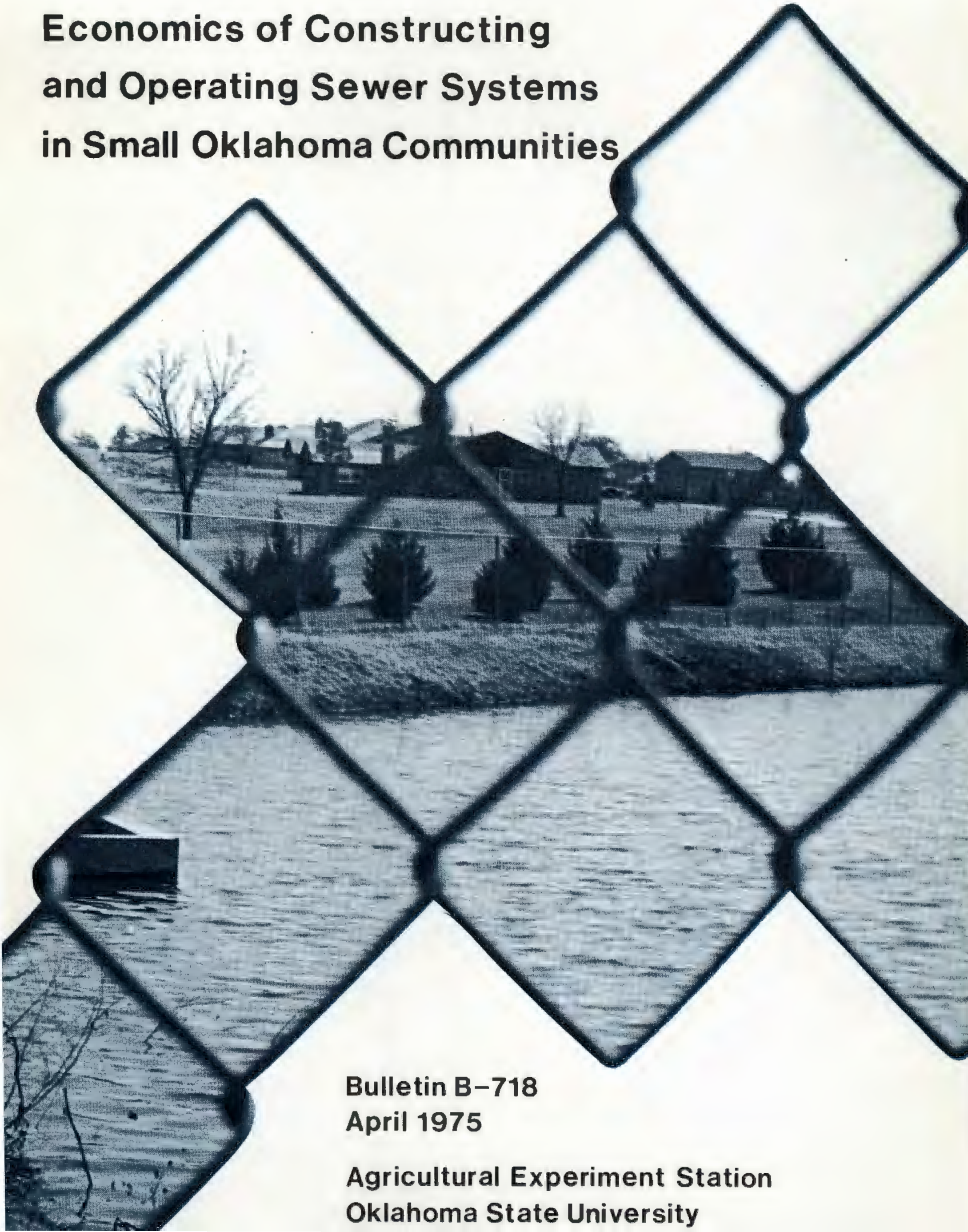
Economics of Constructing and Operating Sewer Systems in Small Oklahoma Communities



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CONTENTS

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Summary and Conclusions

This study explores costs of constructing and operating sewer systems in small Oklahoma communities. At the end of 1970, there were 454 small Oklahoma communities without sewer systems. A sample of 16 communities ranging in size from 151 to 1,200 population that had recently installed sewer systems were selected for study. Information on each system was obtained from Federal, State and local government offices and from published material.

Costs were divided into investment costs and annual costs. Investment costs were defined as the original construction costs plus the costs of added capital improvement. Total annual costs were defined as normal operation and maintenance expenses for lagoons, pump stations and lines plus an expense for amortizing the investment costs.

Investment costs in sewer systems averaged about $81,000 for the smaller communities up to $191,000 for the larger communities.

Two factors were analyzed to determine their effect on investment costs per customer. The first was the number of customers served which showed a decline in investment cost per customer from $1,000 for the smaller systems to $434 for the larger systems studied. Second was the number of customers served per mile of line (density) which indicated that investment cost per customer declined from $1,100 to $575 per customer from the least densely populated to the most densely populated Community.

It was determined from a log-linear regression analysis of these two factors that there are some economies of size in investment costs for the size sewer systems studied but that the density of customers served has a larger impact on investment costs per customer. Together, the two factors explained about 87 percent of the variation in investment costs. The correlation coefficient for the two factors was .82 which indicates a tendency for density and number of customers to move in the same direction; e.g. as one increases or decreases, so does the other.

Total annual costs per customer were also analyzed with respect to density and number of customers and it was found that these two factors explained 93 percent of the variation in total annual costs. It was also determined from this analysis that for the size of sewer systems studied, number and density of customers served were both statistically significant factors affecting total annual cost per customer.

Grants from various government agencies to communities for part of the investment costs in sewer systems have a significant impact on total annual costs. The affect of grants of 0, 25, 50, 75, and 100 percent were considered relative to their impact on total annual costs per customer. The range for this cost was from $75.96 for a 0 percent grant for the smallest system down to $13.82 for a 100 percent grant for the largest systems studied.

For the average annual income received from sewer service fees ($30 for the communities studied) a grant of 75 percent would be required to have the fees cover the total annual cost for systems serving up to 300 customers. For systems serving 300-400 customers, a 50 percent grant would be sufficient. Of course, the fee for sewer service may be set to cover total costs depending on the individual system size, density of customers, and the amount of grant, if any, that is received.

Economics of Constructing and Operating Sewer Systems In Small Oklahoma Communities

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Introduction

At the end of 1970 there were 438 identifiable communities of under 500 population in Oklahoma without sewer systems and 16 communities between 500 and 2,500 population that also had no sewer system. About 60 percent of these communities are unincorporated.[2] Although many families and/or other households and businesses undoubtedly have adequate individual sewage disposal facilities, for sanitary and esthetic purposes, many communities could benefit from a sewer system.

The U.S. Environmental Protection Agency (EPA) has been making grants to communities for part of the construction cost of sewer systems. Recently, EPA has been making grants from up to 75 percent of the total construction cost.[3] These grants are made through the Oklahoma State Department of Health. The Farmers Home Administration (FmHA), of the U.S. Department of Agriculture has also been loaning funds and making grants for construction of sewer systems in small communities. Other rural communities may want to consider installing a sewer system in the near future if grant and loan funds continue to be available.

Purpose and Objectives

This report provides information on the costs of constructing, maintaining and operating sewer systems in small communities and

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[2]These include incorporated and unincorporated communities. The list of communities was compiled from the Rand McNally and Company *Commercial Atlas and Marketing Guide,* 1972, Chicago, Illinois.

[3]*Federal Register,* Feb., 11, 1974, Vol. 39, No. 29, Part III, Title 40, par. 35, 930-935.

Research reported herein was conducted under Oklahoma Station project No. 1484.

analyzes factors that may influence these costs. Specific objectives of the report are: (1) to determine the construction costs of sewer systems in small communities; (2) to analyze what effect the number and density of customers have on investment costs; (3) to analyze total annual costs of sewer systems, and to determine what effect number and density of customers have on total annual costs; and (4) to analyze the effect grants of different sizes have on total annual costs.

Procedure

Sample Selection

A sample of 16 sewer systems in small Oklahoma communities were selected with FmHA assistance and records from the Oklahoma State Department of Health (Table 1). Major criteria for selection of the systems for study were: to include only communities that had installed complete sewer systems since 1960, thus insuring that adequate construction cost data would be available and that recent technology was used. None of the communities could have had any form of public sewage system before the new system was installed. Communities with different populations were to be included. All the major geographic areas of the state should be included. The geographic distribution of the sewer systems selected is indicated in Figure 1.

All of the systems selected for study utilized lagoons as their only method of waste treatment. Since nearly all communities building completely new sewage systems utilized lagoons for treatment in the period being studied, 1960-72, no systems with other forms of treatment were included in the study.

Data Collection

Sources of data included FmHA state and county records (for 9 of the 16 sample systems which received FmHA loans), Oklahoma State Department of Health community record files, and published sources.

Table 1. Population Classification of 16 Communities in Oklahoma Which Have Installed Sewer Systems in the Period 1960-72

	Population[1]			
	Under 300	300-599	600-899	900-1,200
Number of communities.	8	4	2	2

[1]The range in size of communities in the sample was from 151 to 1,200.

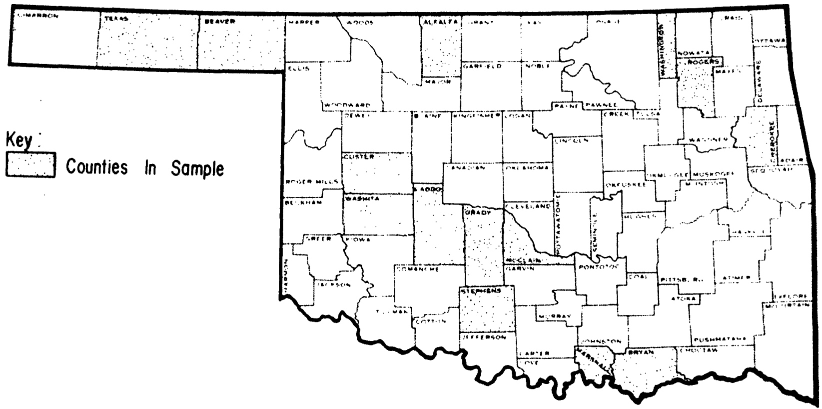

Figure 1. Oklahoma Counties included in study of Rural Sewage Systems.

Construction cost information was taken from county FmHA and/or community records of payments to contractors for construction of the sewer systems. Data on line extensions and rates were obtained from community records. However, costs of operating and maintaining sewer systems were not separated in the community records from other community service costs so these costs were obtained from published sources. A questionnaire was used to collect all data from state, county and community records to assure consistency.

Analytic Procedure

Analytic procedures used in this study were primarily comparative analysis and linear regression. Most comparisons were made on a per customer (household or business firm) basis.[4] Log-linear regression analysis was used to determine the effect of several variables on costs, e.g. what is the effect of number of sewer connections per mile of line on cost of sewer service per customer.

Investment cost data includes the cost of the original system plus any additional improvements made during the period 1960-72. Sewer line extensions, which account for most of the improvements, were assumed to have the same construction costs as the original lines. Since construction costs have been increasing over time, construction cost indices (Table 2) were used to adjust all investment cost data used in this study

[4]For the 16 systems studied, there was an average of 2.5 persons per customer — a community with 100 customers would have a population of 250.

to reflect what it would cost to build the entire system (including improvements) in 1972.

The construction cost index for sewer lines was used to adjust the cost of the whole system because there was not an index available for lagoons. This is not a serious limitation because lagoons only account for about 15 percent of the total sewer cost. The procedure for adjusting construction cost to equal 1972 construction cost is as follows. Assume the sewer system was built in 1965. From Table 2 the percentage change in construction costs is calculated by dividing 150 by 96, which is a 56 percent increase in costs. Multiplying the original total cost of construction, plus improvements, by 156 provides a cost estimate to build the system in 1972.

Sewer system operating and maintenance costs from published sources were not available for the different sizes of communities studies in this report. Therefore, these costs are included in the analysis of costs as a constant cost per capita, i.e. operating and maintenance costs per capita are the same for communities of 200 population as they are for communities of 1,200 population.

Definitions of Costs

Investment costs were defined as the original construction cost plus the cost of added capital improvements. Major components of investment cost include: land, collection and outfall lines, manholes, lift stations, and lagoons. Eight of the 16 systems did not require lift stations. Major

Table 2 — Construction Cost Index for Sewer Lines in Oklahoma

Year	Construction cost index numbers 1957-59 = 100
1960	90
1961	90
1962	92
1963	94
1964	95
1965	96
1966	100
1967	102
1968	104
1969	114
1970	122
1971	141
1972	150

Source: Based on unpublished data furnished by the Office of Water Programs Operations, Municipal Wastewater Systems Division, Evaluation and Resource Control Branch, Environmental Protection Agency, Washington, D.C.

components of operating and maintenance costs taken from published sources include maintenance for lagoons and lines, and general and administrative overhead expenses. Total annual costs were defined as operating and maintenance costs plus amortization payments. Amortization payments are annual payments for borrowed funds, including interest for construction purposes, and are not usually included in the definition of annual cost. However, this definition is used because it reflects an annual expense for investment cost.[5]

Grants will have a significant affect on amortization payments because they will affect the amount of money a community has to borrow to construct a sewer system. The procedure used to analyze this effect was to determine what total annual costs would be for grants of 0, 25, 50, 75, and 100 percent for the investment cost portion of total annual costs.

Analysis of Costs

Investment costs for each of the systems studied were actual construction costs for each of the 16 sewer systems. They were taken from construction and engineering reports made to the communities for payment on their contracts. Operating and maintenance costs were taken from published sources so they are more general and can be considered only as estimates of actual costs. Operating and maintenance costs for this study were estimated as follows:[6]

Lagoons – maintenance and materials, $.67 per capita per year;

Collection system – (lines, lift stations, manholes) maintenance and repair is $.06 per year per lineal foot of line. Informed sources estimate that this cost could be as much as 50 percent less for systems without lift stations;

General overhead – $2.08 per capita per year. Included are office expenses, salaries, administrative overhead, legal, accounting, postage and other.

Total annual cost as defined in this study include operation and maintenance costs plus an annual fixed charge for amortization of the investment cost. For amortization, an interest rate of 5 percent and 50-year time span were assumed. An amortization factor of .05478 was applied to the 1972 cost of constructing the sewer systems (adjusted by

[5]If the system was financed by FmHA, then yearly payments of principal and interest, usually for 40 years are made to FmHA. Other financing such as general revenue bonds are also used by communities to finance sewer systems. However, a uniform amortization rate of 50 years at 5 percent was applied to the investment cost of all systems in the study.

[6]Source: Smith, Robert and Richard G. Eilers, *Cost to the Consumer for Collection and Treatment of Wastewater,* Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio, July 1970, pp 63-69.

the construction cost index).

It was decided that a determination of the size of the various cost categories relative to total annual costs would aid in the analysis of costs (Table 3). Amortization was by far the largest cost item, representing 72.6 percent of total annual costs (assuming no construction grants). Construction grants are generally available for sewer systems which would reduce the amortization cost. However, in most cases amortization will remain as the largest single annual cost item.

Since amortization is the largest single cost item in total annual costs, factors that affect amortization will have a considerable impact on total annual cost (the effect of grants on annual costs are analyzed later in the report). Investment costs are directly related to the annual amortization payments so investment costs are analyzed first.

Investment Costs

The investment costs in sewer systems as described in this report are classified by the size of community they serve. Investment costs range from $80,819 for the smallest communities up to $191,297 for systems that serve communities with an average of 1,100 population (Table 4).

Table 3. Annual Cost Items as a Percent of Total Annual Costs for 16 Sewer Systems in Oklahoma, 1972

	Cost items				
	Maintenance and repair				
	Lagoons	Collection system	General overhead	Amortization	Total annual costs
	Percent				
Annual cost distribution	3.2	14.2	10.0	72.6	100.0

Table 4 — Investment Costs Per Customer for 16 sewer Systems in Oklahoma, 1972

	Population category of community			
Item	Under 300	300-599	600-899	900-1,200
Average population	202	405	761	1,100
Average investment costs ($)	80,819	129,277	180,621	191,297
Average investment cost per customer ($)[1]	1,000	798	594	434

[1]Per customer cost is determined by multiplying per capita cost by 2.5 which is the average number of people per customer for the 16 sewer systems studied.

Investment cost per customer decline from $1,000 for the smaller systems to $434 for the larger systems. Thus, it appears that economies of size do exist in sewer system investment costs for small communities. However, analysis of these costs provides some additional information about the source of investment cost economies of sewer systems.

Sufficient data were available to analyze two factors that could affect investment cost per customer — (1) number of customers per mile of sewer line (density) and (2) number of customers served. It was expected that an increase in either or both of the factors would lead to smaller investment costs per customer.

Investment cost per customer was $1,100 for systems with under 30 customers per mile of line and decreased to $575 for systems with over 50 customers per mile of line (Table 5). Density apparently affects investment cost per customer, but it also appears that systems with higher densities tend to have more customers (line 3, Table 5). Systems were therefore categorized by number of customers served and compared to investment cost per customer and density of customers served (Table 6). As number of customers served increased from under 100 to 300-400,

Table 5. Investment Cost Per Customer Relative to Number of Customers per Mile of Line for 16 Sewer Systems in Oklahoma, 1972

	Customers per mile of line			
Items	Under 30	30-39	40-49	Over 50
Number of systems	5	5	1	5
Average investment cost per customer ($)	1,100	847	696	575
Average number of customers	96	119	310	256

Table 6 — Investment Cost per Customer Compared to Number of Customers Served for 16 Sewer Systems in Oklahoma, 1972

	Number of customers served[1]			
Item	Under 100	100-199	200-299	300-400
Number of systems	6	4	3	3
Investment cost per customer ($)	1,000	798	594	434
Average density of customers	28.3	37.8	49.4	55.2

[1]There were an average of 2.5 persons per customer served in the 16 sewer systems studied.

density of customers increased from 28.3 to 55.2 customers per mile of line. To determine which of these, number or density of customers, had the most effect on investment cost per customer, further analysis was necessary.

Regression Analysis

To test the statistical significance of the effect of number of customers and density of customers had on investment cost per customer a log-linear regression equation was computed (Table 7).[6] The dependent variable was investment cost per customer with density of customers and number of customers served as two independent variables.

By interpreting the results of the regression (Table 7) it was determined that density of customers and number of customers served both have a statistically significant effect on investment cost per customers and that they explain about 88 percent (R^2 = .88) of the variation in investment cost per customer. The correlation coefficient for the two independent variables was .82 indicating that number of customers and density of customers have a tendency to move in the same direction, e.g. an increase in one is accompanied by an increase in the other.

The regression coefficients in Table 7 may be interpreted as follows: a 100 percent increase in density of customers will result in a 48 percent decrease in investment cost per customer assuming number of customers remains the same; a 100-percent increase in number of customers will lead to a 22-percent decrease in cost per customer assuming that density remained constant.

The magnitude of the change in investment cost per customer brought about by a change in density would indicate that density has more effect on reducing investment costs per customer than increased

[6]The log-linear regression equation was used because it gave a better "fit" for the data than the simple linear regression.

Table 7. Log-linear Regression Results for Investment Cost per Customer Relative to Density and Number of Customers Served for 16 Sewer Systems in Oklahoma, 1972

Item	Regression coefficient	R^2,[1]	Correlation coefficient[1]	Student's t
Density of customers	—.48			3.16[2]
		.83	.82	
Number of customers served	—.22			2.66[2]

[1]R^2 and correlation coefficient refer to both variables so they are not on the same line with either one.
[2]Coefficients are statistically significant at the 1 percent level.

numbers of customers served. Thus as a result of this analysis it would appear that much, but not all, of the economies of size in investment cost reported in Table 4 can be attributed to the larger communities being more densely populated. It could also be interpreted to mean that smaller, more densely populated communities could have investment costs per customer similar to larger, less densely populated communities.

Total Annual Costs

As defined for this study, total annual costs include operating and maintenance costs plus an annual amortization payment. Operation and maintenance costs for lagoons and general overhead costs are based on a constant cost per capita (p. 11) so number of customers will have little effect on the per customer cost of these cost items.[7] Sewer line maintenance cost is based on a constant amount per lineal foot of line so cost per customer for sewer line maintenance will be affected by the density of customers, but not by number of customers. Thus, much of the difference in total annual costs per customer for different sizes of systems would depend upon different densities of customers and different amortization payments per customer.

As was indicated earlier, density and number of customers tend to move in the same direction and investment cost per customer declines as the system grows larger and more densely populated. Since amortization payments are directly related to investment costs, total annual costs per customer were expected to be lower for the larger sewer systems in the study.

Total annual costs per customer for different sizes of sewer systems are presented in Table 8. Total annual costs are calculated based on construction grants of 0, 25, 50, 75, and 100 percent because federal

[7]There could be some effect on per customer cost where number of people per customer varied. The effect would be very small, however.

Table 8 — Total Average Annual Cost per Customer for 16 Sewer Systems in Oklahoma With different Levels of Construction Grants by Size of System, 1972

Size of construction grant (percent)	Number of customers			
	Under 100	100-199	200-299	300-400
0 grant	$76.90	$57.55	$52.10	$43.36
25 grant	62.29	46.79	42.76	35.81
50 grant	47.68	36.15	33.43	28.27
75 grant	33.06	25.39	24.09	20.72
100 grant	18.44	14.63	14.75	13.17

and/or state sewer construction grants are available for small communities. As expected, total annual costs were somewhat lower for the larger systems. Average annual costs per customer for the smallest systems ranged from $76.90 to $18.44, depending on the size of construction grant. For the largest systems, comparable costs ranged from $43.46 down to $13.17.

The costs shown on the 100-percent grant line in Table 8 would be the equivalent of annual operation and maintenance costs only because there would be no investment cost and hence no amortization expense. These costs decline from $18.44 for the smallest systems to $13.77 for the largest systems.[8] All operation and maintenance costs are essentially constant per capita except sewer line maintenance which is constant per foot of line. Therefore, the difference between $18.44 and $13.17 must be due to a higher density of customers in the larger systems. This conclusion agrees with earlier findings (Table 6) of higher customer densities in the larger systems studied.

Using total costs per customer as the dependent variable and density and number of customers as two independent variables, a loglinear regression equation was computed to test the significance of the data presented in Table 8. The results of the regression of a 50-percent grant is presented in Table 9. Density of customers had a significant effect on total annual costs per customer but number of customers did not have a statistically significant affect on total annual costs.

Results of the regression also indicate that 90 percent (R^2 = .90) of the variation in cost per customer is explained by the two variables with density as the only statistically significant variable. The regression coefficient may be interpreted to mean that a 100-percent increase in density of customers would result in 57 percent reduction in annual cost

[8]The possibility of obtaining a 100-percent grant is very doubtful. However, the 100-percent grant line in table 8 does give a good approximation of operating and maintenance costs.

Table 9 — Regression results for Total Annual Costs per Customer relative to Density and Number of Customers Served for 16 Sewer Systems Assuming a 50 Percent Construction Grant, Oklahoma, 1972.

Item	Regression coefficient	R^2	Student's t
Density of customers	—.57		—4.70[1]
		.90	
Number of customers served	—.08		—1.37

[1]Significant at the 1 percent level.

per customer, assuming that number of customers remained the same. It was not surprising that number of customers had no significant effect on total annual cost per customer because of the relatively constant operating and maintenance costs per customer incorporated in the total annual costs.

Limitations of Annual Cost Analysis

Using a constant value per capita or per lineal foot of line for all annual costs except the amortization portion limits the analysis of total annual costs in terms of economies of size. Thus, the data on total annual costs should only be used as a general guideline for what total annual costs may be for the size of systems included in this study. They will be helpful, however, in determining the size of grant needed for a sewer system to be economically self-sustaining in view of prevailing rates for sewer service in small communities.

Sewer Rates

The average sewer rate for the systems included in this study was $2.50 per month per customer with a range of $3.65 to $1.50. The average annual income for the communities in this study for sewer service would be $30 per customer ($2.50 x 12). Under these conditions, only communities receiving sewer construction grants of 75 percent or more (except for the largest systems receiving 50 percent grants) could expect the sewer revenues to pay all sewer costs with a $2.50 sewer rate (Table 8). Communities receiving lesser grants must charge more for their sewer service to have it be economically self sustaining or pay for their sewer out of some other community income.

The amount of the grant received by the community, if any, depends to a certain extent upon the needs and income of the community. It is up to the community to determine how it shall pay for their sewer system and set their sewer rate accordingly.

OKLAHOMA

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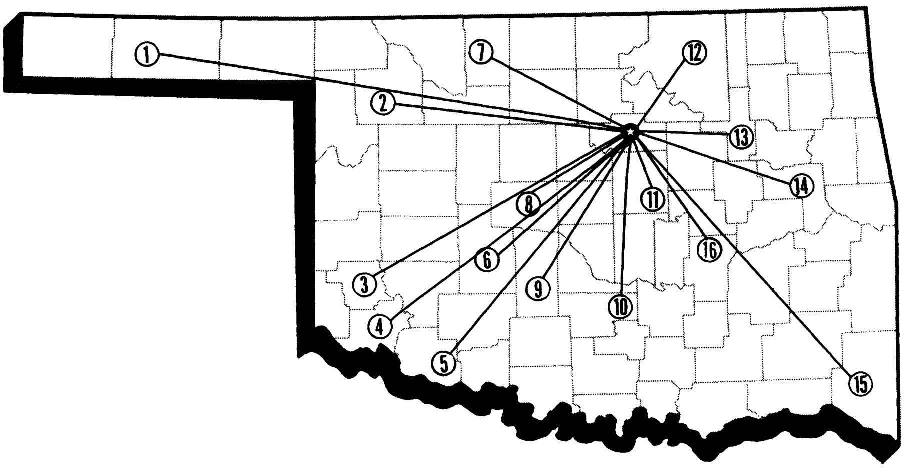
System Covers the State



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