NATIONAL STATISTICAL ASSESSMENT

OF RURAL WATER CONDITIONS

Executive Summary

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Report prepared for

The Office of Drinking Water
US Environmental Protection Agency

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EXECUTIVE SUMMARY

Information about rural water conditions has long been fragmentary and incomplete. The information that existed generally has been limited to the results of unsystematic, localized surveys concentrated narrowly on a few prominent local water quality problems. These surveys have not generally employed compatible sample designs or methodologies. As a result, it has been difficult to formulate a unified understanding of rural water conditions, and difficult to devise informed, comprehensive policies and programs for rural water supplies.

To some extent, the absence of wide-ranging and detailed knowledge of rural water conditions is related to the nature of rural water supplies. Rural water systems are frequently individual and small multiple-connection systems, which fall outside the regulatory and funding programs of the major "water agencies" of government. With enactment of the Safe Drinking Water Act of 1974, Congress set in motion two major efforts to develop systematic, current data on rural water supplies across the nation. First, in response to growing concern with the quality of drinking water and its effects on human health, the Safe Drinking Water Act provided for a uniform, national set of water quality standards and extended the monitoring and regulatory responsibility of the US government over smaller water supplies. Second, the Act mandated a one-time national statistical assessment of the current status of rural domestic water characteristics.

The one-time study was to be an intensive examination of a wide range of factors, but for only a sample of households and systems. The institutionalized national monitoring program was to extensively cover a few factors on all community systems. This document is concerned with the intensive, one-time national statistical assessment of rural water conditions.

THE CALL FOR ASSESSMENT AND RESPONSE

The enabling legislation mandating the one-time assessment study was contained in Section 3(a) of the Act. It reads:

> Sec. 3(a). The Administrator of the Environmental Protection Agency shall (after consultation with the Secretary of Agriculture and the several States) enter into arrangements with public or private entities as may be appropriate to conduct a survey of the quantity, quality and availability of rural drinking water supplies. Such survey shall include, but not be limited to, the consideration of the number of residents in each rural area . . .
>
> (1) presently being inadequately served by a public or private drinking water supply system; or by an individual home drinking water supply system;
>
> (2) presently having limited or otherwise inadequate access to drinking water;
>
> (3) who, due to the absence or inadequacy of a drinking water supply system, are exposed to an increased health hazard; and
>
> (4) who have experienced incidents of chronic or acute illness, which may be attributed to the absence or inadequacy of a drinking water supply system.

The study called for in this provision of the Act has been completed and what follows is a summary of the five-volume, approximately 1,900 page report, submitted to Congress in conformance with the stipulations of the Act. The study and report, labelled the National Statistical Assessment of Rural Water Conditions (NSA), focused primarily on the quality, quantity, availability, cost, and affordability of domestic water in rural households throughout the continental United States. Additionally, some corollary information was presented on water systems serving these households.

RESPONSIBILITY FOR THE STUDY

Primary responsibility for oversight of the contents and conduct of the study was allocated to the US Environmental Protection Agency. Within EPA, the national assessment study was placed under the aegis of the Office of Drinking Water. The planning of the content, scope, and execution of appropriate procedures for conducting the study involved the Office of Drinking Water, various private consulting firms, university researchers, and professional organizations. Subsequently, proposals were solicited and a group of rural sociologists from the Department of Rural Sociology at Cornell University was selected to further conceptualize the study, oversee the sampling and data collection, analyze the results, and write the report summarized herein.

In Section 3(a) of the Act, the Administrator of EPA was directed to consult with the Secretary of Agriculture in the formulation and overview of the study. During the formulation stage of study, two meetings were held with a specially formed study group composed of representatives from Farmers' Home

Administration, Economic Research Service of the Economic Development Division, and the Statistical Research Service of the Statistical Division of USDA. The meetings were primarily devoted to discussions of (1) the general scope of the study effort, (2) the types of data to be collected, (3) the manner in which this study effort would complement and inform USDA programs and research, (4) a critique of the conceptual foundations of the study, and (5) the ways in which the data would be analyzed. In addition, FmHA representatives joined a review team composed of experts representing a spectrum of professions, interest groups, and government agencies. This review team met on three separate occasions to critique the analysis and report writing in progress.

SIGNIFICANCE OF THE STUDY

The study summarized here is the first national study designed to investigate the status of rural water quality at the point of use, in rural households. In addition, it is the first systematic national assessment of quantity, availability, cost, and affordability of rural domestic water supplies. It is the first national assessment of the links between the status of domestic water in rural households and characteristics of the supply which provides that water.

Prior to this study, the most complete information, at the national level, about rural water was contained in the Community Water Supply Study: Analysis of National Survey Findings, conducted by the Bureau of Water Hygiene, US Department of Health, Education, and Welfare (1970), and Survey of Operating and Financial Characteristics of Community Water Systems, conducted by Temple, Barker, and Sloane, Inc. for the US Environmental Protection Agency (1977). Studies other than these were either local in scope or examined water pollution in bodies of water located in rural areas, not the characteristics of the water at the point of consumption.

This study complements and extends the information from the earlier reports. But, its focus on the character of the water as it is actually consumed at the household differs from earlier efforts. Additionally, it uniquely provides complementary information about the water supply system. In short, it is the first national portrayal of rural household water conditions and associated system characteristics.

METHODOLOGY AND RESEARCH PROCESS

A review was undertaken of available information and procedures for studying the status of rural domestic water conditions. This review pointed up serious deficiencies in knowledge, conceptual maturity, and methodological tools. A conceptual reformulation and development of data collection procedures was undertaken by the Cornell research group. Members of this group developed the interview schedule in consultation with management and technical personnel at EPA, and with various representatives from other governmental agencies, consulting firms and research groups. The instrument was pretested and refined four times, and the final version was submitted and approved by the Office of Management and Budget.

Data collection involved, at each selected household, personal interviews with occupants, physical inspection of on-premises water supplies, drawing samples of the major household water supply, various observations on sources of potential contamination; and, where appropriate, separate interviews with managers and operators of off-premises water supply systems which provided water to these rural households.

TransCentury Corporation was selected by the EPA, after competitive bid, to administer the data collection activities. Oversight and general coordination of these activities was accomplished in coordination with the Cornell University research group.

Interviewers underwent a two-week intensive training course on all aspects of the data collection effort, including the drawing, packaging, labelling, and transportation of specimens of "tap" water. Quality control of the field work included constant and comprehensive monitoring. Data coders were also intensively trained and monitored.

Water samples collected at each household participating in the study were shipped to central laboratories for analysis of as many as 40 separate biological, physical, chemical, or radiological properties. Responsibility for these analyses was shared by several organizations including the Energy Resources Corporation, the Medical School of the University of South Carolina, the Mississippi State Chemical Laboratory, the EPA-MERL Laboratory (Municipal Environmental Research Laboratory) in Cincinnati, and the EPA-EMSL Laboratory (Environmental Monitoring Systems Laboratory) in Las Vegas.

The sampling plan for the study defined the target population to conform to the US Bureau of the Census' definition of rural population and households: civilian, noninstitutionalized persons located in unincorporated or incorporated places of less than 2,500 population, or located in rural areas not designated as a place. The sample was proportional to rural population (and households) in: (1) the four broad census regions—Northeast, North Central, South, and West; (2) located in areas designated as Standard Metropolitan Statistical Areas; (3) in rural communities of 2,499 to 1,000 population, under 1,000 population, or open country. The county was designated as the primary sampling unit. From the approximately 3,000 counties in the continental US, 400 were selected. Within those counties, a total of 2,654 households and their associated water supply systems were evaluated. They represented an estimated 21,974,000 occupied rural households. Of these, an estimated 8,765,000 households were served by individual, single connection systems; 2,228,000 households were served by 845,000 intermediate systems (two through fourteen connections); and 10,981,000 households were served by 34,000 community systems (fifteen or more connections). Total counts of households and systems were derived using standard statistical weighting procedures. Each unit's weight, in broad terms, was the inverted sampling fraction adjusted for nonresponse.

Collected data were compiled by the Cornell research group for statistical analysis and report production. All aspects of the report underwent extensive scrutiny by various review mechanisms.

MAJOR FINDINGS

This study considered five dominant dimensions of the status of domestic water: quality, quantity, availability, cost, and affordability. Rural residents were asked about health effects but the results were modest in that very few rural residents reported adverse health conditions which they associated with the water supply. Attempts to secure detailed information about the health effects of the water being consumed would have required a large-scale epidemiological investigation, which was not possible within the scope of this study.

Information was secured from both the households and water supply systems. The major findings and conclusions will be presented first from the household perspective, then from information collected at the systems.

WATER QUALITY

Water quality was assessed using as many as 40 indicators, including all of the contaminants given primary and many given secondary maximum contaminant levels (MCLs) by the EPA (see Table 1). The study used the MCL levels to establish benchmarks for comparing various segments of the rural population. These benchmarks, or reference values as they were called, were not totally isomorphic to the MCLs. The MCLs included components which could not be reasonably accommodated in the study such as: (1) retesting provisions; or, (2) in the case of fluoride, a range of MCL values. However, reference values were chosen to match the MCL specified level, whenever possible, to provide perspective on interpretation.

A quality assurance program was in effect in each of the participating laboratories. A follow-up attempt to secure results on the quality assurance was not entirely successful. Some records had been discarded, others were not in an easily usable format, and some were inaccessible. Quantification of the quality assurance results for the purposes of this report was not complete. However, there was no indication that quality assurance programs at the laboratories deviated from quality assurance procedures that were EPA-approved at the time of the NSA study.

The NSA investigation of rural water quality suggested problems of greater magnitude and prevalence (especially regarding mercury, lead, cadmium, silver, and selenium) than had been generally expected, based on data from monitoring community water systems and from other studies. Since it is the first nationally systematic consideration of rural domestic water quality, there is no direct verification of its findings in previous work. There is also no way, within the confines of the study, to absolutely ensure that the reported levels of metals (or the levels of any of the other constituents) were valid indications of water supply contamination, nor to prove they were artifacts induced in some way by the study itself. On the other hand, since no previous study has looked as extensively at individual home supplies, intermediate systems, and small community systems, this study may have been the first opportunity to view the extent of water quality problems. But, rather than conclusively proving the status of rural water quality, the study strongly suggests important avenues for concern, and stands as a guide to further work.

Table 1

Constituents Measured in NSA Survey

Category	Constituent	Has Primary (P), Secondary (S), or No (N) MCL	Measured in All NSA Household Samples or only in Group II Subsample
Microbial	Total coliform	P	All
	Fecal coliform	N	All
	Fecal streptococcus	N	All
	Standard plate count	N	All
	Fecal coliform/fecal streptococcus ratio	N	All
Physical and Chemical	Turbidity	P	All
	Color	S	All
	Temperature	N	All
	Specific conductance	N	All
	Total dissolved solids (as determined from conductance)	S	All
	Hardness (as determined from calcium and magnesium)	N	All
Inorganic	Calcium	N	All
	Magnesium	N	All
	Nitrate-N	P	All
	Sulfates	S	All
	Iron	S	All
	Manganese	S	All
	Sodium	N	All
	Lead	P	All
	Arsenic	P	Subsample
	Selenium	P	Subsample
	Fluoride	P	Subsample
	Cadmium	P	Subsample
	Mercury	P	Subsample
	Chromium	P	Subsample
	Barium	P	Subsample
	Silver	P	Subsample
Organic	Endrin	P	Subsample
	Lindane	P	Subsample
	Methoxychlor	P	Subsample
	Toxaphene	P	Subsample
	2,4-D	P	Subsample
	2,4,5-TP	P	Subsample
Radioactive	Gross alpha	P	Subsample
	Gross beta	P	Subsample
	*Radium 226	P	
	*Radium 228	P	
	*Uranium	P	
	*Stontium-89	P	
	*Strontium-90	P	
	*Cesium-134	P	
	*Tritium	P	
	*Iodine-131	P	

*Measured only if the laboratory analyst considered gross alpha or gross beta readings sufficient to warrant further investigation.

Among those contaminants which are covered by primary MCLs (because they are potential health hazards), total coliform emerged as the most prevalent problem, exceeding the reference value in 28.9 percent of all rural households. Among constituents which tend to be aesthetically objectionable or impose economic costs (e.g., degrading to plumbing, laundry, etc.), iron was the most common.

The presence of total coliform organisms was the most common single problem and received the greatest attention in the analysis. Coliform organisms represent a problem in that they are used as indicators of the possible presence of pathogenic bacteria. The rate of total coliform presence in excess of one coliform per 100 milliliters of water (28.9 percent nationwide) was 15.5 percent among households served by community systems, and over 40 percent among those served by intermediate and individual systems (43.3 and 42.1 percent, respectively). Households served by systems with fewer than fifteen connections that were not wells (i.e., cisterns, springs, surface water, hauled, purchased bottled) had more than one coliform per 100 milliliters of water in 77.7 percent of cases. In general, households with low income (under $10,000) and low education (less than high school) were more commonly found to have coliform problems than other households. Poorly accessible and privately owned supplies tended to have coliform problems more often than other supplies. Households served by dug and bored wells, wells in which the water leaves the casing above ground level, wells with inadequate covers, inadequately maintained wells, and shallow wells all tended to have high coliform levels more commonly than those served by wells without those characteristics. Small systems, with few connections, repeatedly exceeded coliform levels more frequently than most large community systems.

Fecal coliforms were found among 12.2 percent of all rural households, but among only 4.5 percent of households using community water systems. Fecal coliform counts were above 200 organisms per 100 milliliters of water (a suggested upper limit in water used for swimming) for 1.6 percent of rural households.

Standard plate counts of more than 500 organisms per milliliter of water were encountered at 19.3 percent of households. In this case, the percentage of households with the problem, which used community water systems, was not dramatically lower than for those using intermediate and individual systems.

Turbidity was measured above one NTU among 16.5 percent of rural households. That rate varied from 23.8 percent in the North Central to 8.5 percent in the West. Households using community systems were least likely to have more than one NTU readings, 8.9 percent, compared to 24.0 percent for intermediate systems, and 24.7 percent for individual systems.

Color was measured above fifteen standard color units among only 2.3 percent of all rural households.

Total dissolved solids, estimated from specific conductance readings, was found above 500 milligrams per liter among 14.7 percent of all rural households. Households in the North Central and West were over that level 23.9 and 22.2 percent, respectively. The Northeast, on the other hand, had only 5.0 percent of households with levels above 500 milligrams per liter.

Magnesium was found above 125.0 milligrams per liter in only 0.1 percent of rural households.

Nitrate-N concentrations above 10.0 milligrams per liter occurred among 2.7 percent of households. Regionally, the proportion over that level was 0.3 percent in the Northeast, compared to 5.8 percent in the North Central.

Sulfates exceeded 250 milligrams per liter among only 4.0 percent of rural households, but households in the West and the North Central were over at rates of 11.7 percent and 7.4 percent, respectively. The Northeast and South had household supplies at that level in less than 1 percent of the cases.

Iron concentrations over 0.3 milligrams per liter were found in 18.7 percent of all rural households. North Central households exceeded that level among 28.2 percent of households, compared to 7.0 percent in the West. Households served by community water systems were over at the rate of 7.7 percent across the nation. By contrast, the percent of households with iron concentrations over 0.3 milligrams among intermediate and individual systems was 28.7 percent and 29.9 percent, respectively.

The pattern of manganese occurrence was very similar to iron. Households with more than 0.05 milligrams per liter occurred among 14.2 percent of the cases. The rate in the North Central was highest (19.9 percent); and lowest (4.7 percent) in the West. Households served by community systems were over that level at a rate of 7.2 percent, compared to 23.3 percent and 20.7 percent, respectively, among households served by intermediate and individual systems.

Sodium levels higher than 100 milligrams per liter appeared in 14.2 percent of rural households nationwide. That rate was as low as 6.0 percent in the Northeast, and as high as 19.2 percent in the North Central.

Lead was above 0.05 milligrams per liter at 16.6 percent of the households. The percent of households exceeding that level was lowest in the Northeast (9.6 percent) and highest in the South (23.1 percent). It was discovered subsequent to the data collection that a thin line of blue paint which marked the breakpoint on the glass ampules of nitric acid preservative contained cadmium and lead. It is likely that the average lead contamination due to the paint was 36 parts per billion (0.036 milligrams per liter). Assuming relatively constant contamination from the paint at that level, the estimated proportion of rural households over 0.05 milligrams dropped to 9.2 percent nationwide.

Arsenic levels in rural household water were encountered above 0.05 milligrams per liter in only 0.8 percent of all rural households. The preponderance of those households were found in small rural communities (population less than 1,000). Households in those communities were found with the high arsenic levels among 6.6 percent of the cases.

Selenium, nationwide, was found above 0.01 milligrams per liter among 13.7 percent of households. Most of that occurred in the North Central and West. Households in the Northeast and South had high rates in roughly 2 percent or fewer of the cases. In the North Central, that rate was much greater at 25.7 percent, but in the West a remarkable 41.3 percent of all rural households had more than 0.01 milligrams per liter of selenium.

Fluoride concentrations exceeded 1.4 milligrams per liter in only 2.5 percent of all rural households. The rate in the West, at 6.2 percent, was more than double the rate found in any of the other regions.

Cadmium was measured above 0.01 milligrams per liter among 16.8 percent of all rural households. Only 1.6 percent of rural households in the Northeast were over that level while 27.1 percent of those in the West were high. Households served by both community and intermediate systems had the high cadmium rates in more than 20 percent of the cases (21.2 percent and 26.9 percent, respectively) while 7.9 percent of the households with individual systems registered high. Here again, however, the paint on the acid preservative ampules apparently imparted some cadmium background to the readings. The average contamination was probably in the neighborhood of .92 parts per billion (0.00092 milligrams per liter). With that assumption, the national rate of high cadmium values dropped to 15.9 percent.

Mercury was found among 24.1 percent of all rural households to be in concentrations exceeding 0.002 milligrams per liter. That proportion climbed as high as 31.8 percent in the North Central, and dropped as low as 10.4 percent in the West.

Chromium was virtually nonexistent above concentrations of 0.05 milligrams per liter throughout the US.

Barium concentrations over 1.0 milligram per liter were rarely found (0.3 percent of all rural households).

Silver exceeded 0.05 milligrams per liter among 4.7 percent of all rural households. Among the types of systems serving rural America, community systems had the lowest rates (2.1 percent), and individual systems had the highest rates (7.1 percent).

Endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP were virtually never detected among rural household water supplies.

Gross alpha radiation in excess of acceptable exposure occurred among 0.5 percent of rural households—predominantly in the South. Unacceptable gross beta radiation was never encountered in the survey.

While these findings are startling, they must be kept in perspective. The large percentages of rural households with high contamination levels was a function of the level chosen to represent "high"—in this case, the primary MCLs. Again, these levels should not be interpreted as the proportion of households with domestic water exceeding an MCL since no resampling for verification, as required for MCLs, was performed. The levels established as MCLs generally incorporate substantial safety margins. So, even though these levels were identified as "high," and they were higher than was generally expected, they should be evaluated concurrent with the fact that widespread water-related health problems were not apparent throughout the rural US.*

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*The Environmental Protection Agency has participated with other agencies on another national research effort on drinking water quality. The national Health and Nutrition Examination Survey (HANES I) has an augmentation survey of adults aged 25 to 74 years in the United States in 1974-1975. The HANES I study differed from the rural water survey in its purpose, in its statistical sampling plan, in the

Of course, the long term effects of waterborne contamination at currently encountered levels is not known. Even the relatively short-run impairment of health from what it would be without the ingestion of these substances is unclear. Rather than being clear indicators of possible health effects, these high percentages of households with water quality problems, especially coliform bacteria, reflected the marginality of rural water supplies against the backdrop of the primary MCLs mandated for community water systems.

In terms of general water quality, considering all constituents, households in the North Central had the poorest quality water followed by households in the West. Households in the Northeast tended to have the best water quality.

Households served by community systems tended to have the best overall water quality, followed closely by individual systems (usually wells), with those on intermediate systems generally having the poorest quality. Households in SMSA areas and those in large communities tended to have better quality water because they had higher proportions of households on community water systems.

WATER QUANTITY

Relatively few rural households across the US reported a shortage of domestic water. Perhaps because of the essential nature of water, most rural households have made arrangements for adequate quantity, on a regular basis, to satisfy most or all their needs. Moreover, the perception of occupants at most rural households was that their water supplies were ample: about 80 percent reported that the major household supply completely satisfied their water requirements, and another approximately 16 percent reported that it usually or almost always provided sufficient water.

Though most households had adequate quantities of water, a significant number did not. An estimated 700,000 households reported that their supply usually or always provided an insufficient quantity. Most often the insufficiency was attributable to deterioration or inadequate construction of the physical facilities. However, at the extreme, roughly 370,000 rural households hauled water from an off-premises supply, on a regular basis.

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water collection, in the water preservation, and in the laboratory analytical techniques. But some of the contaminants examined were the same. In general, the HANES I Augmentation Study results for metals showed lower concentrations than the rural water survey. Various inquiries into the differences have provided no satisfactory resolution.

The Augmentation Study Survey of adults aged 25 to 74 years in the United States of the national Health and Nutrition Examination Survey I (HANES I) is currently in preparation and will be published jointly by the National Center for Health Statistics and the National Heart, Lung, and Blood Institute.

Among households not connected to community systems, problems of insufficient quantity were more commonly experienced by those supplied by small systems (two through fourteen connections) than by those with their own individual system. Among households with their own supply, those with dug wells more frequently experienced insufficient quantity.

Among rural households connected to a community water system, the median daily household consumption was 664 liters (175 gallons). The median daily per capita consumption was 227 liters (60 gallons).

Consumption of domestic water was not uniform across the US. Western households had a consistently higher consumption pattern than rural households in other regions. No table differences occurred between households located inside and outside SMSAs, or among places of different size.

Among households connected to community systems, locational factors were less important in accounting for variability of consumption than: (1) unit cost (cost per 1,000 gallons); (2) number of people in the household; and (3) number of water-using devices in the household. Although of less importance, the affordability of water and type of ownership of the system were systematically related to variation in consumption. In general, the higher the unit cost, other things constant, the lower the consumption. As would be expected, the greater the number of occupants and the greater the number and usage of water-using devices (dishwashers, washing machines, swamp coolers, as well as toilets and bathing facilities), the greater the consumption. Likewise, the lower the ratio of cost of water to the household's total income, the larger the consumption. Somewhat unexpectedly, households connected to privately owned systems tended to consume approximately 50 percent more water than those connected to publicly owned systems, even after controlling for a number of other, potentially confounding factors.

AVAILABILITY

Most rural households had a readily available domestic water supply. Quantity referred to the usual amount of water. Availability, on the other hand, was defined, for purposes of this study, in terms of two components: (1) the supply's reliability, or uninterrupted service, and (2) the supply's accessibility—one which provided water, under sufficient pressure, when needed and for which the source was not at an inconvenient distance relative to the point-of-use by household occupants.

A total of 5.6 million rural households (roughly 26 percent) experienced water supply breakdowns during the year preceding the interview. Among those households, the majority experienced only one or two interruptions of service. About 15 percent of these households (3.2 million) indicated the breakdowns lasted more than six hours.

In terms of regional differences, household supplies in the South seemed to be somewhat less reliable than in the other regions. Although the reliability of SMSA and nonSMSA supplies was similar, there were differences according to the size of place classification. Generally, households in small rural communities

reported supply breakdowns more frequently than households in large rural communities or other rural areas. Similarly, water supply breakdowns which were considered severe--lasting more than six hours—occurred more often among households situated in small rural communities.

Compared with households using individual or community systems, a larger proportion of households served by intermediate systems reported one or more supply breakdowns. In addition, a greater proportion of households served by intermediate systems reported breakdowns that were severe.

Regarding accessibility, sources were generally located at convenient distances from the household. Among rural households connected to community systems, connections involved only piping from the edge of the property to the house, generally a modest distance. Moreover, among households with their own, on-premises supply, over half were located within 10 meters (33 feet) of the house. However, comparatively greater distances were recorded at approximately 15 percent of the households—implying the need for more extensive piping or other mode of conveyance. For the approximately 370,000 households that had to haul water, accessibility imposed a far greater relative hardship.

Supplies were less accessible in the South and West than in the Northeast and North Central. Though accessibility of SMSA and nonSMSA supplies was similar, households located in open country were relatively less accessible than those located in villages.

COST AND AFFORDABILITY

The cost of water was not estimated for rural households using their own supply or for those connected to a system that didn't explicitly charge for water on a regular basis. Assessment of the cost of water was restricted to rural households served by community systems which had a billing system. Perceptions of cost, however, were assessed for all rural households.

Compared to many other consumable items in the US economy, water is inexpensive. The median household monthly cost per thousand gallons was $1.35 nationally. The median total monthly bill for water was $7.00. A ratio of billed cost to total household income (times 100), as a measure of affordability, indicated that three-quarters of all rural households were paying less than 1 percent of their income for water. Across the nation, water was found, at the extremes, to be as inexpensive as $.08 and as expensive as $23.41 per thousand gallons. Occupants in the majority of rural households (79 percent) felt the water was reasonably priced or inexpensive. Domestic water was perceived as expensive or very expensive at about 14 percent of households.

Costs of domestic water were not uniform across the US. Regionally the median cost per thousand gallons ranged from a high $2.00 in the West to $1.33 in the South. Households within SMSAs had lower water costs than those located outside SMSAs. The respective medians were $1.08 and $1.62. Median water costs varied only slightly according to the size of community in which the household was located.

Despite these findings, a greater proportion of rural households in both the South and West felt the water was expensive or very expensive. A greater proportion of residents living within SMSAs reported their water costs were high than was reported by those living outside SMSAs. Likewise, perceived costs tended to rise the larger the size of place.

In addition to locational differences, several other factors were found to be systematically related to household water costs. Regarding the amount billed monthly, the single most important factor was, as expected, the amount of water consumed. After adjusting for this factor, it was still discovered that total monthly costs increased with the number of household occupants, and the education level of the head of the house. Households connected to privately owned systems paid more than those connected to publicly owned systems. On the other hand, the longer the household had been connected to the system, the lower the total monthly cost.

It was found that lower unit costs (price per thousand gallons) were associated with (1) the size of the water system providing the water, (2) the system's source water, and (3) the amount of water consumed at the household. Generally, the larger the system, the lower the unit cost. Systems using ground water usually had lower unit costs, probably due to the lowered treatment and storage costs. Some price break resulted for households with large monthly consumption.

WATER SYSTEMS

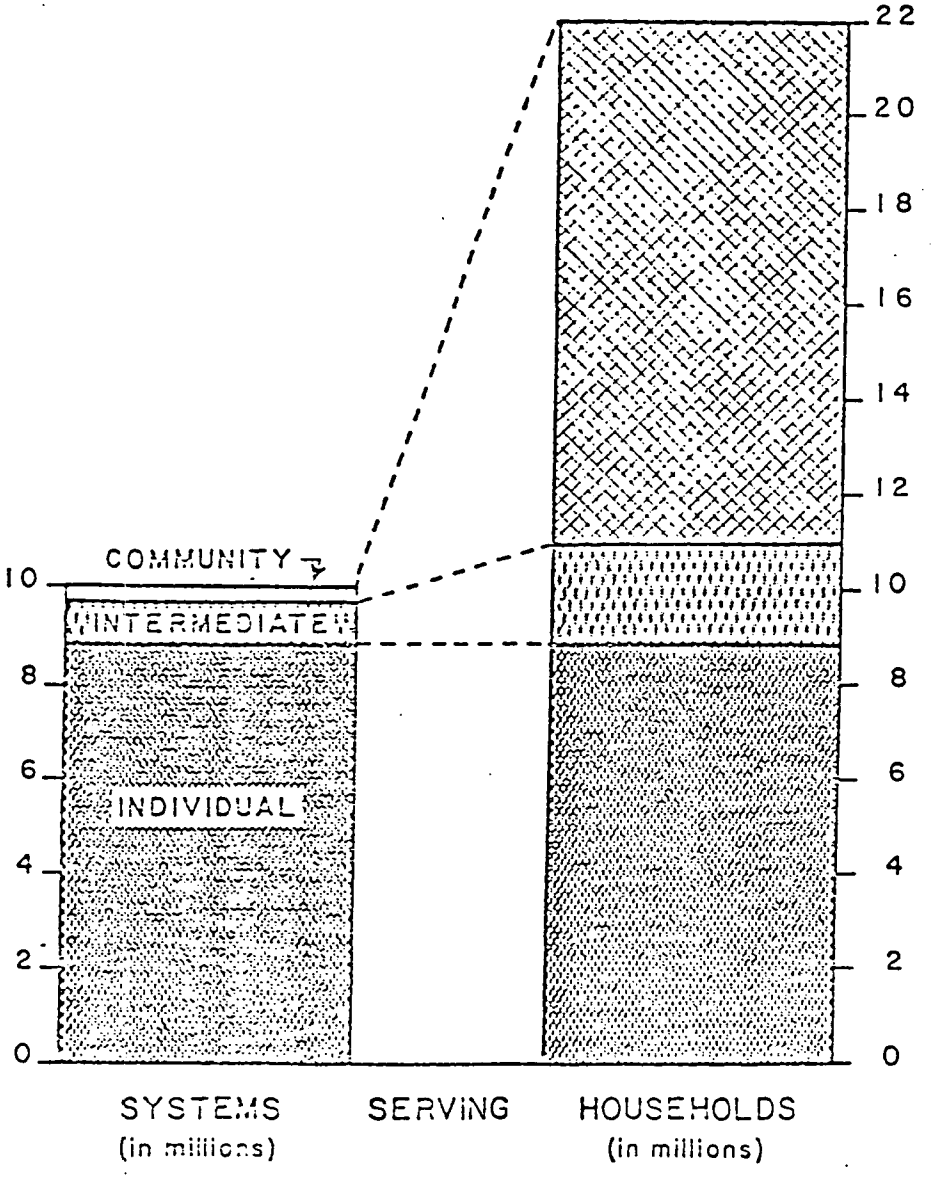
In this study, water systems were examined in order to specify technical, economic, and organizational features associated with delivering water to rural households. Rural water systems were classified according to three major system-size categories: individual systems (single connection), intermediate systems (two through fourteen connections), and community systems (fifteen or more connections). The community systems were further classified as independent (with self sufficient features) versus consolidated systems (with operating or organizational features integrated with other systems or administrative bodies).

Overall, individual systems were by far the most prevalent, numbering 8,765,000. In contrast, there were 845,000 intermediate systems and only 34,000 community systems. Because of this multiple-connection feature, however, intermediate systems and especially community systems were far more important in rural water delivery than implied by their numbers. When taking into account the number of rural households served by each type of system, community systems were most prominent (serving 10,981,000 households), followed by individual systems (serving 8,765,000 households), and intermediate systems (serving 2,228,000 households). See Figure 1.

Community water systems were defined for purposes of the study as those having fifteen or more connections. The standard EPA definition of public water systems is somewhat different. It refers to fifteen or more connection systems used by year-round residents or to systems which regularly provide service to 25 or more year-round residents. The NSA study's definition yielded a count of 34,000 community water systems. Had the study's definition been altered to ten or more

Figure 1

Comparison of Number of Systems and
Number of Households Served in Rural America



connections, the count of community water systems serving rural America would have been about 47,200. The latter count is probably much closer to the standard EPA definition.

Individual Systems

Of the 8.8 million individual systems in rural America, 90 percent relied on wells. Other types of supply—surface water, springs, cisterns, hauled and purchased supplies—comprised the balance of individual systems across the country. These supplies were more often associated with poor quality water.

Nearly six of every ten individual wells were installed by drilling, which is one of the more highly recommended methods of installation because of the usually good contamination protection it offers. Dug or bored wells, which were often linked with bacterial contamination, represented nearly 18 percent of all individual wells. Individual wells were generally located 50 feet or more from most potential contamination sources, with the exception of sewage disposal systems. About one-fifth of all wells were within 50 feet of sewage disposal. Field inspection classified 62 percent of rural wells as appearing to have wellheads which were adequately sealed from solid or liquid pollutants.

Bacteriological tests and chemical (or physical) water tests by rural residents were not common. Slightly more than one-third of all rural households with individual systems had tested the water at least once, with bacteriological tests being more frequent than chemical tests. Test results, when they could be recalled, were generally classified broadly as "acceptable." But, nearly 45 percent of the bacteriological test results and nearly two-thirds of the chemical results were not known. This lack of knowledge may be attributable to the respondent's lapse of memory, poor filing practices, the length of time since the test was completed, or may have implied incomplete or uninterpretable reporting of test results.

Treatment practices can in many situations alter the quality of the source water provided to rural households. Among individual systems, the most common treatment device was a water softener (used in 18 percent of systems). Other water treating devices were rarely found.

Intermediate Systems

Intermediate systems were similar to individual systems. Over 90 percent had only two or three connections and less than 2 percent were metered. About 88 percent relied on wells, the majority of which were installed by percussion or rotary drilling (65 percent). Dug and bored wells comprised 17 percent of all intermediate systems wells.

Intermediate system wells were generally not located close to potential sources of contamination, except for roughly 16 percent which were within 50 feet of a sewage disposal system. Field inspection classified 67 percent of intermediate system wells as acceptably sealed against pollutants.

Water quality tests were performed less frequently among intermediate systems than individual systems. Bacteriological testing had been done at least once during the lifetime of the system at 22 percent of systems. Testing for chemical properties of the water had been done at 10 percent of systems. In contrast to individual systems, among those intermediate systems which tested, owners could usually provide information about the testing history as well as the test results. Of the bacteriological tests performed, over 91 percent showed acceptable counts of bacteriological content. As to treatment practices, among intermediate systems, softening—the most common treatment process—occurred in only 6 percent of the systems.

Information on average daily use and maximum daily (design) capacity collected at water systems provided some indication of the quantity of water provided to rural households connected to those systems. About one-third of intermediate systems had information on production and design capacity. Among those with readings, the median for average daily use was 758 liters, or about 200 gallons. The median design capacity was 44,000 liters (11,600 gallons). The median of the maximum daily design capacity was nearly 60 times the median "average daily usage" level among intermediate systems serving rural households. This difference suggests that some intermediate systems, similar to larger community systems, overbuild to a certain degree, allowing for expansion, fire protection, or increased consumption.

Availability indicators included the number and severity of system breakdowns, and the ease or difficulty in acquiring water from the source. About one-quarter of intermediate systems reported breakdowns of any kind, and few reported any difficulty obtaining water from ground or surface sources. The majority which did report breakdowns had experienced only one or two during an entire year. Despite these favorable findings, a very high proportion of households connected to intermediate systems reported reliability problems in the sense that nearly all breakdowns resulted in a loss of service to water users.

Most intermediate systems did not report revenues or any monetary charging structure for the water service they provided. This fact suggested that water was very cheap for intermediate system customers, but may have also indicated that system owners bear the entire cost of installation, operation and maintenance.

Independent Community Systems

Independent community systems were self-contained systems which secured water from their own sources, treated the water, distributed it, and managed their own organizational and financial affairs. They comprised about 88 percent of the 34,000 community systems in rural America.

Although independent community systems had more extensive extraction, treatment, and conveyance arrangements than intermediate systems, they still were very small in comparison to the larger, more complex systems such as those based in large cities. The median number of connections was 59 and the median length of distribution lines was 1.5 miles. About half of these systems metered their connections. Similar to smaller systems, the predominant source of water

was ground water (90 percent). The labor-time demands involved in operation and maintenance of the system were modest, with many requiring two or fewer man-days of labor per month.

Water testing and treatment were much more frequent and extensive at independent community systems than at systems with fewer than fifteen connections. Fully 91 percent had conducted bacteriological tests and about 54 percent had done chemical testing. Treatment equipment was installed at nearly two-thirds of all independent systems. Most independent systems relied on facilities outside their own organizations for performing water quality tests. For the most part, bacteriological tests conducted during the year prior to the study (1977) reportedly met the levels prescribed by regulations affecting the systems. In general, there were too few chemical and physical tests performed to suggest meaningful patterns.

About 63 percent of independent community systems provided average daily usage and design capacity figures. Among those which reported, the median for average daily usage was 136,000 liters (36,000 gallons). The median design capacity was 546,000 liters (144,000 gallons). Maximum daily production capacities among independent systems were four times larger, on the average, than the estimated average daily use. Though this ratio was less than for intermediate systems, it was large enough to accommodate fire protection, increased usage, and increasing the number of connections because of the larger volume being produced daily.

Independent community systems were less reliable than intermediate systems. A larger proportion of independent systems (55 percent, compared to 26 percent) had breakdowns, although fewer resulted in an interruption of service to customers. As was true for intermediate systems, few had difficulties in obtaining water from any source.

Consolidated Community Systems

The consolidated community systems relied on interdependent links with other organizations. One type of consolidated system had a number of separate, individual facilities of which each served one community, but which were jointly owned and administered by a central company. Another type consisted of a facility which purchased water from another organization—a situation which was the distinguishing feature at nearly 90 percent of the consolidated systems.

The consolidated systems tended to be the largest of the systems serving rural America. The median number of connections for the 4,000 consolidated systems was about 153—two and one-half times the median number for independent community systems. Likewise, consolidated systems employed more system operators and metered a larger proportion of all connections.

Testing for water quality was more extensive at consolidated community systems than at independent community systems. Bacteriological testing was done at almost all (98 percent) consolidated systems, and chemical testing was performed at about 90 percent of systems. Results for bacteriological tests were not uniformly interpretable. But, about 96 percent of the systems reporting tests had acceptable results for either the previous twelve tests or for those tests conducted

over the last year. The variety of constituents tested, disparities in the age of the tests, and the lack of information on analytic procedures combined to render the chemical testing results uninterpretable.

Similar to independent community systems, consolidated community systems could produce, on the average, over four times the quantity of water that was consumed on a daily basis. The median for average daily use was 162,000 liters (43,000 gallons) among the 88 percent of consolidated systems which had the information. Design capacity was obtained for half of the consolidated systems. The median design capacity was 719,000 liters (190,000 gallons).

About 50 percent of consolidated systems had breakdowns during the year preceding the study. This proportion was slightly smaller than for independent systems (55 percent), but still considerably greater than for intermediate systems (26 percent). This finding could be interpreted to mean that problems of reliability were more often associated with larger, more complex systems. However, it was also the case that these larger systems more frequently had alternatives in the event of some malfunctions (such as auxiliary pumps, storage capacity sufficient to cover demand during a breakdown, and so forth).

CONCLUSIONS

1. Most rural households had a domestic water supply which was acceptable by most of the quality indicators used, was in sufficient quantity to meet consumption demands, was readily available on a continuous basis, had a reasonable cost, and was affordable. But, the exceptions were not rare and the difficulties were not always minor.

2. The overwhelming majority of rural households had water judged to be of acceptable quality for any particular characteristic studied. But, almost two-thirds of all rural households had water judged unacceptable for at least one of the constituents which have been given primary MCLs (excluding turbidity). Bacterial contamination, in particular, was the predominant problem encountered.

3. The quality of the water available in most rural households was due to numerous factors, but a few can be highlighted. Most rural households (on the order of 90 percent) relied on ground water. High quality well technology and well construction practices were generally evident throughout rural America. Their employment apparently helped minimize alteration of the water from the quality it had at the source until it was delivered to the tap.

4. Larger, more frequently monitored community water systems generally delivered water of higher quality than smaller and less frequently monitored systems.

5. By comparison with community systems, individual and intermediate systems employed less complex technologies and less frequently used water treatment devices. Therefore the quality of the water delivered to the household was mainly a reflection of the quality of the source water (which was ground water for 90 percent of these systems). As long as the fundamental quality of the ground water source remains intact, further improvements in well technology and construction practices would beneficially affect the quality of delivered water by ensuring the protection of the quality from source to tap. A larger benefit would probably result from presently deficient wells being replaced or brought up to current standards of good practice for well construction. Direct regulation of small (usually individual) water systems would probably not dramatically alter water quality because of the common lack of treatment devices and the improbability of their installation due to the relatively large capital costs for the individuals involved.

Therefore, perhaps the greatest protection for the continuing quality of water from noncommunity water systems would be the preservation of ground water quality, particularly the freedom from bacterial contamination. Acceptable well construction practices for households using individual and intermediate wells appeared to reduce bacterial contamination potential. Proper siting of wastewater disposal, or wastewater removal by public sewer systems were also associated with lower bacterial contamination for households served by individual systems. Additional improvement in water quality among water systems with fewer than fifteen

connections might result from wider availability of water testing services and public education on their availability, their importance, and on possible response alternatives to identified problems.

6. The more extreme the rural householder's evaluation of the water supply, whether good or bad, the better was the correspondence with the composite indicators of laboratory-measured quality. Households which were very positive about their supply usually rated well on the laboratory measures. Households in which the water supply was given a poor rating also tended to have laboratory-measured deficiencies.

Responses to questions regarding the relative cost of the supply and the respondent's willingness to pay more for an improved supply were both useful indicators of the quality as measured by the laboratories. In general, households reporting low relative costs or strong willingness to pay more for an improved supply, tended to have poor water quality according to composites of laboratory measures. Households which reported their supply was expensive or where the respondents lacked a willingness to pay more for an improved supply tended to have superior quality water according to the laboratory indicators.

7. It was noted that average daily consumption of water was greatest in the West. This was so even though the unit cost of water was highest in the West. Rural households of the West generally relied upon their major household supply—usually a community water system—for virtually every water need around the home, yard, and garden.

Over the last fifty years or so, there has been a federal subsidization of Western water through low interest construction loans on large scale reclamation projects. Water cost comparisons among large Northeastern cities and large Western cities have frequently resulted in the observation that Western cities often charged far less for domestic water than those in the Northeast. That effect was not borne out by the NSA for systems serving rural Westerners. Most of the community water systems in the West were relatively small and they were charging on the average the highest rates among systems serving rural America. (Possibly, there is an important economy of scale related to the acquisition and transport of the water. Large systems are more likely to be primary customers, that is, to have a direct arrangement in terms of payment and piping with large scale reclamation projects. Smaller systems, on the other hand, may end up being secondary customers which buy from large systems at some higher price. But even when a small system obtains its water directly from a large scale reclamation project, or from a smaller local project, or from a deep well, the relative cost per connection would generally be higher than that experienced by large systems. Thus, even with the federal subsidization of much of the developed water in the West, the average unit cost for water among rural Western households was higher than for other rural parts of the country.)

8. Intermediate systems were found to provide generally inferior service compared to community and individual systems. It is suspected the reasons for this lay with the nature of the design.

Apparently most of these small systems were not originally designed or intended to be integrated, multiple-connection systems, but were originally installed as individual systems to which additional households were later connected. For instance, a relative, hired hand, or friend could build a home adjacent to a house with an existing individual supply. Because of the cost of installing a new system, occupants of the new household might ask, or be invited, to hook up to the existing well rather than install a separate facility. It appeared that many small intermediate systems seem to have started as individual systems and evolved to become two and three connection systems without any accompanying redesign. Many of these extended connections were probably homeowner installed.

The result of these extensions and modifications to the original system is a strain on the capacity of the system. These apparently stressed systems provided, as a group, the poorest overall service of any system configuration studied. A higher proportion of households connected to intermediate systems experienced problems with water quality, they more frequently had insufficient quantity, and they tended to report a greater number of breakdowns.

The trend in many parts of the country toward falling ground water levels and increasing well construction costs may increase the likelihood of more rural households entering into multiple connection arrangements on individual systems not designed for that purpose.

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This executive summary captures in only the broadest form the detail of the full, 1,900 page, report. The five volume document describes attributes of rural water users, households, supplies, and systems as they related to the quality, quantity, availability, and cost of rural domestic water conditions. Each topic is explored for the nation as well as for various subnational categorizations. The study is a one-time effort which strives to be comprehensive, rather than exhaustive on any particular topic. The report is the first systematic, nationally representative examination of the broad issues related to rural domestic water.