A COST EVALUATION

OF

RURAL PUBLIC WATER SYSTEMS

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INTRODUCTION

Community services provision in terms of quality and availability in rural areas of the United States is at a lesser level of development relative to urban areas. New Hampshire data of the last 1970's suggest that more than half of the 240 cities and towns in the state do not have public water systems that serve at least 200 people [1]. In the New Hampshire seacoast counties of Strafford and Rockingham from 1970 to 1980, there has been an increase from 20% to 25% and 38% to 41%, respectively, for each county in the percentage of year-round housing units that utilize individual on-site wells. For the northern part of New Hampshire, Carroll County in the early 1980's had approximately 50% of all year-round housing units attached to individual wells. In the late 1970's, about 60% of the total of seventy New Hampshire towns classified as part of the Connecticut River Valley Basin were denoted as having individual on-site wells.

The percentages become much higher if one evaluates the number of year-round housing units having hookups to septic tanks or cesspools. In 1980, approximately half of the year-round housing units in the state of New Hampshire contained septic tanks or cesspools for their sewage operation. The counties of Strafford and Rockingham ranged from 39% to 58%, respectively. The counties of Coos and Carroll in the northern portion of the state were 32% and 83%, respectively [2].

An Army Corps of Engineers study [3] completed in the mid 1970's, which focused upon the water supply needs and resource availability for 47 communities in southeast New Hampshire, concluded that 28 of these towns were likely to experience water supply shortages by the year 2020. Of these 28 communities, 12 towns do not presently have public water supply systems.

With the state facing high levels of residential and industrial development, concerns are being expressed about the need to insure adequate water quantities and water that is usable. These emerging rural quality and quantity concerns will cause rural and regional planners and community officials to consider the feasibility of central water supply and waste water disposal systems. These systems will be looked at as alternatives to individual on-site wells that often have a high degree of uncertainty pertaining to future supply and possible ground water contamination from poorly implemented and maintained septic tanks and cesspools [4]. Central water and wastewater disposal systems allow for the use of state of the art technology that will improve the monitoring of water quantity and quality. These operations allow a central management to promote efficiency and continuity in system operation.

It seems that two types of situations are existing in the state. On one hand, there are communities lacking any centralized water supply and wastewater disposal systems and needing to undertake and finance a program of major capital implementation. There are other communities that have their water system facilities already in place, but need to expand the capacity to meet increasing water demands or request a major improvement program to replace, rehabilitate, or upgrade the existing system [5]. Town officials and residents face very high monetary costs in handling either of the two situations. In rural areas, the implementation of a new water supply system would normally involve very large capital cost expenditures for storage, a pipeline system, a distribution network, and treatment plants. This would occur in areas where population density is low and service delivery would be costly. Improvements in an existing water supply system could result in capital costs related to any combination of the components of a water system. Implementation of a sewage disposal system would involve similar cost components.

Town government officials realize the difficulty of attempting to absorb the associated costs of such community service provisions on their own. As a result of these financial hardships, various governmental agencies have come forth with institutional arrangements designed to insure the availability of adequate community water supply and disposal service provisions for meeting rural needs. One such agency is the Farmers Home Administration (FmHA).

Since the early 1960's, the year the Consolidated Farmers Home Administration Act was enacted by Congress, the Federal Government has allocated a large sum of dollars into public services in rural areas through the programs of the FmHA. Through grants which are intended to reduce the debt service portion of annual water costs, small communities and groups of rural residents received over 1.4 billion dollars for water and waste disposal systems during the 1970's. Loans, at reduced interest rates, provided an additional 4.9 billion dollars in capital for these services [6]. The FmHA gives its priority to public entities in areas smaller than 5,500 people for the purposes of restoring a deteriorating water supply, or improving, enlarging, or modifying a water facility or an inadequate waste facility.

Using past FmHA data, it is the purpose of this study to estimate the cost of selected components for rural water distribution systems located in the states of New Hampshire and Vermont. Data for the two states will allow for comparisons to determine if rural public cost differences exist between the two states. Data are viewed from the perspective of different size towns, number of users, and density of users. The costs could be used as input in the development of initial capital budgets for town officials and planners contemplating water system implementation, expansion, or rehabilitation. The empirical results could also be utilized in optimization planning models such as a mathematical programming model aimed at cost effective design. For purposes of this study, wastewater disposal systems were not considered because of the nature of the data. Emphasis was placed on water supply systems.

This report is organized as follows. The second chapter contains a highlight of the related research that has been previously completed. The third chapter denotes an overview of the methodology used. The following chapter is designated as empirical results with the last chapter of this report denoting a summary and conclusions.

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1. "Report of the New Hampshire Water Supply Policy Commission", February 1981.
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PREVIOUS RESEARCH

Whitlach and Asplund [1] provide cost estimates for installed components of a rural water distribution system for the state of Ohio. The components represent 92% of the capital cost of the pipeline distribution systems studied. They reported some economies of size for ground storage tanks and the distribution network. They emphasize that rural water systems are unique in their design features, as well as in the various inputs and processes used. For such reasons, data from urban systems are not applicable to the rural design setting.

Stoltenberg [2] provides data on a small number of components of rural water systems, but overlooks the cost of valves, services, and other main features. Pipe strength cost data are also presented.

Kuehn and Nelson [3], according to [4], found some evidence that cost estimates for rural water systems are not substitutable among areas. Treatment and storage facility costs for a typical rural water system of about 200 users was found to be 25% larger in northern Missouri and about 50% larger in Oklahoma than in the Ozark area. Distribution capital costs were highly variable among the studied regions. It was felt that topography, labor rates, and transportation rates may have been some variables that contributed to this differential.

Ramamurthy and Chicoine [4] carried out an econometric analysis of capital costs, using Illinois rural water system construction contract bids. Their regression results suggest some decline in the rate of increase in pipe costs with an increase in quantity. Ground storage tanks, the distribution network, and treatment plant bid costs were invariant to quantity, indicating no declining average cost reduction for larger sizes.

Johnson and Hobgood [5] studied the cost of providing public water services in rural Louisiana. They developed cost functions which can be used to estimate annual operating costs per user. Emphasis is placed on the effects of the number and density of population on operative costs per user.

The following chapter of this report contains information about the methodology for the present study.

REFERENCES

1. Whitlatch, E. E. and P. L. Asplund. "Capital Cost of Rural Water Distribution Systems," Water Resources Bulletin, 310-314, April 1981.
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METHODOLOGY

Data Collection

To build the data base for this study, bid tabulations for various Farmers Home Administration water projects funded in the states of New Hampshire and Vermont during the time period of 1978 to 1986 were obtained from FmHA offices in both states. The projects were for the expansion and upgrading of rural water distribution systems in each state or for the initial implementation of a rural water distribution system. Data were collected in fourteen towns in Vermont and nine communities in New Hampshire involving 32 projects in the former state and 11 projects in the latter state.

The New Hampshire communities included were Whitefield, Lisbon, Jackson, Woodstock, Franklin, Epsom, Farmington, Raymond and Bennington.

The Vermont towns selected were Alburg, Swanton, Troy, Newport, Milton, Bridport, Randolph, Hartland, Poultney, Pittsford, Chester, Manchester, Worcester, and Brighton. For Vermont, this included 304 bids received for their total amount of projects and for New Hampshire this involved a total of 63 bids. A project was not included for study if only incomplete information was available. Each bid tabulation usually contained multiple bids and the type of information varied among projects.

The project contracts can be identified into four major category types. They are as follows: (1) pipeline and distribution network; (2) water treatment facility; (3) water storage facility; and (4) well facility. This study focuses upon the first three categories with the latter category containing insufficient information for an empirical evaluation.

As Ramamurthy and Chicoine [1] and Whitlach and Asplund [2] have previously described, the pipeline and distribution network contracts contain data on such components as pipes, valves, pipeline, stream, highway, and railroad crossings, and hydrants. Each component type in a contract bid may have multiple data and thus were classified as separate observations.

Water treatment facility contracts contained data on the construction costs of water treatment plants. Each of the plants varied in size, but were similar in level of technology.

The water storage facility contracts provide the construction costs of an elevated or ground storage tank. This includes such essentials as site preparation and foundation to fabrication, erection, and painting.

The ENR Construction Cost index was used to adjust all cost date to 1985 price levels. This allowed the cost information to be compared in each of the states as well as between states.

User and Density Data Overview

The size of a rural water community system is measured in terms of the number of users (households and firms) purchasing water from the system. The New Hampshire systems ranged in size from 81 to 2408 users, with the average size being about 648 users. For Vermont, the systems ranged in size from 58 to 1525 users, with the average size approximately 540 users. The systems were divided into three size groups for descriptive and analytical purposes. Systems with 58 to 500 users were classified as small, 501 to 1000 users as medium, and 1001 to 2408 users as large systems. Table 1 gives an overview of the distribution by user-size group for the aggregate of both states and for each individual state.

Density is represented by the number of users for each mile of water line in the distribution system. The New Hampshire systems had a density that ranged from 39 to 2084 users per mile with an average density of 657.

The Vermont systems ranged from 21 to 1760 users per mile with an average density of 448. Three levels of density were designated. Systems with 21 to 200 users per mile were classified as low density, 201 to 1000 users per mile as medium density, and 1001 to 2084 users per mile as high density sytems. Table 2 denotes the distribution by density level for the combined data from both states as well as the individual state disaggregation.

It is important to note that the user and density category designations as established above will be used extensively in the empirical results portion of this report.

Construction Bid Cost Data Overview

Table 3 contains cost data aggregated for New Hampshire and Vermont that relates to various components that are considered essential in a rural water system. This table is presented so that a general descriptive overview can be looked at initially. Practical application for the categories can be derived from an analysis later in the report. Hydrants and valves can vary in cost per unit based upon the type and size. The costs for booster pumps, water treatment facilities, and storage tanks involve construction costs that involve site preparation, the actual physical building, and required equipment. The costs of extending a water distribution system over highways, railroad tracks, and streams can vary depending upon the terrain and length of obstacle.

The following chapter contains empirical results of the statistical analysis, based upon density level and user size as well as ordinary least-squares regression analysis.

REFERENCES

1. Ramamurthy, G. and D. L. Chicoine. "Capital Costs of Rural Water Systems: An Empirical Approach", Water Resources Bulletin, 255-260, April 1984.

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Table 1. Distribution by User-Size Group for Aggregate and Disaggregate Data for New Hampshire and Vermont[1]

User Size Level	Range of Users	Average No. of Users	Towns
		New Hampshire and Vermont	
Small	58-500	200 (135)	13
Medium	501-1,000	692 (110)	6
Large	1,001-2,408	1,541 (530)	4
All Systems	58-2,408	573 (547)	23
		Vermont	
Small	58-500	181	8
Medium	501-1,000	688 (121)	5
Large	1,001-2,408	1,252 (203)	3
All Systems	58-1,525	540 (431)	16
		New Hampshire	
Small	58-500	284 (132)	5
Medium	501-1,000	711 (---)	1
Large	1,001-2,408	2,408 (---)	1
All Systems	81-2,408	648 (742)	7

[1]Standard deviation values are in parentheses

Table 2. Distribution By User-Density Level For Aggregate And Disaggregate Data For New Hampshire And Vermont[1]

User Density Level	Range Of Users/Mile	Average Number Of Users/Mile	Number of Towns
		New Hampshire and Vermont	
Low	21-200	103 (57)	10
Medium	201-1,000	429 (242)	9
High	1,001-2,084	1,714 (262)	4
All Systems	21-2,084	514 (613)	23
		Vermont	
Low	21-200	103 (55)	8
Medium	201-1,000	281 (70)	5
High	1,001-1,760	1,590 (175)	3
All Systems	21-1,760	448 (584)	16
		New Hampshire	
Low	21-200	105 (66)	2
Medium	201-1,000	576 (262)	4
High	1,001-2,084	2,084 (---)	1
All Systems	39-2,084	657 (650)	7

[1]Standard deviation values are in parentheses

Table 3. Cost Of Selected Components For Rural Water Systems In New Hampshire And Vermont[2]

	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Hydrants	213	1,264	384	470	2,590
Valves	735	595	309	11	3,173
Booster Pumps	28	172,531	90,771	82,962	400,173
Water Treatment Facilities	12	1,865,215	488,405	948,657	2,467,529
Storage Tanks	81	342,030	209,473	12,950	1,135,018
Highway and Railroad Crossings	177	374	1,243	32	13,629
Stream Crossings	42	106	46	39	259
Rock Excavations	299	35	50	0	793

[2]Costs are on a per unit basis in terms of 1985 dollars except for highway, railroad, and stream crossings which are in dollars per foot and rock excavations which are in dollars per cubic yard.

EMPIRICAL RESULTS

In order to better understand the influence of user-size and density upon constuction costs of various major components of a rural water system, comparisons are made between the individual user-size categories as well as user-density groupings. Also, this data was used for comparisons that focused upon the low value bid for a construction bid contract and the average value bid. This allows for an understanding of the potential variability that can exist between individual bids.

User-Size and Density Analysis

Table 4 contains aggregated data for New Hampshire and Vermont for the construction costs in terms of 1985 dollars of various major components typically part of consideration in rural public water system improvement or implementation. This table, based upon the low value bid for each construction contract bid tabulation, classifies the categories of pumping stations, water treatment facilities, storage facilities, and pipe distribution system according to the user-size groupings. This data for each component includes facility, construction, and preparation costs.

In theory, it is expected that per unit costs for a user would normally decrease for increasing levels of users [1]. This is called the principle of economies of size. The rationale is that as total costs increase for larger scale projects, the resulting costs are spread over a greater number of users. Thus, the costs per user would decrease for higher user levels. This theory was partially true for this study, as will be shown below.

For each user-size category of small, medium, and large, the four water system components were considered in terms of the total cost of the system component and cost per user. In comparing the cost per user for pipeline distribution over the size categories, the cost per user decreased as the number of system users increased. This pattern for cost per user did not hold for the other three system components. This was because the number of observations for the system component were too few. Rather than use questionable data, only the data for water systems that could be verified were utilized.

Tables 5 and 6 contain numerical results for New Hampshire and Vermont, respectively, for the construction costs in terms of 1985 dollars of the four major water system components based upon the low value bid for each construction contract bid tabulation. As before, total costs per system and cost per user are calculated for each component and classified according to user-size levels.

The number of systems utilized as observations for New Hampshire and Vermont was disappointingly low. A high degree of ambiguity seemed to exist in the observed contract bids.

For a similar analysis as above, but based upon average value bids for each contract bid tabulation rather than low value bids, see Appendix A. Again, the economies of size theory was partially verified.

Table 7 contains construction costs per user for the aggregate and disaggregate New Hampshire and Vermont data for rural water systems by user-density levels, based upon low value bids. Across any row for each system component, the cost per user decreases as the user-density increases. This phenomenon occurs for each component category and for each state and their aggregate. Economies of size seem to be an important concept when considering costs to the user when classifying water systems according to density of users per mile of pipeline. Appendix B contains a similar table as the above, but data are based upon average value bids from a construction contract bid tabulation.

<u>Regression Analysis Applied To Pipe Size</u>

Regression models were developed to analyze the affect of various variables upon the cost of selected components of a rural water system using ordinary least-squares procedures. These models were formulated for predictive purposes so that the costs of various pipeline sizes and water distribution involving stream crossings, highway crossings, and railroad crossings could be estimated with statistical reliability.

The following conceptual models were specified and tested for prediction purposes for pipeline of various sizes:

(1) $C = a_o + a_1Q + z_1$

(2) $C = b_o + b_1Q^2 + z_2$

(3) $C = c_o + c_1Q + c_2Q^2 + z_3$

(4) $C = d_oQ^{d_1}e^{z_4}$

(5) $C = f_o + f_1Q + f_2x + z_5$

(6) $C = g_o + g_1Q^2 + g_2x + z_6$

(7) $C = h_o + h_1Q + h_2Q^2 + h_3x + z_7$

(8) $C = k_oQ^k e^{k x}e^{z_8}$

where:

C = adjusted total cost for pipeline of a specified diameter in terms of 1985 dollars

Q = quantity in terms of feet of distribution pipeline of a specified diameter

x = binary variable reflecting state (NH or VT) of where information is from (1 if from New Hampshire and 0 if from Vermont) a, b, c, d, f, g, h, k = estimated parameters

e = natural e

z = stochastic disturbance term

The C, Q, and x data were obtained from individual bids contained in contract bid sheets for each FmHA project in the states of New Hampshire and Vermont for the years 1978 to 1986. The pipeline cost information was adjusted to 1985 dollars. The binary variable, x, was included to determine if there is a statistical difference between costs for distribution pipelines in New Hampshire and Vermont.

As done by Ramamurthy and Chicoine (1984), a similar procedure was followed, where individual pipes were fixed according to pipe dimensions and aggregated over type of pipe material. In other words, a ten-inch pipe could be composed of cast-iron, PVC, or asbestos-cement. It was felt that pipeline costs vary more with size than with pipeline material.

To select the model that best fit the data for each pipe size, the coefficient of determination (R_2), the t-ratios for each estimated parameter, and the pattern of residuals were considered. Table 8 contains the empirical results for each pipe size that were considered the best for predictive purposes given the established criteria. Model (8) proved to be the best for all pipe sizes except for the four-inch pipe where model (4) tested the best.

For predictive purposes, pipe sizes four through twelve show coefficient of determination (R^2) results that are considered very high (95 percent and above). Substituting values for Q and x, estimates can be generated which show a high degree of statistical reliability for the range of study data. For example, if one wanted to predict the cost of six-inch pipe for one thousand feet (Q) in the state of New Hampshire (1 for x), these numbers would be substituted into equation (9) below:

(9) $C = 27.94Q^{.94}e^{.08x}$

The total cost prediction for six-inch pipe would be approximately $19,930 in terms of 1985 dollars.

Looking at the t-statistic values for the estimated parameters corresponding to the x variable, the only two pipe sizes where there is a statistical difference between New Hampshire and Vermont total costs for a given pipe size is the six-inch and twelve-inch cases. New Hampshire costs are higher in each case. For all other pipe sizes, there is no statistical difference between total costs for each of the states for a given size.

Regression Analysis Applied To Stream, Railroad, and Highway Crossings

Conceptual models (1) through (8) were applied to each category of pipeline crossing. Again, criteria based upon the coefficient of determination (R^2), t-statistics of the estimated parameters, and pattern of the residuals were used to select the best predictive model. The dependent variable, C, for each case was the total cost for each particular type of crossing. Q was again the total number of feet for a specific crossing type and x was a binary variable reflecting a value of one if a unit of data is from New Hampshire and zero if from Vermont. The predictive models for each crossing type that are found to be the best fit can be used to generate benchmark cost estimates for different pipeline crossing types of varying footage. The same procedure as illustrated previously can be used.

Table 9 contains the ordinary least-squares results that denote the best data fit for each pipeline crossing type. In terms of predictive reliability for the study data range, these models with lower coefficient of determination

(R^2) values are not as good as those pipeline size models previously estimated. Caution should be taken when using this set of models for predicting. The t-statistics of the estimated coefficients are all statistically significant at the .01 level of significance. This suggests that these models are very good explanatory models--independent variables are strongly related to the dependent variable of total cost for a specific crossing type. The t-statistics for x are highly significant in the railroad and stream crossing equation. This suggests that the total costs for each type of crossing in New Hampshire are statistically higher than those in Vermont of similar type.

REFERENCES

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Table 4. Construction Costs of Rural Water Systems by User-Size Group Based On Low Value Bid For New Hampshire and Vermont Aggregated Data[3]

	No. of Systems	Cost Per System	Cost Per User
		Small	
Pumps	1	102,307 (---)	222 (---)
Treatment	1	981,556 (---)	3,208 (---)
Storage	5	143,305 (142,467)	736 (552)
Distribution	14	215,711 (110,611)	1,616 (1,387)
		Medium	
Pumps	3	76,267 (9,534)	99 (12)
Treatment	1	473,303 (---)	538 (---)
Storage	2	283,701 (32,802)	367 (83)
Distribution	9	222,009 (122,831)	340 (206)
		Large	
Pumps	1	104,706 (---)	209 (---)
Treatment	1	1,804,168 (---)	1,514 (---)
Storage	1	545,333 (---)	457 (---)
Distribution	5	280,089 (219,343)	194 (197)

[3]Standard deviation values are in parentheses. Construction costs are in terms of 1985 dollars for this table and all following tables.

Table 5. Construction Costs of Rural Water Systems by User-Size Group Based On Low Value Bid For New Hampshire[4]

	No. of Systems	Cost Per System	Cost Per User
		Small	
Pumps	1	102,307 (---)	222 (---)
Treatment	---	---	---
Storage	1	22,519 (---)	100 (---)
Distribution	4	230,926 (67,565)	1,327 (1,249)
		Medium	
Pumps	1	82,963 (---)	117 (---)
Treatment	---	---	---
Storage	---	---	---
Distribution	1	133,241 (---)	187 (---)
		Large	
Pumps	---	---	---
Treatment	---	---	---
Storage	---	---	---
Distribution	2	222,257 (67,031)	92 (28)

[4]Standard deviation values are in parentheses.

Table 6. Construction Costs of Rural Water Systems by User-Size Group Based On Low Value Bid For Vermont[5]

	No. of Systems	Cost Per System	Cost Per User
		Small	
Pumps	---	---	---
Treatment	1	981,556 (---)	3,208 (---)
Storage	4	173,502 (144,263)	895 (505)
Distribution	10	209,626 (123,179)	1,732 (1,422)
		Medium	
Pumps	2	72,919	91
Treatment	1	473,303 (---)	538 (---)
Storage	2	283,701 (32,802)	367 (83)
Distribution	8	233,105 (125,957)	360 (210)
		Large	
Pumps	1	105,706 (---)	89 (---)
Treatment	1	1,804,168 (---)	1,514 (---)
Storage	1	545,333 (---)	457 (---)
Distribution	3	318,644 (271,062)	262 (230)

[5]Standard deviation values are in parentheses.

Table 7. Construction Costs of Rural Water Systems by User-Density Level Based On Low Value Bid[6]

	Low		Medium		High	
	Number of Systems	Cost per User	Number of Systems	Cost per User	Number of Systems	Cost per User
			New Hampshire and Vermont			
Pumps	--	--	4	129 (55)	1	94 (--)
Treatment	1	3207 (--)	1	1513 (--)	1	537 (--)
Storage	3	809 (557)	4	539 (381)	1	366 (--)
Distribution	11	1970 (1367)	12	374 (158)	5	100 (20)
			New Hampshire			
Pumps	--	--	2	170 (53)	--	--
Treatment	--	--	--	--	--	--
Storage	--	--	1	100 (--)	--	--
Distribution	2	2137 (1343)	3	407 (169)	2	92 (28)
			Vermont			
Pumps	--	--	2	88 (54)	1	94 (--)
Treatment	1	3207 (--)	1	1513 (--)	1	537 (--)
Storage	3	809 (557)	3	686 (329)	1	285 (--)
Distribution	9	1933 (1370)	9	362 (152)	3	106 (10)

[6] Standard deviation values are in parentheses.

Table 8

Pipeline Regression Results For New Hampshire And Vermont Rural Water Systems In Terms Of Estimated Parameters

	Intercept	Q	X	R^2	Number of Observations
2-Inch Pipes	74.44	.65 (1.98)[2]*	.32 (.47)	.70	20
4-Inch Pipes[1]	23.81	.96 (66.04)**		.98	112
6-Inch Pipes	27.94	.94 (70.53)**	.08 (1.56)	.96	235
8-Inch Pipes	29.37	.96 (105.31)**	-.02 (-.48)	.98	232
10-Inch Pipes	32.46	.97 (44.34)	-.13 (-.87)	.96	84
12-Inch Pipes	83.93	.87 (45.75)**	.09 (1.60)	.95	167

1] Based upon model (4) with all other pipe sizes based upon model (8).

2] The values in parentheses are t-statistics.

* Significant at the .05 level

** Significant at the .01 level

Table 9

Pipeline Crossing Regression Results For New Hampshire And Vermont Rural Water Systems In Terms Of Estimated Parameters

	Best Fit Model	Intercept	Q	X	R^2	No. of Observ-ations
Highway Crossing	$C=d_0Q^d$	601.84	.75 (6.84)[7]*		.35	90
Railroad Crossing	$C=k_0Q^k e^{k\ x}$	10.91	1.71 (6.43)*	.74 (4.00)*	.66	44
Stream Crossing	$C=k_0Q^k e^{k\ x}$	487.85	.62 (4.55)*	.77 (3.57)*	.68	56

[7]]t-statistics are in parentheses
*Significant at the .01 level

SUMMARY AND CONCLUSIONS

Cost data in both aggregate and disaggregate form for New Hampshire and Vermont were presented so that towns of various user size and density level can be looked at for comparative purposes. Also, the costs for selected components (hydrants, values, ...) were calculated which included mean and standard deviation values and minimum and maximum range values. These sets of data present rough "ball park" estimates of typical costs.

It was expected that per unit water costs for a user would normally decrease for increasing levels of users. In comparing the cost per user for pipeline distribution over various user size, the cost per user decreased as the number of system users increased. Declining costs did not hold for increasing user size for the categories of pumps, treatment, and storage. Thus for these latter categories, the concept of economies of size was not adhered to. An additional number of observations would be needed for establishing the validity or lack of the theory of economies of size.

Various regression models were formulated relating pipeline costs for designated size as a function of quantity and a variable designating if the cost observation is from New Hampshire or Vermont. It should be emphasized that this latter variable was uniquely designed and used for the first time in a study relating to water system costs.

The regression results suggest a high degree of statistical reliability for the range of study data and can be readily utilized for predictive purposes for similar ranges of cost and quantity data. There is a statistical difference between New Hampshire and Vermont total costs for six-inch and twelve-inch pipe sizes with New Hampshire costs being higher.

Regression models were also developed for three types of pipeline crossings. The results suggest that the models are more useful for explanatory purposes than as predictors. This was because the coefficient of determination values were low, but estimated parameters were highly statistically significant. Important factors influencing pipeline crossing costs have been emphasized.

Rural town officials can realize from this study that user size and density are important components that influence water system costs. This does not play such an important part in urban areas because of the lack of a wide spatial distribution.

It should also be emphasized that bids received for a particular water project can vary widely according to costs. Both the New Hampshire and Vermont data had this basic characteristic.

Town officials and planners should realize that the estimates that can be made for their individual situations from the developed relationships in this study can only be looked upon as "rough" estimates. This study gives a good indication of important cost factors that should be considered when formulating preliminary plans concerning rural public water systems.

APPENDIX A

Construction Costs of Rural Water Systems by User-Size Group Based On Average Value Bid For New Hampshire And Vermont Aggregated Data

	No. of Systems	Cost Per System	Cost Per User
		Small	
Pumps	1	122,666	266
Treatment	1	1,089,401	3,560
Storage	5	205,741	1,033
Distribution	14	288,313	2,102
		Medium	
Pumps	3	102,429	132
Treatment	1	634,660	721
Storage	2	370,651	481
Distribution	9	268,504	386
		Large	
Pumps	1	269,067	226
Treatment	1	2,179,377	1,828
Storage	1	619,239	520
Distribution	5	347,987	238

APPENDIX B
Construction Costs of Rural Water Systems by User-Density Level Based On Average Value Bid
(Standard deviations are in parentheses)

	Low		Medium		High	
	Number of Systems	Cost per User	Number of Systems	Cost per User	Number of Systems	Cost per User
New Hampshire and Vermont						
Pumps	--	--	4	184 (62)	1	148 (--)
Treatment	1	3,560 (--)	1	1,828 (--)	1	721 (--)
Storage	3	6,611 (7,965)	4	636 (440)	1	365 (--)
Distribution	11	2,506 (1,809)	12	512 (283)	5	128 (31)
New Hampshire						
Pumps	--	--	2	256 (68)	--	--
Treatment	--	--	--	--	--	--
Storage	--	--	1	103 (--)	--	--
Distribution	2	2,448 (1,469)	3	745 (395)	2	121 (39)
Vermont						
Pumps	--	--	2	172 (54)	1	148 (--)
Treatment	1	3,560 (--)	1	1,828 (--)	1	721 (--)
Storage	3	1,245 (537)	3	814 (363)	1	366 (--)
Distribution	9	2,519 (1,877)	9	435 (175)	3	133 (25)