in the public water system (68 percent did not submit bacteriological samples).

CHAPTER VI

CONCLUSION

The data indicated that small water supply systems are significantly deficient in water quality, physical equipment and operation. In general, the smaller the particular system, the more deficient its level of operation appeared to be.

Water quality testing was based on the chemical, physical and bacteriological sampling records. A few chemical analyses failed to meet recommended standards. Physical characteristics were not shown to be a problem to the small public water supply systems under study. The bacteriological samples submitted on a monthly basis appear to demonstrate a significant deficiency of the available data. It was impossible to document any response whatsoever to unsatisfactory quality.

The cross connection programs were deficient in the following areas:

1. No on-going cross connection program.
2. No cross connection ordinance.
3. No signed statement sent to the department.

Two common operational deficiencies were failure to maintain a chlorine residual throughout the distribution system and failure to routinely flush the system. No system

was found to have disinfection and contamination problems.

Training and certification of operators have had a beneficial impact on the small public water supply systems. Data have indicated that trained and certified personnel operate better systems. A great deal has to be done, however, to upgrade the training and certification program to reach the remaining percentage of those who are not certified.

The data showed that larger public water supply systems had fewer deficiencies than smaller systems. In all but the largest operations, the TDPH, in 1977, approved a greater percentage of municipal systems rather than utility districts.

CHAPTER VII

RECOMMENDATIONS

The following recommendations are made:

1. The appropriate governing authorities should initiate action to upgrade existing utility systems in the ETDD and to correct all deficiencies.

2. A study should be made on the effect of expanding existing water utility districts on a regular basis rather than to establish new systems on a county level.

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APPENDIX

APPENDIX

DEFICIENCIES OF THIRTY-ONE PUBLIC WATER SUPPLIES IN ETDD

Water Quality Deficiencies

The classification of water quality is broken down into seven categories: (1) physical characteristics, (2) chemical characteristics, (3) bacteriological quality, (4) source of supply, (5) cross connection, (6) distribution system, reservoirs and tanks and lastly, (7) operation and laboratory control of treatment works.

The analysis indicated that 90 percent of public water utility systems had cross connection problems and 84 percent had problems with the distribution systems, reservoirs, and tanks. Also, tabulations showed that 68 percent of systems had difficulties with bacteriological quality; 61 percent had difficulty with chemical characteristics. Only 42 percent of the existing systems were confronted with both sources of supply, operation, and laboratory control of treatment work problems. Fortunately, no system had problems with the physical characteristics (Figure 2).

Physical Equipment Deficiencies

The divisions of physical equipment were classified into four categories: (1) equipment, building, and grounds,

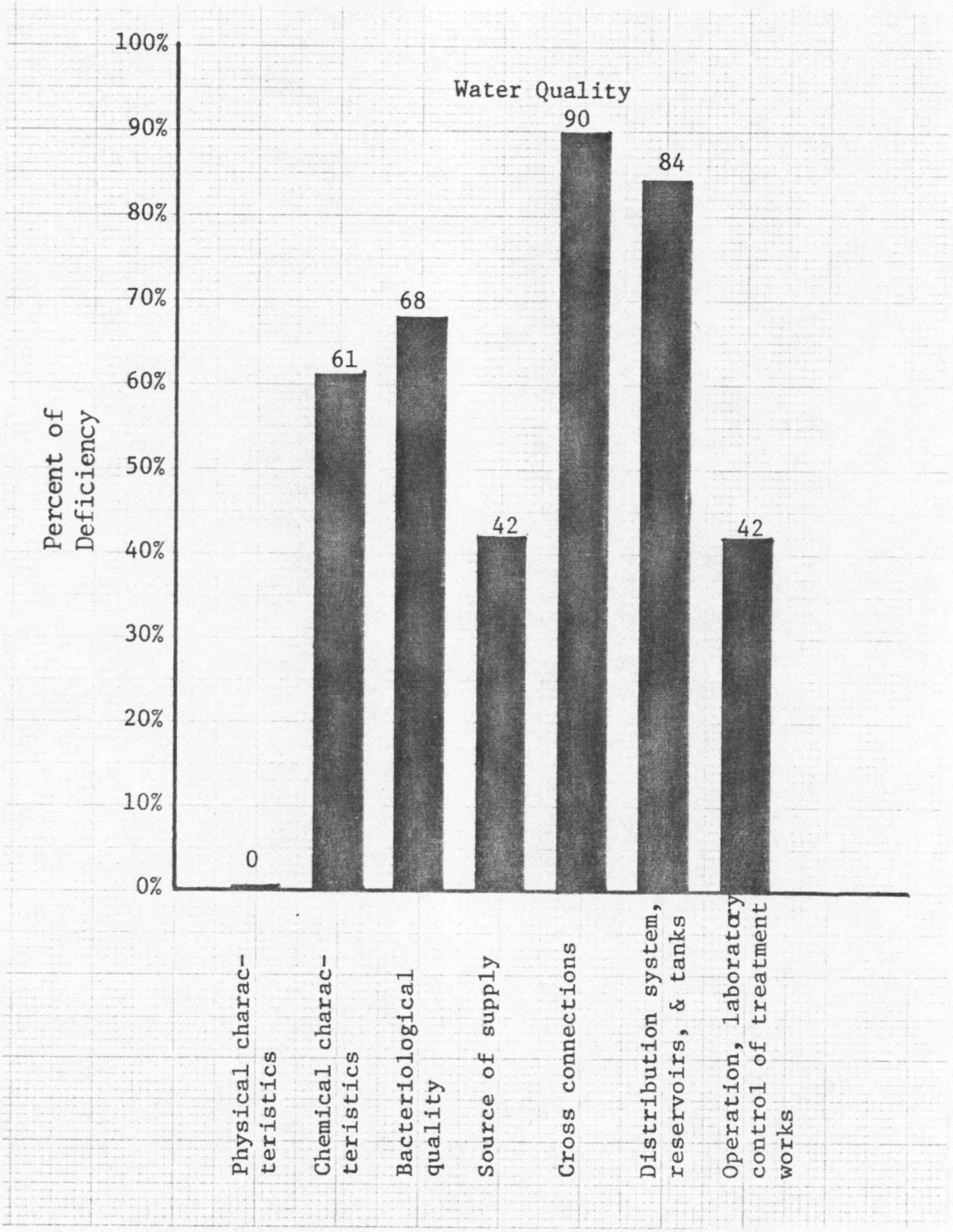

Figure 2. Water quality. Major deficiencies in water quality (31 public water supplies in the ETDD, 1977).

(2) treatment facilities, (3) laboratory facilities, and (4) distribution and system piping.

The division of physical equipment indicated that 52 percent of the systems had problems with equipment, buildings, grounds, and also the distribution system piping. In the area of laboratory facilities, only 29 percent had deficiencies; most problems (68 percent) were existent in the category of inadequate treatment facilities (Figures 3).

Operation Deficiencies

Operation deficiencies included three categories: (1) certified operator, (2) maintenance of equipment, buildings, and grounds, and (3) cooperation with the department. Problems were existent in all three categories. A number of certified operator positions (49 percent) was vacant; and 26 percent reported difficulties in the maintenance of equipment, buildings, and grounds. A majority of problems (77 percent) resulted in a lack of cooperation with the TDPH (Figure 4).

Water Quality Deficiencies (Subcategories)

Physical characteristics. Physical characteristics were not shown to be a problem to the small public water utility system under study (Figure 5).

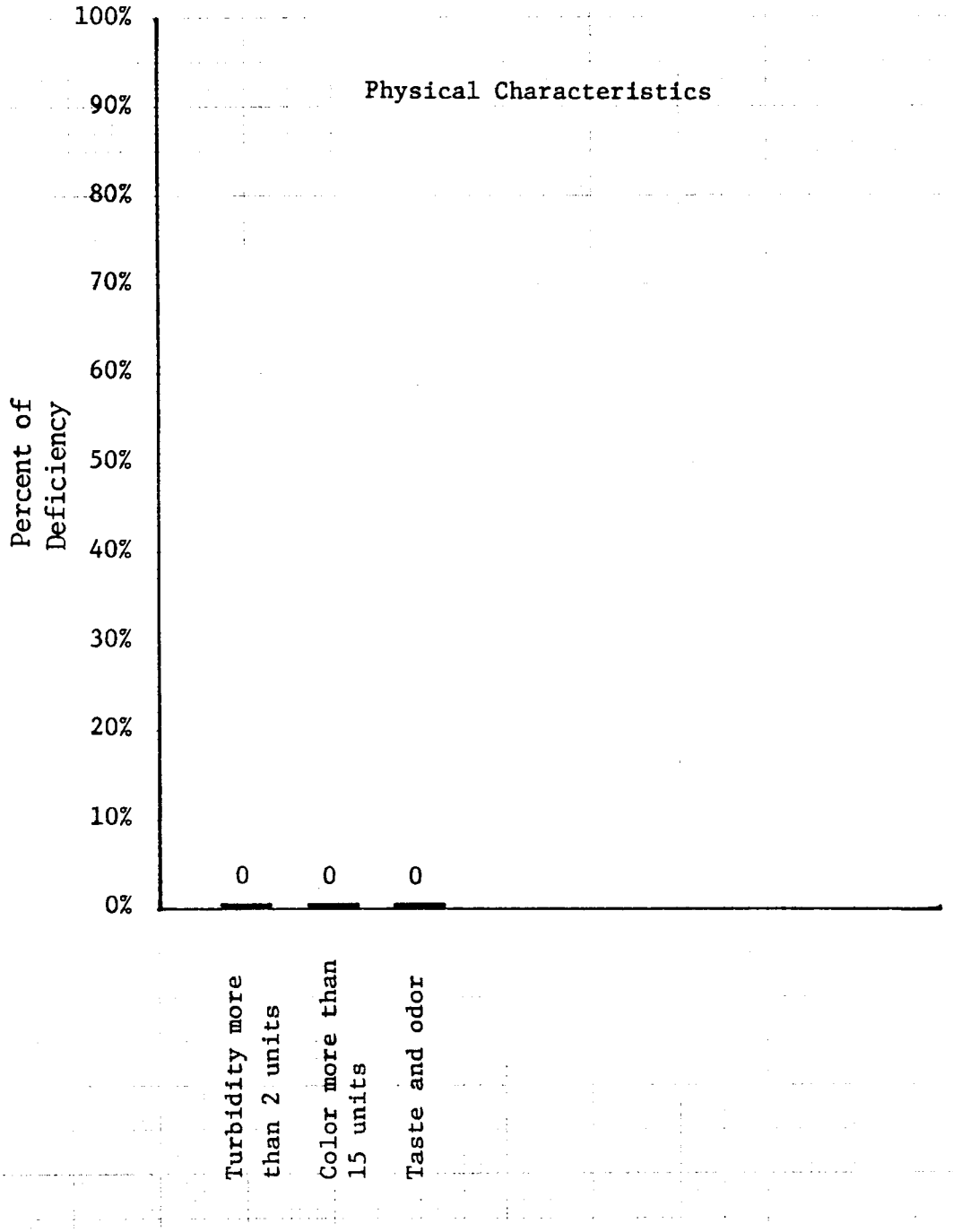

Figure 3. Physical equipment. Major deficiencies in physical equipment (31 public water supplies in the ETDD, 1977).

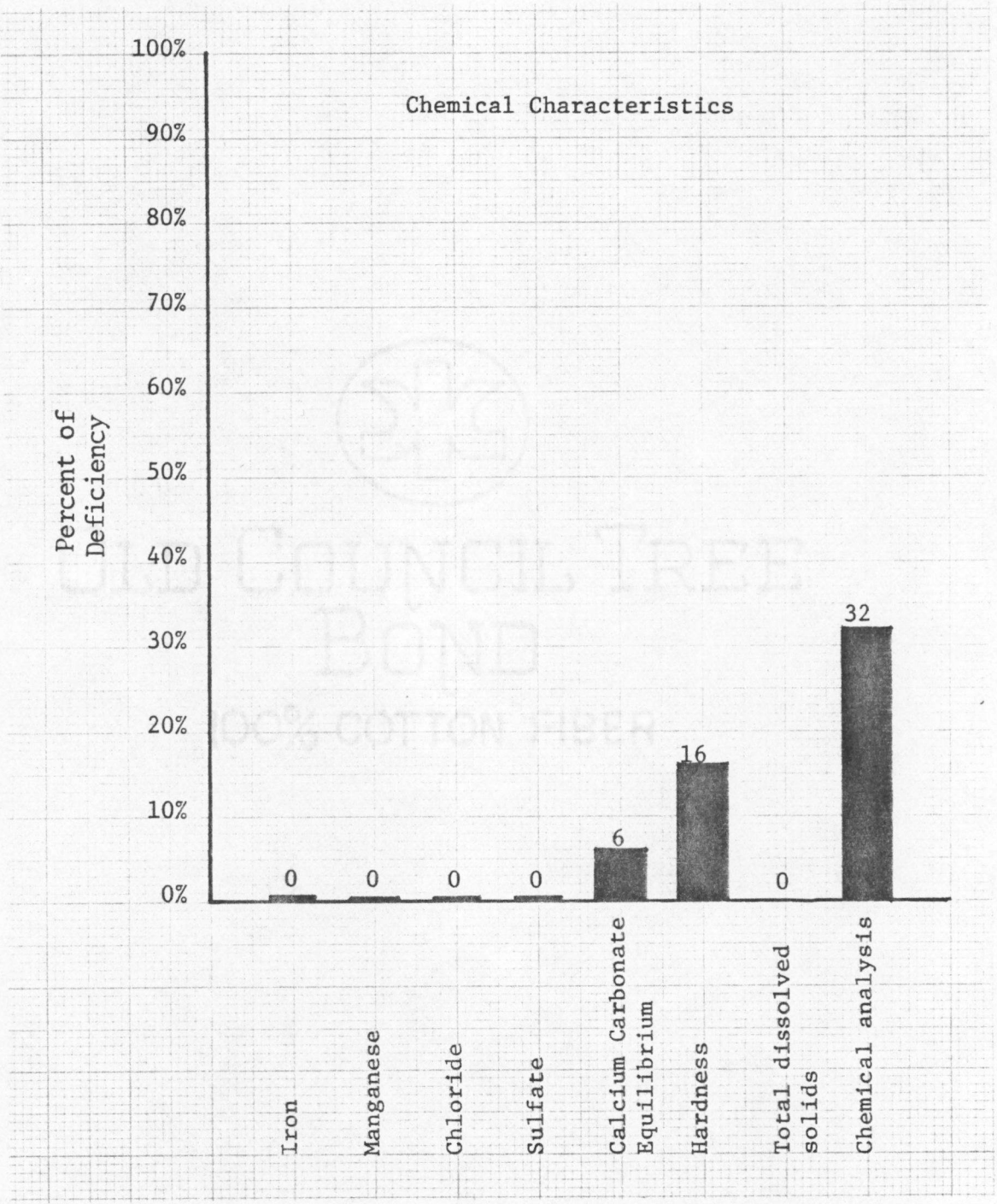

Figure 4. Operation. Major deficiencies in operation (31 public water supplies in the ETDD, 1977).

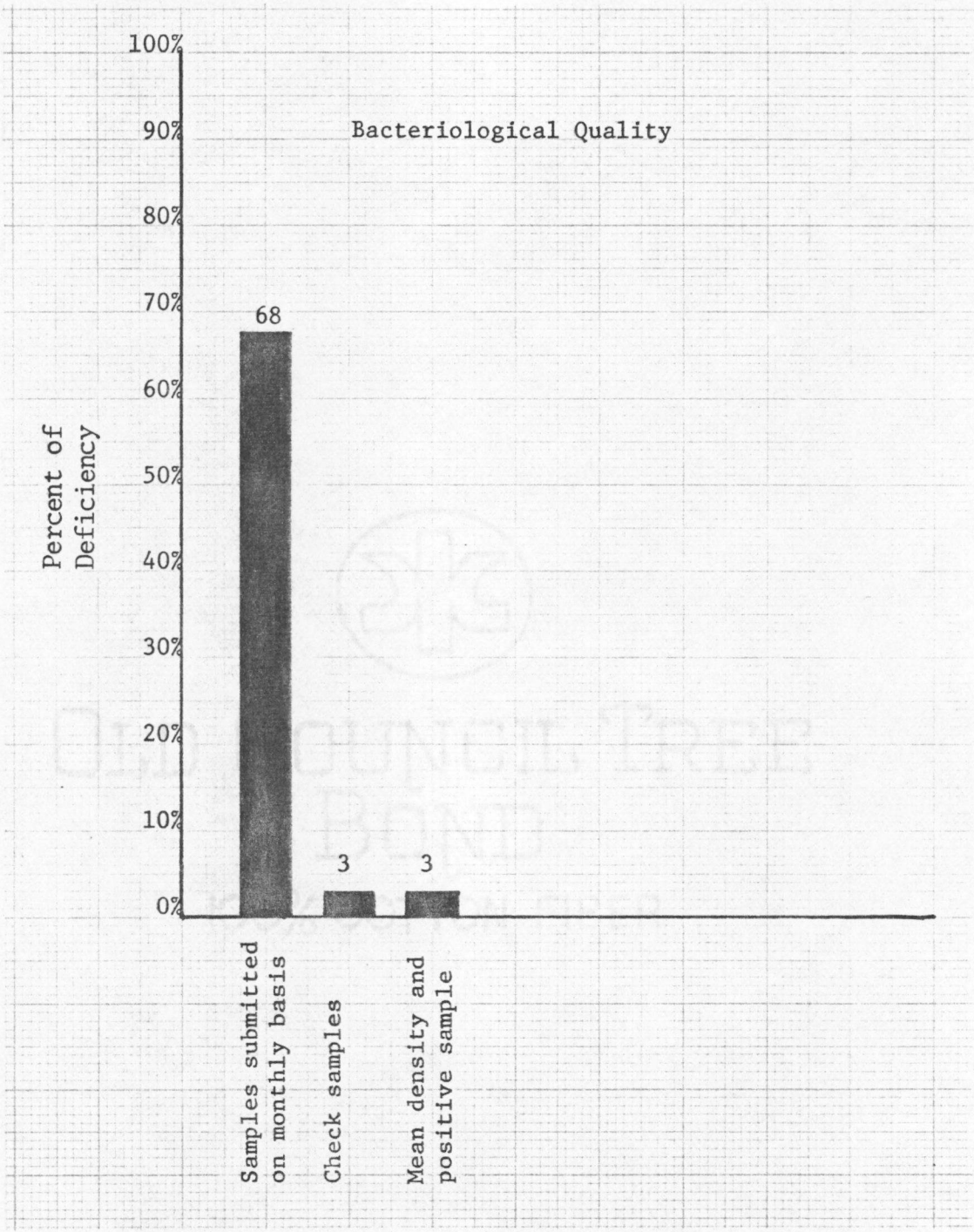

Figure 5. Physical characteristics. Major deficiencies in water quality (31 public water supplies in the ETDD, 1977).

Chemical characteristics. The chemical characteristics were analyzed into eight subcategories. It was reported that only three subcategories were considered a problem. A total of 32 percent of systems had problems with chemical analysis, 16 percent had difficulties with hardness and 6 percent had a problem with calcium carbonate equilibrium of the water (Figure 6).

Bacteriological quality. There are three categories that specify bacteriological quality. Among the categories specifying bacteriological quality were the checking samples, mean density and positive samples. The samples were indicative of two tests showing only 3 percent of systems having problems. A total of 68 percent of public water utility systems did not submit samples on a monthly basis (Figure 7).

Source of supply. The subcategories are five in number. A minimum of 3 percent of systems was not adequate in supplying water while 16 percent exhibited pollution hazards. In addition, 35 percent of raw water conditions exhibited problems with the quality of the water in use. Only 13 percent had difficulty with supply protection (Figure 8).

Cross connections. Most of the systems analyzed demonstrated a type of problem with cross connections. All the problems were subcategorized into three areas.

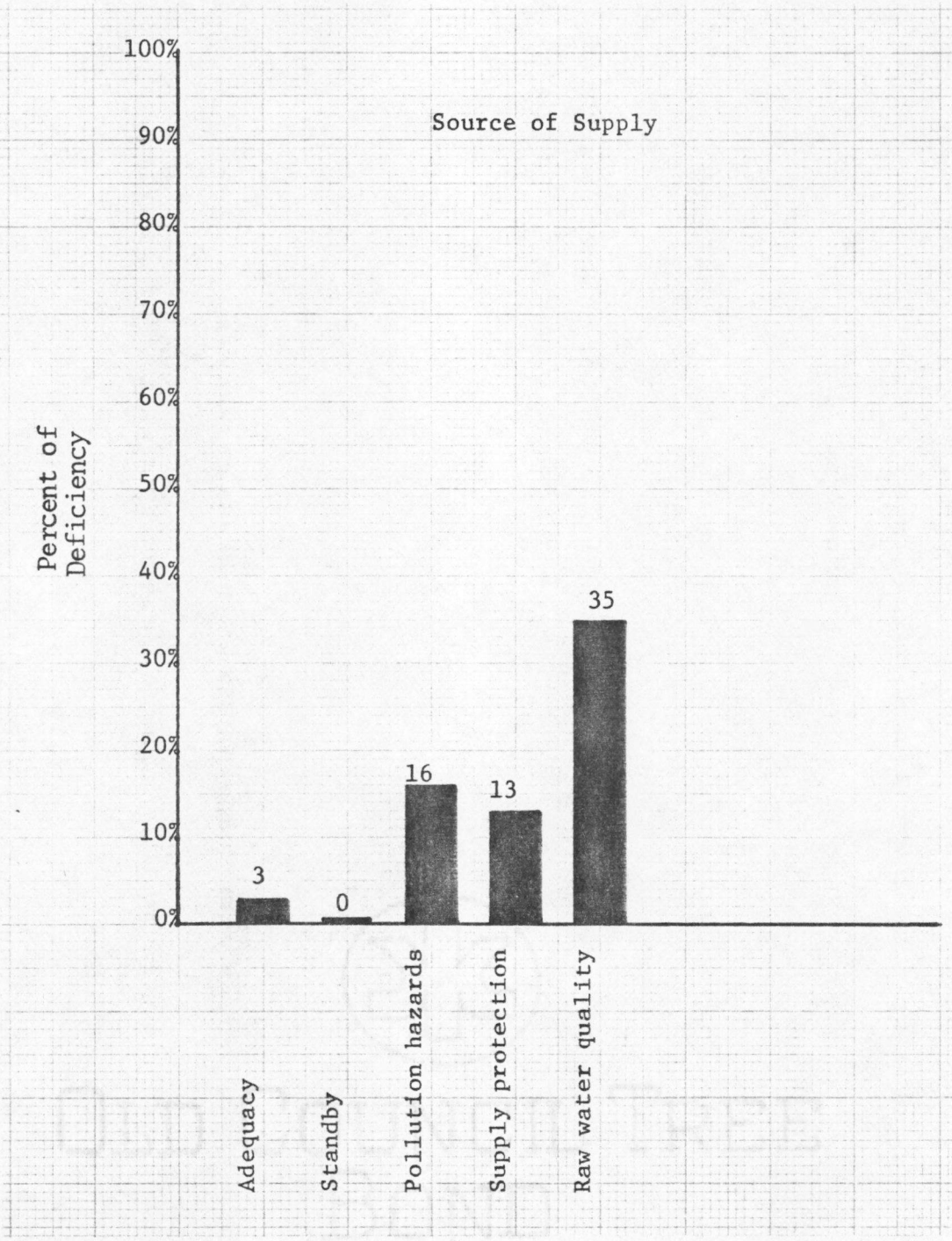

Figure 6. Chemical characteristics. Major deficiencies in water quality (31 public water supplies in the ETDD, 1977).

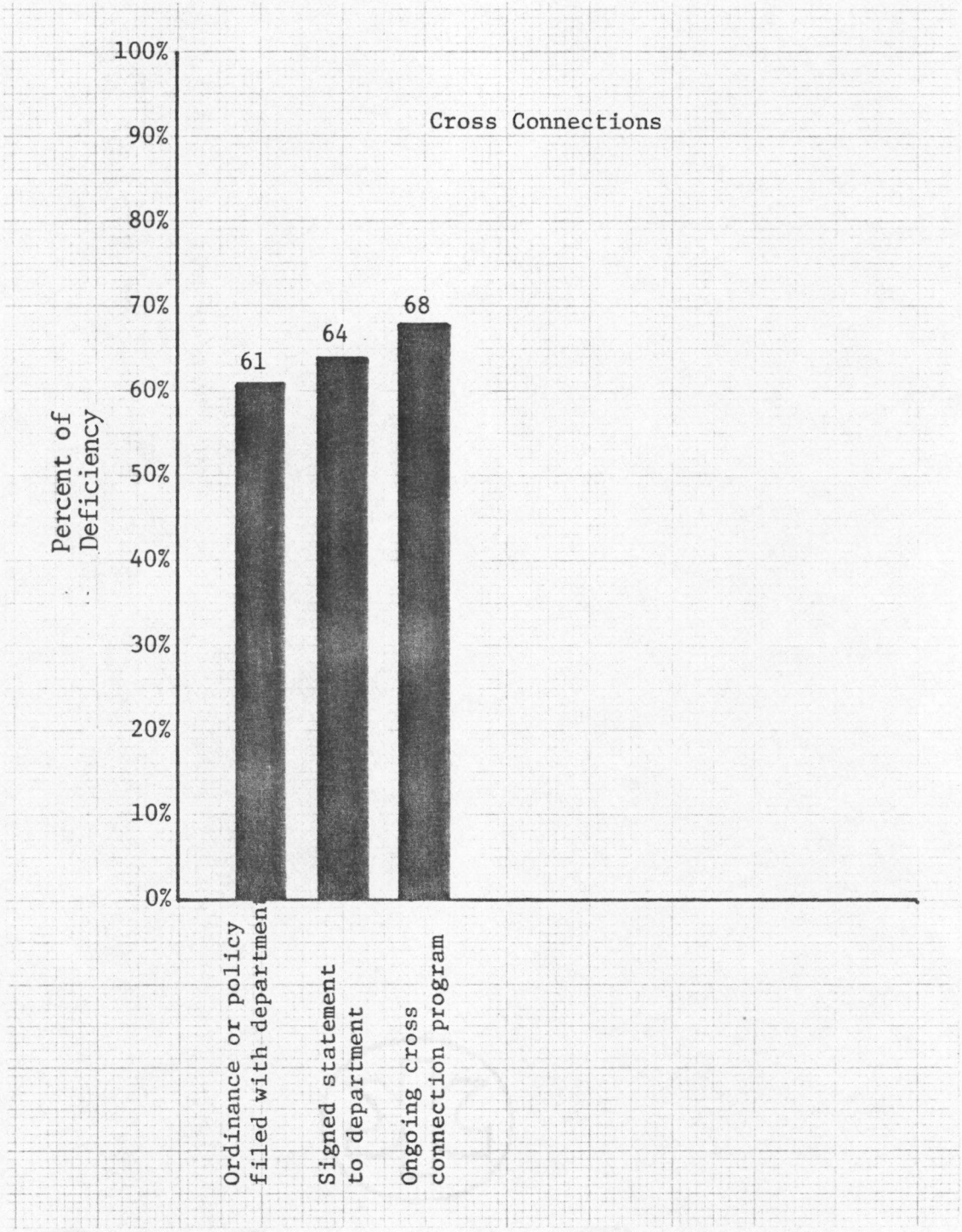

Figure 7. Bacteriological quality. Major deficiencies in water quality (31 public water supplies in the ETDD, 1977).

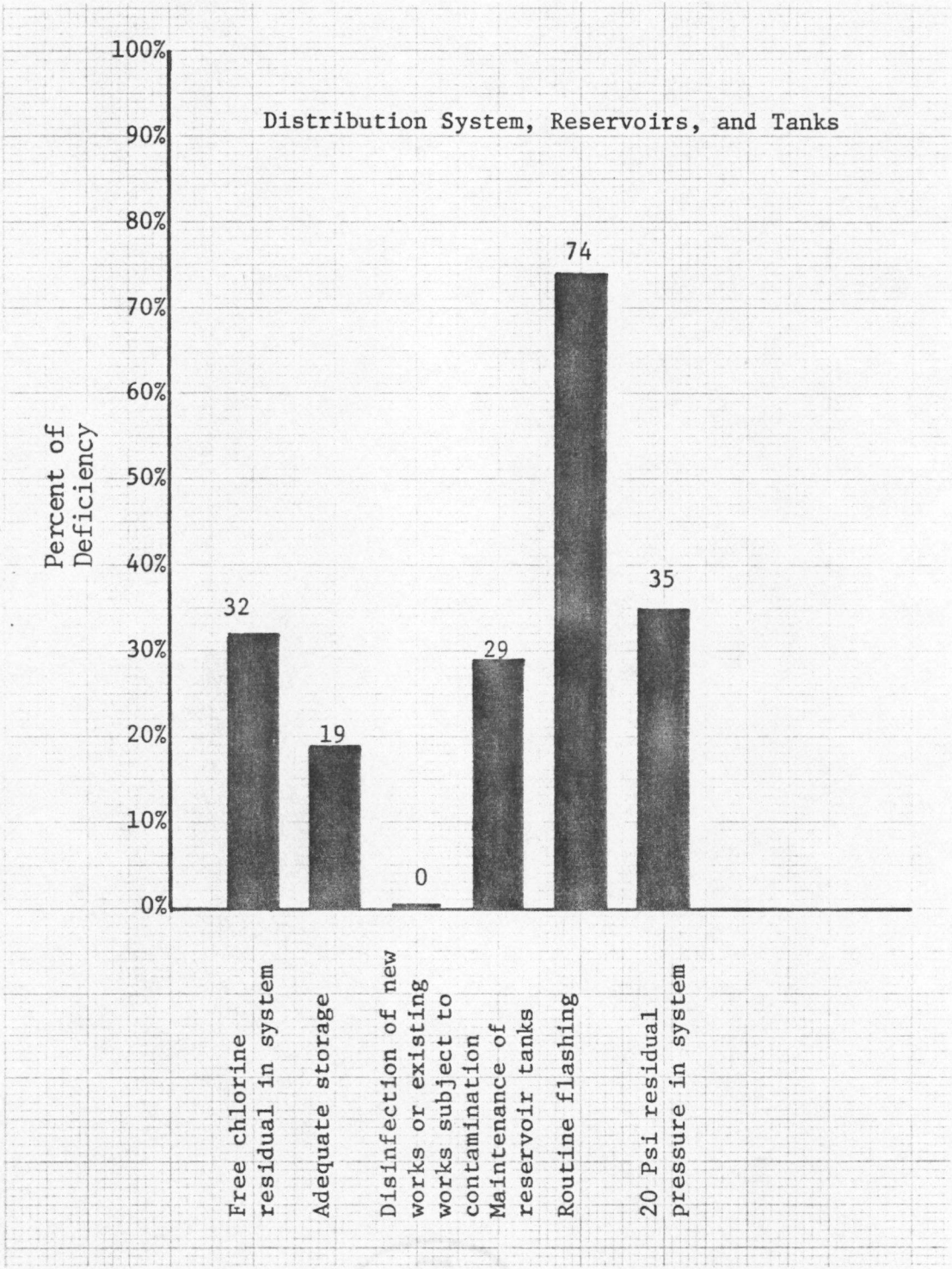

Figure 8. Source of supply. Major deficiencies in water quality (31 public water supplies in the ETDD, 1977).

Tabulations showed that 61 percent were deficient in filing an ordinance or policy with the department; 68 percent indicated an on-going cross connection program. It was also pointed out that 64 percent failed to send a statement to the department (Figure 9).

Distribution system, reservoirs, and tanks. The tabulations presented were classified into six subcategories. According to this classification, 32 percent had free chlorine residual in their systems; 10 percent exhibited an inadequate storage; and, 35 percent had insufficient pressure in their systems. Not any system was found to have disinfection and contamination problems.

In this study, 74 percent were not routinely flushing their system. This was significant as 90 percent equaled the highest figure of problems or deficiencies in this study (Figure 10).

Operation and laboratory control of treatment works. In the two subcategories, 10 percent showed a lack of systematic operation of treatment facilities and 42 percent also showed a lack of control in the treatment of laboratory procedures (Figure 11).

Physical Equipment Deficiencies (Subcategories)

Equipment, buildings, and grounds. A majority of problems (39 percent) was found in the master motors;

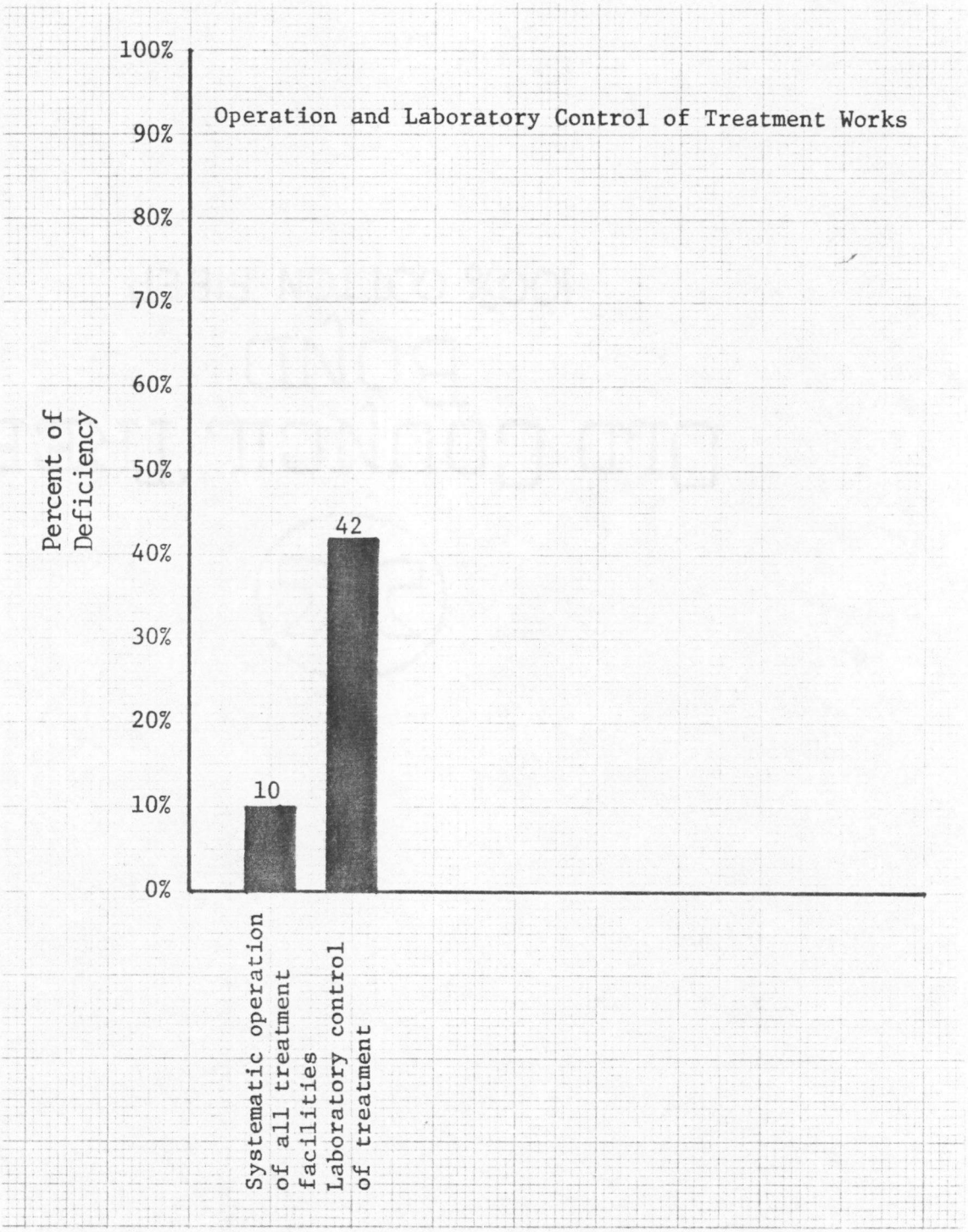

Figure 9. Cross connections. Major deficiencies in water quality (31 public water supplies in the ETDD, 1977).

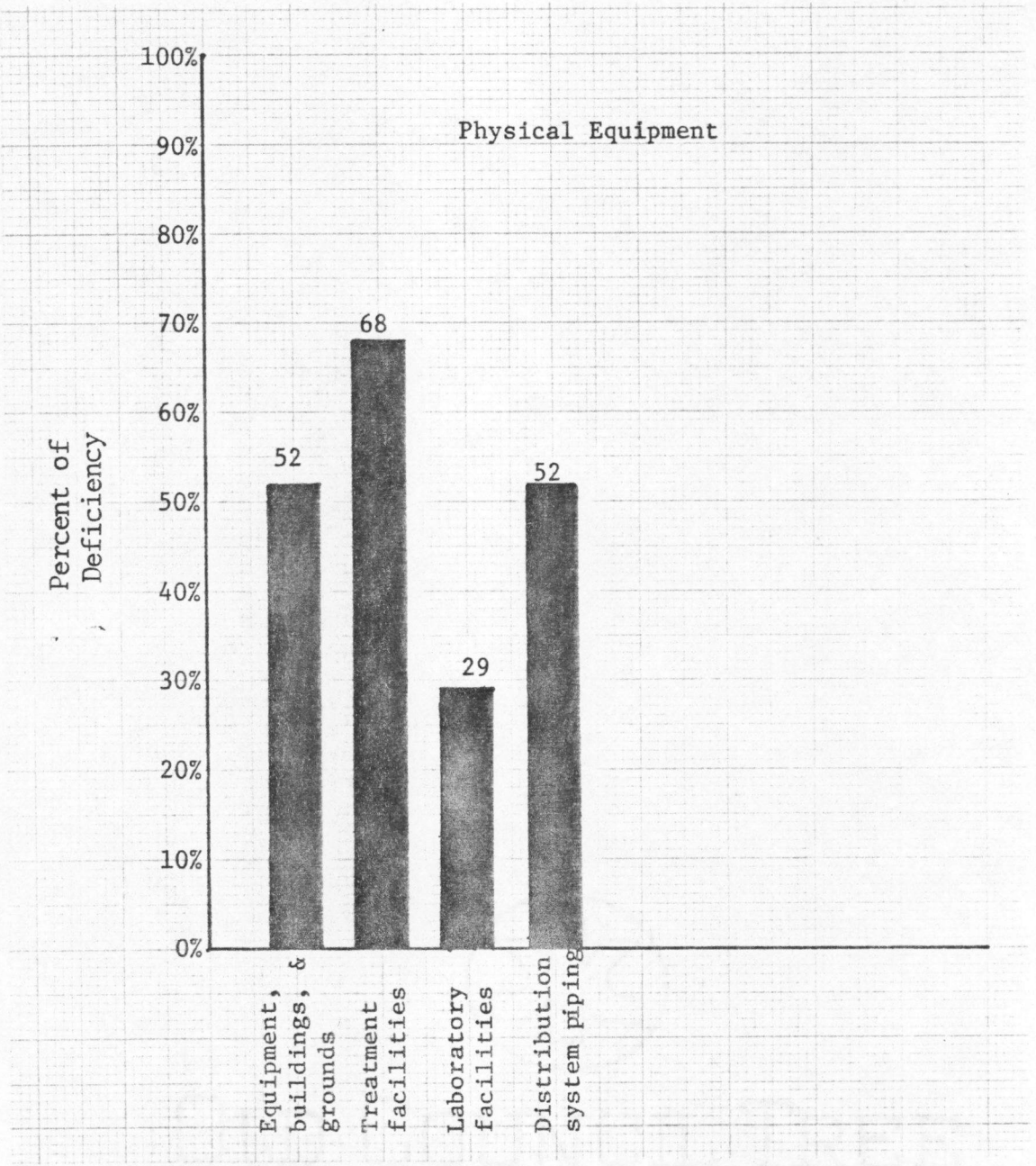

Figure 10. Distribution system, reservoirs, and tanks. Major deficiencies in water quality (31 public water supplies in the ETDD, 1977).

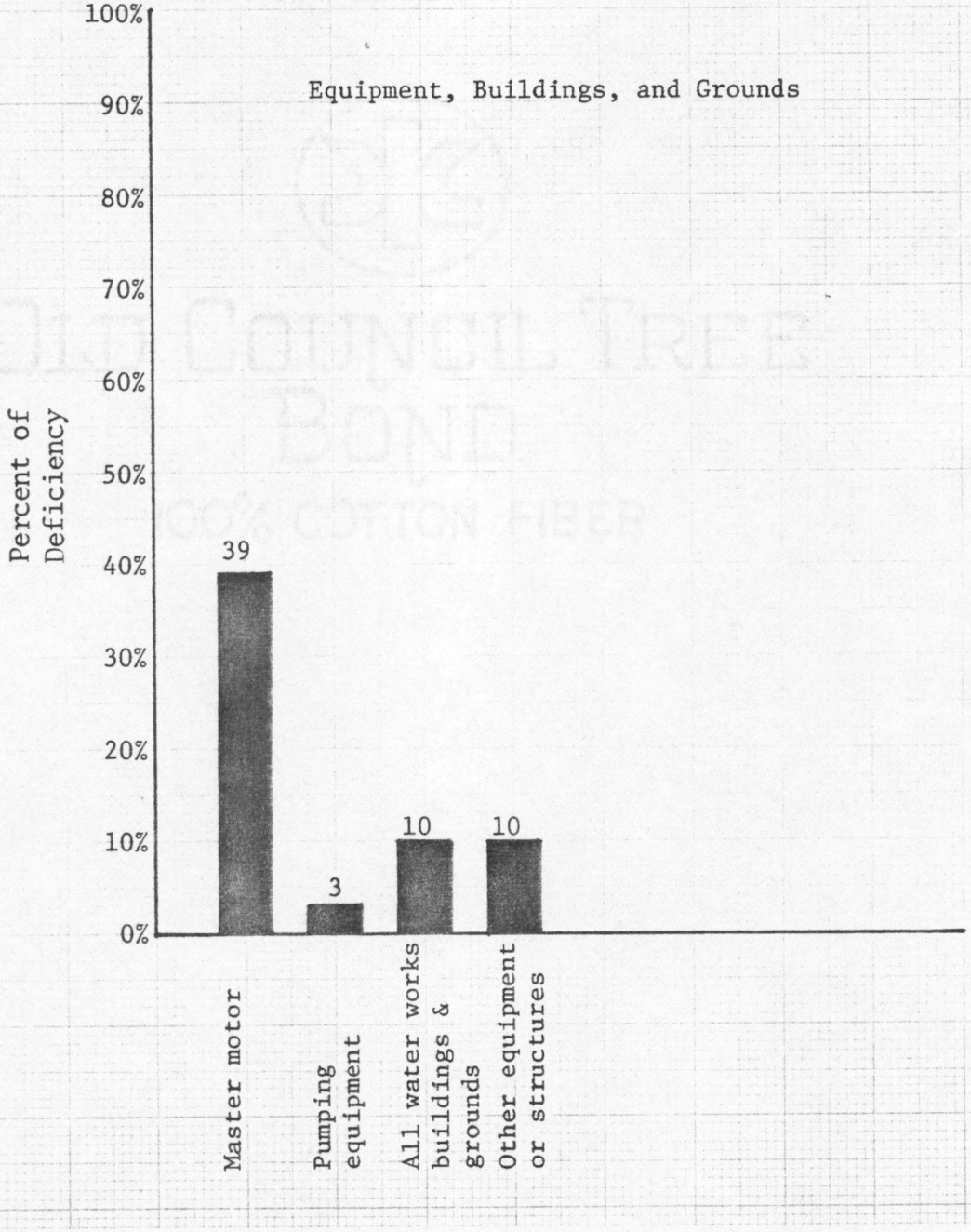

Figure 11. Operation and laboratory control of treatment works. Major deficiencies in water quality (31 public water supplies in the ETDD, 1977).

3 percent experienced difficulty with pumping equipment; and 10 percent of the systems were deficient in the water works buildings, grounds, and other equipment or structures (Figure 12).

Treatment facilities. There are nine major treatment facilities. Only 3 percent of the systems have problems with aeration, coagulation basins, chemical feeders, contact time, sludge, and waste water facilities. A minimum number (6 percent) had difficulty with sedimentation basins, and 13 percent with filter units and appurtenances. The major areas of problems were in turbidimeters and disinfection equipment. Turbidimeters showed a 16 percent deficiency, and disinfection equipment indicated a 35 percent deficiency (Figure 13).

Laboratory facilities. The laboratory facilities were evaluated on three conditions: chemical and physical, bacteriological, and space to conduct laboratory testing.

Very few systems under study exhibited insufficient chemical and physical space for work. Only 3 percent pointed out problems concerning bacteriological testing (Figure 14).

Distribution system piping. The distribution system piping contained four sections. The sections included: (1) kind, size, and location of mains, (2) valves, hydrants,

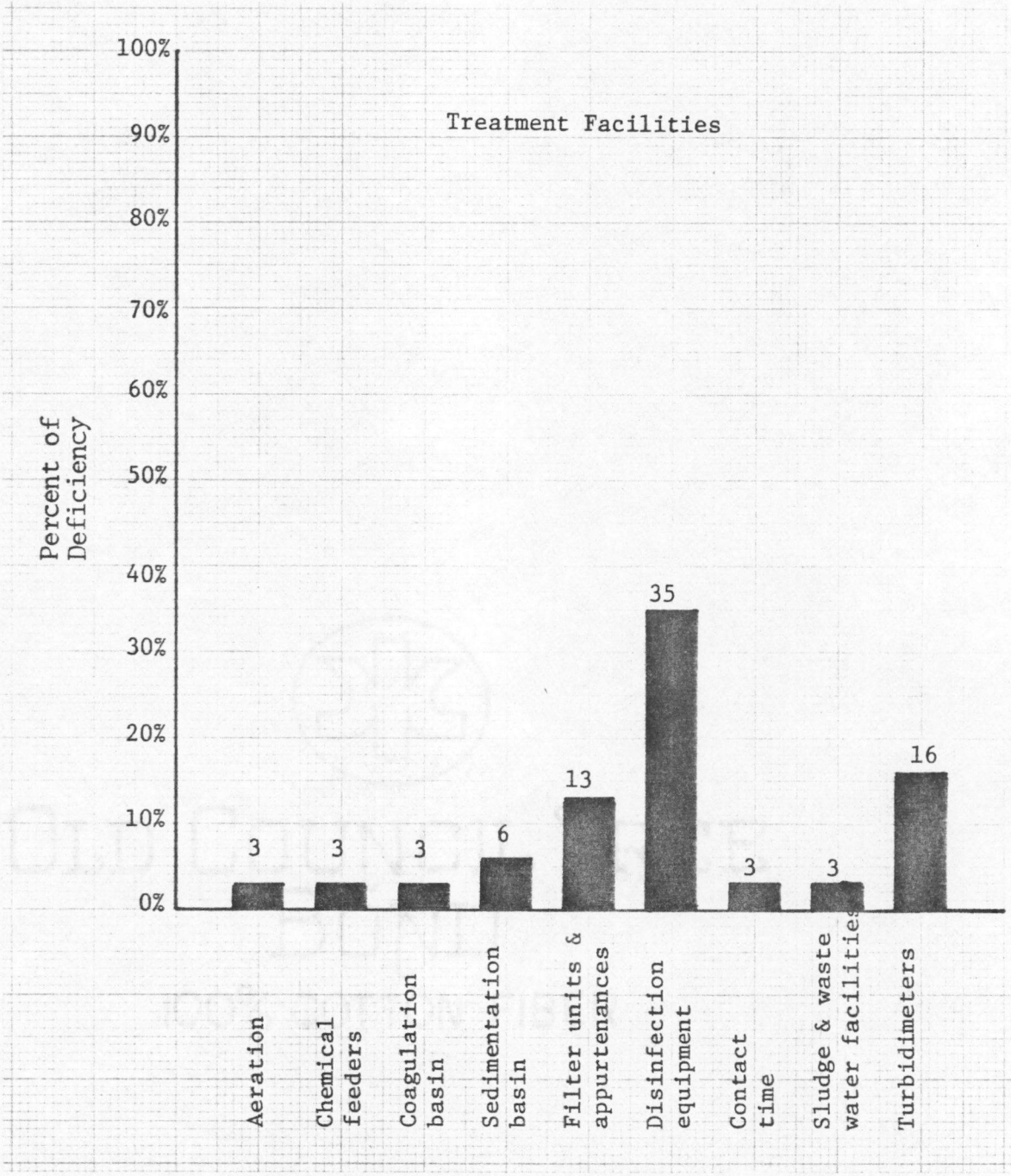

Figure 12. Equipment, buildings, and grounds. Major deficiencies in physical equipment (31 public water supplies in the ETDD, 1977).

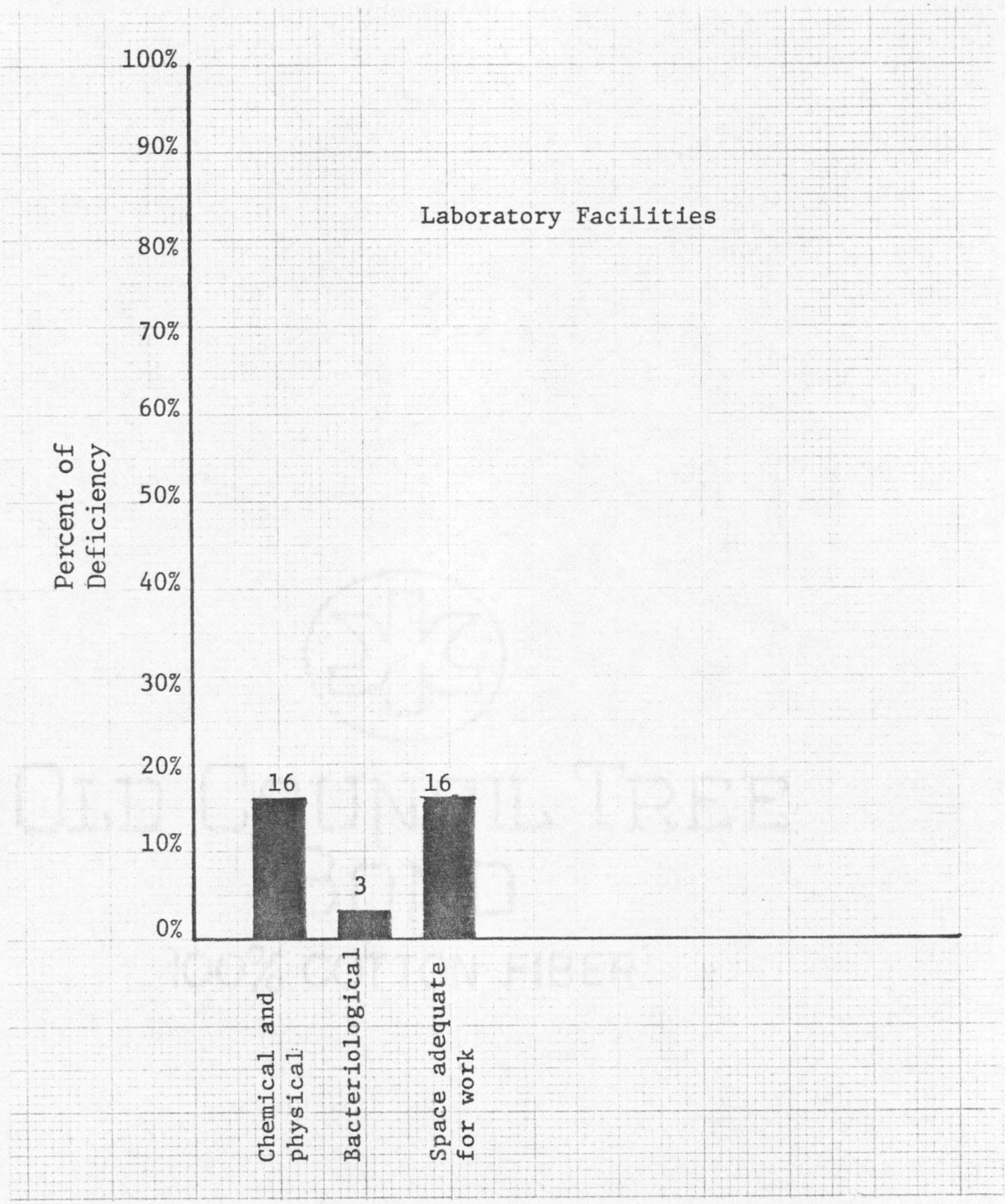

Figure 13. Treatment facilities. Major deficiencies in physical equipment (31 public water supplies in the ETDD, 1977).

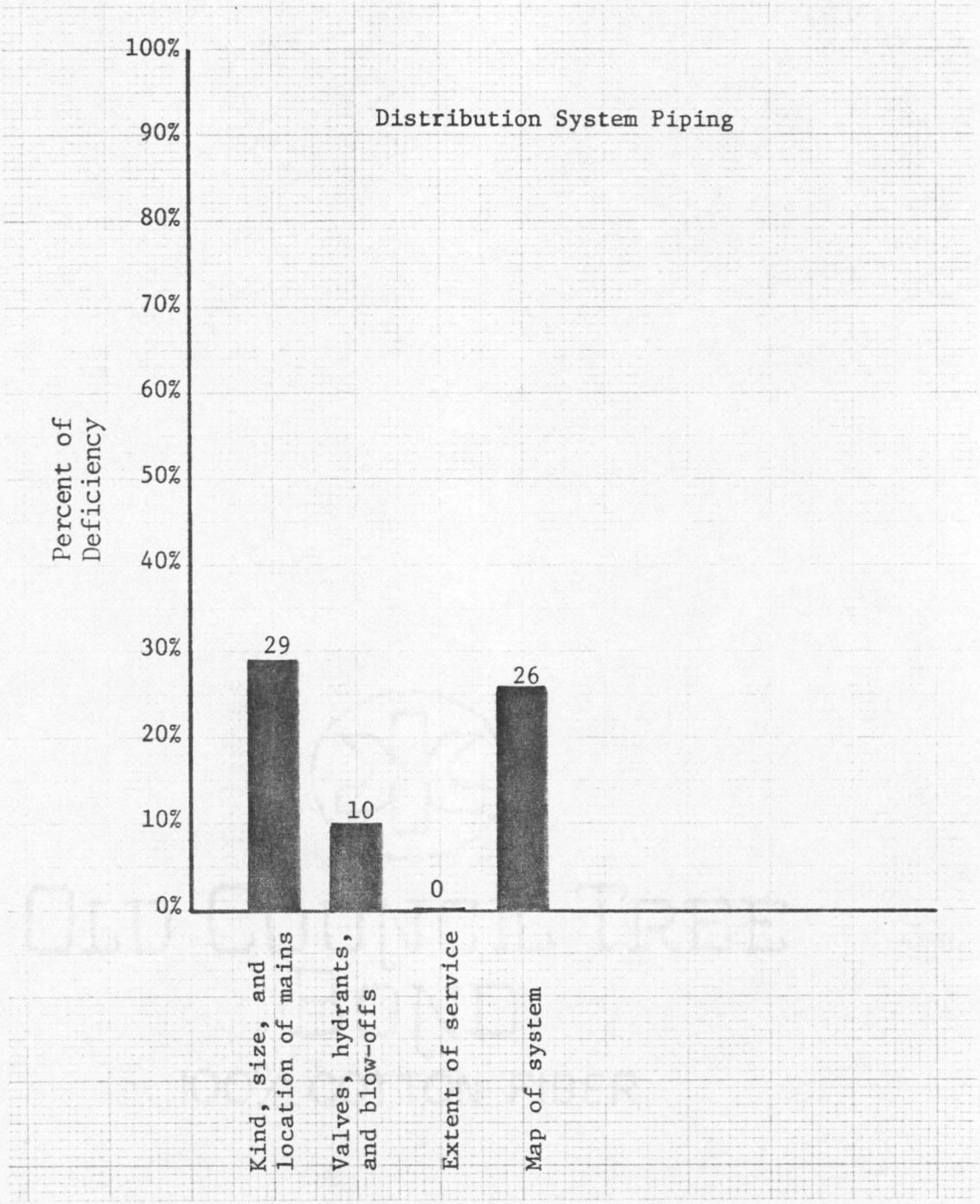

Figure 14. Laboratory facilities. Major deficiencies in physical equipment (31 public water supplies in the ETDD, 1977.

and blow-offs, (3) extent of services delivered, and (4) a map of the system. There were no difficulties experienced with services delivered. On the contrary, 29 percent of systems had problems with the kind, size, and location of mains. A small minority (10 percent) had problems with valves, hydrants, and blow-offs; another 26 percent of systems encountered incorrect and inaccurate map designs (Figure 15).

Operation Deficiencies (Subcategories)

Certified operator. Two sections are listed with the classification of certified operator. The plant operator and distribution categories showed a 42 percent lack of plant operators and also a 35 percent difficulty with distribution (Figure 16).

Maintenance of equipment, buildings, and grounds. Results indicated an average of 16 percent having problems in maintaining existing structures, grounds, and buildings. A small minority (10 percent) were not maintaining their treatment units. A number of systems (3 percent) were not maintaining proper cleaning methods in facilities (Figure 17).

Cooperation with the department. The cooperation between the public water utilities and the TDPH was classified into three levels. Submitting reports, submission and

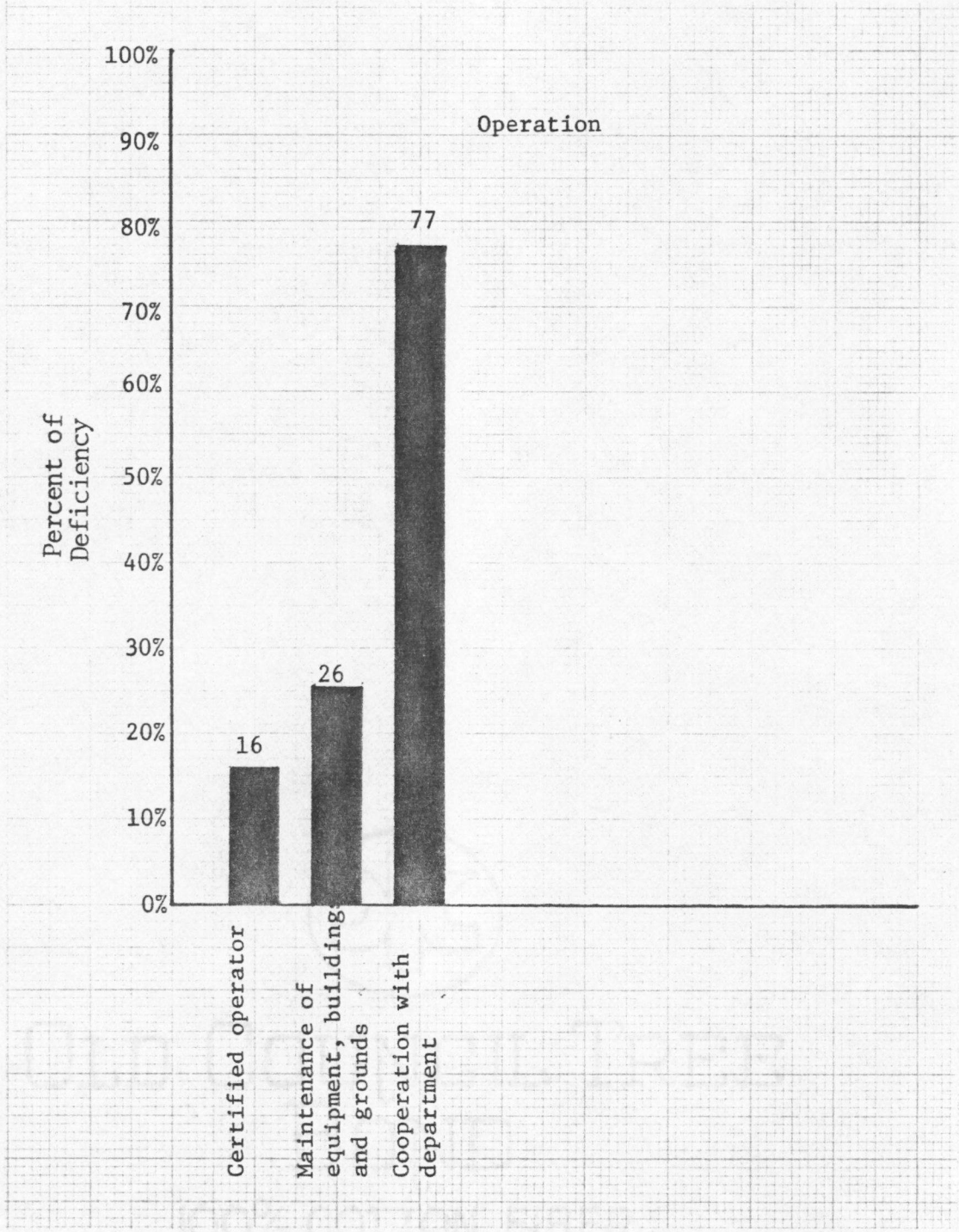

Figure 15. Distribution system piping. Major deficiencies in physical equipment (31 public water supplies in the ETDD, 1977).

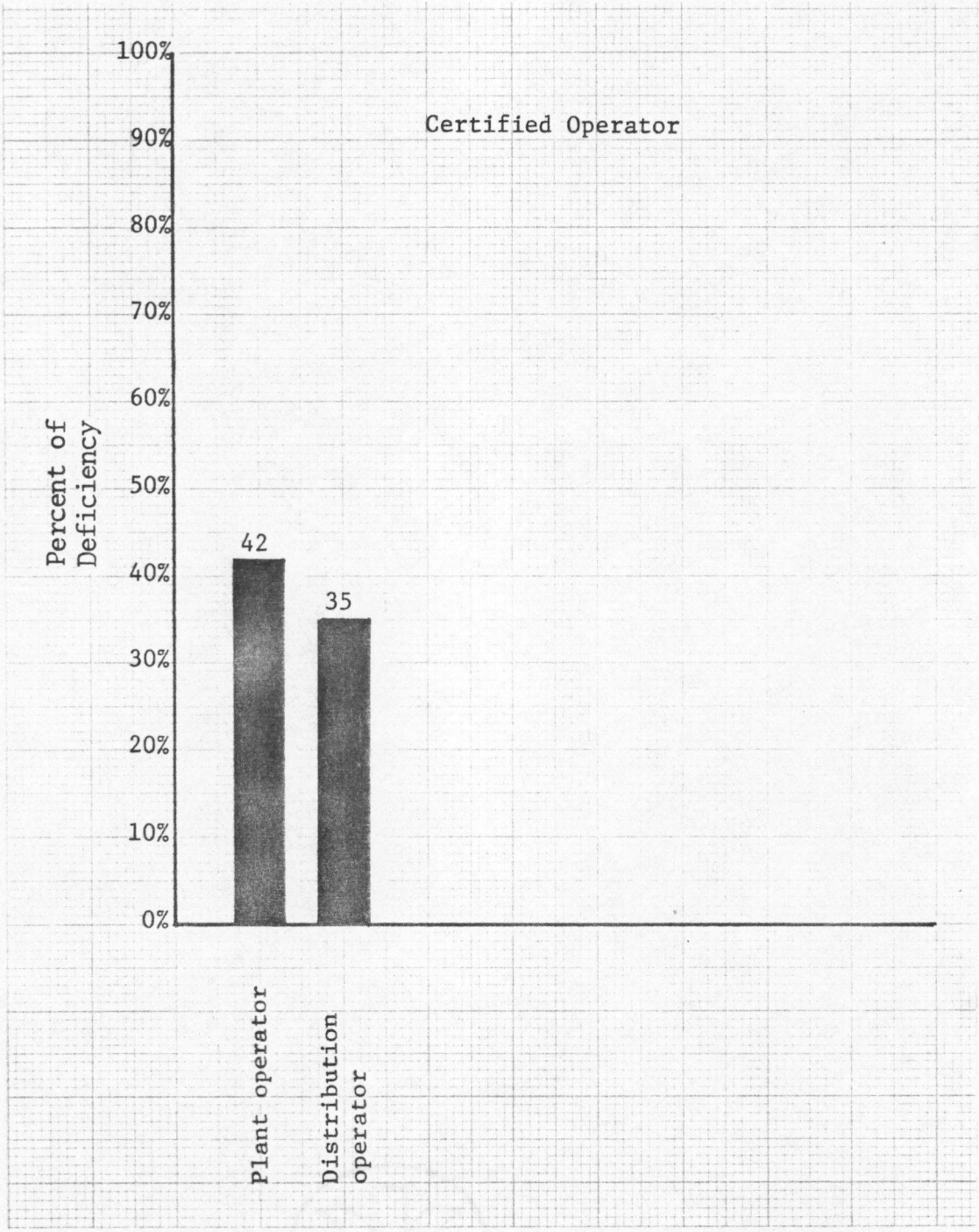

Figure 16. Certified operator. Major deficiencies in operation (31 public water supplies in the ETDD, 1977).

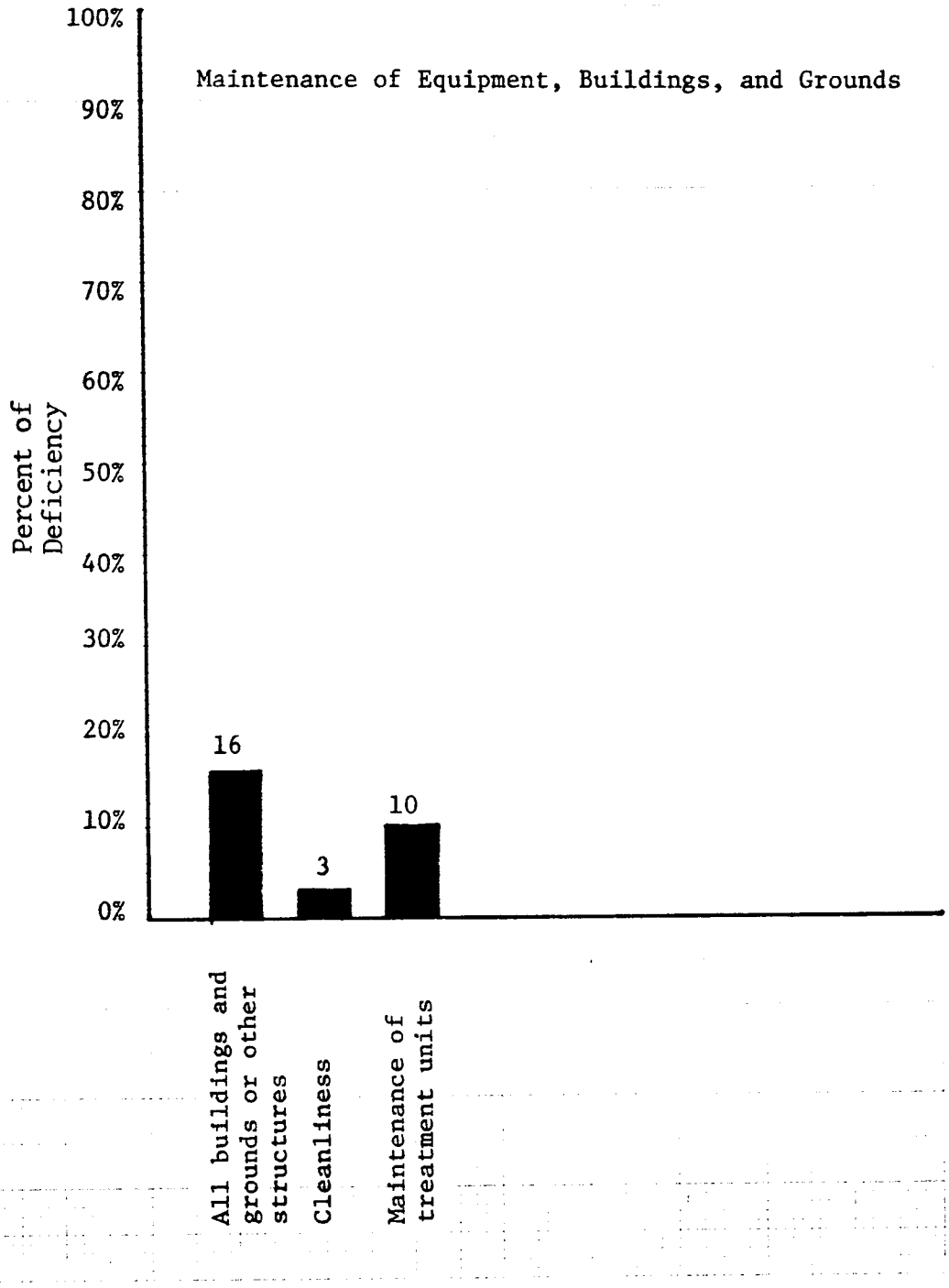

Figure 17. Maintenance of equipment, buildings, and grounds. Major deficiencies in operation (31 public water supplies in the ETDD, 1977).

specification for approval, and the general attitude were of importance in the relation between the water utility systems and the TDPH. The lack of cooperation showed that 68 percent were not submitting operation reports; 16 percent were not cooperating with the department; and 3 percent were not submitting their plans and specifications for approval (Figure 18).

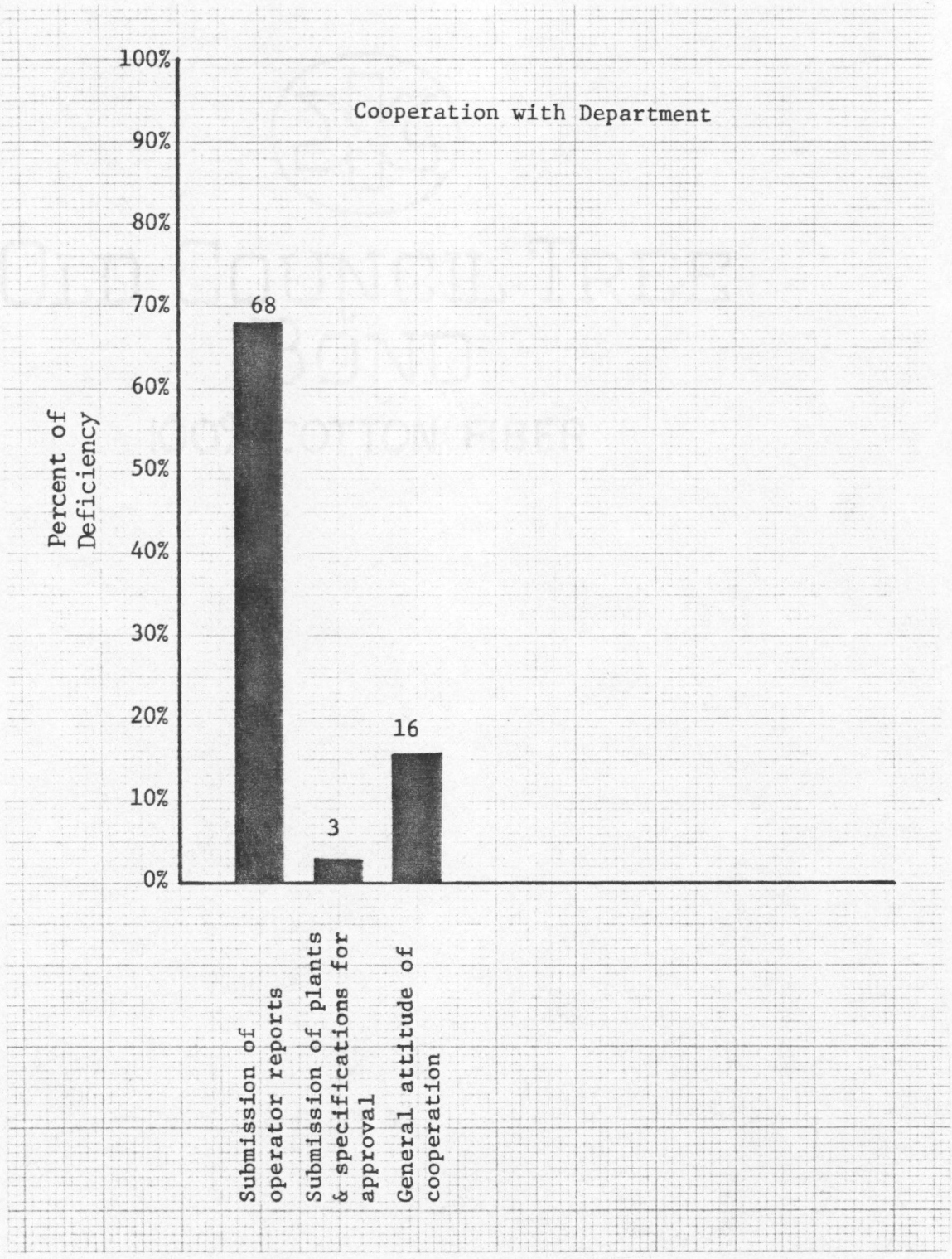

Figure 18. Cooperation with department. Major deficiencies in operation (31 public water supplies in the ETDD, 1977).

PUBLIC WATER SYSTEM RATING FORM–DIVISION OF SANITARY ENGINEERING

Tennessee Department of Public Health

NAME OF SYSTEM _____ DATE _____

WATER QUALITY (58)

DEFICIENCY POINTS | SCORE

1. PHYSICAL CHARACTERISTICS – Turbidity more than 2 units ( ) Color More than 15 units ( ) – Taste and Odor ( ) _____ ( ) ( )
2. CHEMICAL CHARACTERISTICS – Iron ( ) – Manganese ( ) Chloride ( ) Sulfate ( ) – Calcium Carbonate Equilibrium ( ) – Hardness ( ) – Total dissolved solids ( ) – Other ( ) Chemical Analysis ( ) – Other ( ) ( )
3. BACTERIOLOGICAL QUALITY – Samples submitted on monthly basis ( ) Check Samples ( ) Mean Density and positive sample ( ) ( )
4. SOURCE OF SUPPLY – Adequacy ( ) Standby ( ) – Pollution Hazards ( ) Supply protection ( ) – Raw water quality _____ ( ) ( )
5. CROSS CONNECTIONS – Ordinance or policy filed with department ( ) Signed statement to department ( ) – On-going cross connection program ( )
6. DISTRIBUTION SYSTEM, RESERVOIRS & TANKS – Free chlorine residual in system ( ) Adequate storage ( ) – Disinfection of new works or existing works subject to contamination ( ) – Maintenance of Reservoirs or tanks ( ) – Routine flushing ( ) – 20 psi residual pressure in systems _____ ( ) ( )
7. OPERATION & LABORATORY CONTROL OF TREATMENT WORKS – Systematic operation of all treatment facilities ( ) – Laboratory control of treatment ( ) – _____ ( ) _____

PHYSICAL EQUIPMENT (21)

8. EQUIPMENT, BUILDINGS & GROUNDS – Master meter ( ) – Pumping equipment ( ) All water works buildings and grounds ( ) – Other equipment or structures _____ ( ) ( )
9. TREATMENT FACILITIES – Aerators ( ) – Chemical feeders ( ) Coagulation basin ( ) – Sedimentation basin ( ) Filter units & Appurtenances ( ) – Disinfection equipment ( ) – Contact time ( ) _____ ( ) – Sludge & Wastewater Facilities ( ) – Turbidimeters ( ) ( )
10. LABORATORY FACILITIES – Chemical and physical ( ) – Bacteriological ( ) Space adequate for work ( ) _____ ( ) ( )
11. DISTRIBUTION SYSTEM PIPING – Kind, size, and location of mains ( ) – Valves, hydrants, and blow-offs ( ) Extent of service ( ) Map of system ( ) _____ ( ) ( ) _____

OPERATION (21)

12. CERTIFIED OPERATOR – Plant Operator ( ) – Distribution ( ) _____ ( ) _____ ( ) ( )
13. MAINTENANCE OF EQUIPMENT, BUILDINGS AND GROUNDS – All buildings and grounds or other structures ( ) – Cleanliness ( ) Maintenance of treatment units ( ) _____ ( ) ( )
14. COOPERATION WITH DEPARTMENT – Submission of operation reports ( ) – Submission of plans and specifications for approval ( ) – General attitude of cooperation ( ) _____ ( ) ( ) _____

NOTE: Defects marked with a Cross (x)

TOTAL SCORE _____

Signed _____

Revised Jan. 1975

VITA

Farhad Forouzesh was born in Teheran, Iran on October 3, 1944. He was reared in Teheran. He received the B.A. in Economics from the National University of Iran.

After graduating from the National University of Iran, he served with the Iranian Military Service as a Second Lieutenant in Teheran. He entered the Graduate School at The University of Tennessee in September, 1974, and will receive the Master of Science degree in Water Resources Development in March 1978.