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Water supply

Assessing the financial and economic feasibility of rural water system improvements

Steven Piper and Wade Martin

Financial feasibility of a rural water supply improvement is based on the ability of households to pay for it and economic feasibility on willingness to pay, or benefit, compared to costs. A simple household budgeting methodology is presented which can be used to estimate the ability to pay of water users for a water supply improvement. The contingent valuation method and benefit transfer techniques can be used to estimate rural water supply benefits. Using these procedures, the desirability of investing in rural water improvements is analyzed for a particular application. These methodologies can help policy-makers assess the viability of proposed water supply projects.

Keywords: contingent valuation; water supply improvements; ability to pay; willingness to pay

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MANY RURAL WATER SYSTEMS in the United States rely on groundwater for their domestic water supplies. Groundwater systems typically have minimal water treatment capabilities and many have water quality and/or reliability problems. As a result, some of these systems cannot comply with national water quality standards. Contaminants from pesticides and other chemicals have been detected in groundwater supplies throughout the United States (Lee and Nielson, 1986) and many systems have problems with high mineral content, which increases hardness and adversely affects the taste of water. Groundwater aquifers in many areas of the western United States are being used increasingly, resulting in declining water tables and additional reliability problems.

One possible solution for water quality and reliability problems associated with groundwater use is to convert to surface water sources. However, the cost per household of a rural surface water supply and treatment system is relatively high because of the small number of households served over a large area. As a result, water utilities must determine whether water users can pay the cost of water supply improvements. In addition, state and federal agencies that may be asked to share a portion of the costs must know whether the benefits generated by the project justify the costs.

This paper presents methodologies for estimating the ability of water users to pay for rural water supply improvements and the benefits that would be generated by these improvements. Different techniques are presented based on the level of information and time available to complete the analysis. Increasing the availability of these evaluation methodologies can help policy-makers assess the financial and economic

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viability of water supply projects, given limited budgets. A consistent methodology for such evaluations can help policy-makers select rural water supply projects that generate economic benefits but do not require large government subsidies.

Ability to pay

Rural development agencies have used water payments and household income estimates as a basis for evaluating the potential of water users to pay for water system improvements. Financial investment firms evaluate the revenues and expenses of public and private water utilities seeking funds for improvements as a measure of investment risk. The primary consideration in evaluating the financial viability of such improvements is the cost of the proposed improvement relative to available income. Many of these analyses do not account for the effect of varying household expenses on ability to pay for increased water rates.

The ability to pay can be defined as the maximum amount households can pay for water given their income and other household expenses. This does not consider consumer preferences in determining the allocation of income to goods and services. The cost of water, household income, and other expenses, such as housing costs and local taxes paid by households, all affect ability to pay.

The proportion of income that households can pay towards water bills will vary considerably from region to region. In areas with low housing costs, the percentage may be much greater than in areas with high housing costs. Households in areas that have very poor water supplies may be willing to give up some goods and services and use those payments toward higher water costs.

A simple household budgeting methodology can be used to estimate the ability to pay of water users for a water supply improvement. This uses information on observed payments for water service and for other goods and services, and household income. The preferred source of information on observed household spending patterns would be households that do not reside in the area being analyzed but live somewhere that is similar to the study region in terms of service population, political boundaries, geographic boundaries, or economic conditions. The ability to pay for water supplies within a study region can be estimated by following five steps.

Step 1 Gather water cost information for water users outside the area being evaluated.

Step 2 Collect household income, housing cost, tax payment, and insurance payment data for households outside the study area.

Step 3 Calculate residual household income (income less payments for housing, taxes, utilities other than water, and insurance).

Step 4 Calculate the cost paid for water per US$1,000 of residual income by water users outside the study area (ability to pay factor).

Step 5 Apply the ability to pay factors to the residual income of households in the study area. The factors applied could be the highest factor found for all the suppliers examined, the factor which separates the top 10% from the other 90% of the factors, or some other factor that represents maximum ability to pay.

The ability to pay factors represent the proportion of discretionary income that households served by various utilities must spend for domestic water supplies. Therefore, they are a measure of dollars spent on water service per dollar of discretionary household income. The ability to pay factors represent actual payments made by households for water. Therefore, the higher factors are likely to be the best estimate of maximum ability to pay.

Housing costs, local tax payments, utility costs other than water, and average health insurance payments. which represent payments for necessities are subtracted from household income to derive discretionary income. Food and clothing expenses are not included in the calculation because they are not consistently available on a site-specific basis; they could be included when data are available. Costs excluded from the ability to pay factor are assumed to be the same for each region.

The calculations used to estimate the ability to pay factors and total ability to pay for each household in the study area are shown below:

$$\text{residual income} = \text{household income} - \text{home payment} - \text{non-water utilities} - \text{insurance and tax payments} \quad (1)$$

$$\text{ability to pay factor} = \text{average water bill paid} \div \text{residual income in 1,000's of dollars} \quad (2)$$

$$\text{ability to pay} = \text{ability to pay factor} \times \text{residual income in study area in 1,000's of dollars} \quad (3)$$

This methodology provides a better estimate of ability to pay than simply using current water bills paid for two reasons. First, it is the variation in the water bill paid per unit of income that is important in estimating ability to pay. If households in one municipality pay a large portion of their income for water service compared to another municipality, then the low-cost municipality may be able to pay more than they currently do.

Second, higher income households would be expected to use greater amounts of water and have higher water bills than lower income households. However, lower income households are likely to spend a greater proportion of their income on water because that is a necessity that requires some base level of use. Accounting for the variation in the percentage of total income spent by different income classes better represents household ability to pay.

If household expense data are not available for areas similar to the study region, national housing expenditure data could be used. For example, data from the Bureau of the Census 1993 American Housing Survey includes data on: household income; amount of home mortgage; and the cost of taxes and insurance. The same steps can be used to estimate ability to pay factors using national level data.

Willingness to pay

The conceptual basis for evaluating the benefits from improved municipal and industrial water supplies is society's willingness to pay for improvements attributable to the water supply (US Water Resources Council, 1983). Willingness to pay is the monetary value an individual places on a good or service. The willingness of consumers to pay for a reliable, good quality water supply depends on the satisfaction or utility they obtain from it, as well as the utility they obtain from all other goods and services, constrained by available income.

Therefore, willingness to pay takes preferences and income constraints into account, while ability to pay reflects only income constraints in the household budget. Any water payment in excess of willingness to pay will reduce the total satisfaction of the population in the project area, because it is money they would rather spend on other goods and services.

Using willingness to pay as a measure of benefit presents some potential problems. First, willingness to pay is constrained by ability to pay, so households with high incomes will appear to place a higher value on water service than those with low incomes. This may conflict with some ideas of fairness or justice (Pearce, 1994). Secondly, if a water quality or supply problem is created by new households or businesses moving into a region, willingness to pay may be objectionable, because it may seem unfair that households adversely affected by others should have to help pay to solve the problem (Pearce, 1994).

Despite the potential problems in using willingness to pay to measure water supply benefits, it does represent the theoretically correct measure of water supply benefits. However, it should be realized that, when using this measure, areas with relatively low incomes may need to be given special consideration for financial assistance when compared to a high income area.

Measuring willingness to pay

The contingent valuation method (CVM) and benefit transfer are two techniques which can be used to estimate rural water supply benefits. Estimating natural resource benefits using CVM involves the use of a survey that creates a hypothetical market for an environmental good (see Mitchell and Carson, 1989; Cummings *et al*, 1986).

The CVM is based on survey responses to a proposed change in resource use or a change in the distribution of use. For example, the benefits to water users of converting from groundwater to surface water supplies could be estimated by asking those users their willingness to pay for the project, given the improvements in municipal and industrial water quality and reliability that would result.

The ability to pay can be defined as the maximum amount households can pay for water given their income and other household expenses: willingness to pay is the monetary value an individual places on a good or service

For CVM to produce accurate estimates of resource values, survey respondents must be familiar with the good they are valuing and they must understand the proposed change in the resource (Smith, 1993). The use of CVM to estimate the benefits of expanding municipal and industrial water supplies or improving water quality is likely to result in useful benefit estimates due to the familiarity of water users with water supply problems that may exist and the familiarity of potential solutions such as pipelines and water treatment facilities.

The steps that should be followed when estimating municipal and industrial (M&I) benefits using CVM are:

Step 1 Determine the extent of the water supply problem and the preferred alternative for solving the problem.

Step 2 Determine the area that will be affected by the improvement, which is also the survey area.

Step 3 Produce a survey questionnaire which includes a willingness to pay question with enough detail to allow the respondents to know what they are getting for their money. Questions need to be included which represent variables that are expected to influence willingness to pay.

Step 4 Send a questionnaire to (or telephone or interview) a representative sample of the survey population.

Step 5 Estimate M&I benefits using the willingness to pay responses and the other survey data, these benefits may be estimated directly from the survey data or from modeling results.

There is disagreement among economists about the accuracy of contingent valuation derived benefit estimates. Potential biases exist in the presentation of information in a survey, the hypothetical nature of contingent valuation questions, and the sampling methods used (Smith and Desvouges, 1986; Cummings and Harrison, 1994). However, contingent valuation has gained acceptance as a result of a better understanding of the accuracy and limits of the method and little evidence of strategic behavior (Brookshire and McKee, 1994).

Variable values used in the transferred benefit model should represent conditions at the site, and could be the mean, median, or a number representative of the area's population: more than one value could be used as a sensitivity analysis

Benefit transfer is the application of benefit estimates obtained from one site to another site for which benefit data are not available (see Boyle and Bergstrom, 1992; and Brookshire and Neill, 1992). Generally the site where a detailed analysis has been completed and the study site should have similar characteristics. Similarity can be defined in terms of economic conditions, population characteristics, resources within an area, and other socio-economic characteristics.

The application of the benefit transfer method assumes that a natural resource valuation relationship exists which can be estimated and applied to any geographical area. For example, if a relationship can be estimated which includes the important factors that influence water supply values, then benefit transfer can in theory be completed by applying a benefit model to a study site. Potential benefit transfer problems that must be considered include: uncertainty, differences in water supply problems between sites, and differences in population characteristics.

The over-riding considerations in the application of a benefit transfer model are the applicability of the transferred model to the study site and the inclusion of all explanatory variables that are theoretically important. Some of the important water supply benefit variables that should be included are: household size; age; income; the cost of water; water quality; and the existence of any unusual hardship, such as the need to haul water or purchase bottled water for drinking.

Household size can be a proxy for use and can also be a measure of water supply importance, where larger households represent greater dependence on supplies. Age may be a reflection of attitudes, where experience with problems and situations affects how people perceive and react to difficulties. Income reflects the resources available to spend on all goods and services purchased by the household. The cost of water indicates the current amount that must be spent for water at the current level of quality and reliability. Unusual conditions are an indication of the inconvenience associated with current water supplies.

The variable values that should be used in the transferred benefit model should represent conditions at the desired study site. The value could be the mean, median, or some other number that is representative of the study area population. More than one value could be used as a sensitivity analysis. Once the representative values are input into the model, M&I water supply benefits can be estimated.

It is important to note that the quality of the estimates of benefits derived by benefit transfer are limited by the availability of technically sound water supply studies. A partial list of published studies estimating the benefits from improving or preserving domestic water quality and reliability are presented in Table 1. The models and benefit estimates in these studies and other appropriate studies, can be used as a basis for benefit transfer analyses estimating the benefits from domestic water supply improvements.

Ability to pay applications

The methodology outlined in the ability to pay section is applied to two areas in the western United States: the Lewis and Clark Rural Water System in southeast South Dakota and the Black Hills region of western South Dakota and eastern Wyoming. These two areas

Table 1. Water quality and supply benefit studies

Area	Concern	Approach*	Annual benefit estimate (US$)	Source of estimate
West Virginia	Rural water quality	AE	320 – 1,090	Collins and Steinback (1993)
Pennsylvania	Giardia	AE	67 – 402	Laughland *et al* (1993)
Pennsylvania	Groundwater contamination	AE	252 – 383	Abdalla (1990)
North-Central USA	General water quality	CVM	65 – 84	Dahl (1992)
Colorado Front Range	Supply reliability (WTP)	CVM	12 – 96	Howe and Smith (1994)
Colorado Front Range	Supply reliability (WTA)	CVM	54 – 193	Howe and Smith (1994)
Georgia	Improved quality	CVM	66 – 193	Jordan and Elnagheeb (1993)
Massachusetts	Groundwater protection	CVM	64 – 125	Powell and Allee (1990)
New Hampshire	Groundwater protection	CVM	40 – 129	Shultz and Lindsay (1990)
Montana	Reliability/future supply	CVM/BT	49 – 138	Piper (1998)
Western USA	Reliability/future supply	CVM	53 – 207	Piper and Martin (1997)

Note: * AE = avoidance expenditure, CVM = contingent valuation method, BT = benefit transfer are different in terms of both socio-economic characteristics and the type of water supply improvement under consideration.

The Lewis and Clark Rural Water System (LCRWS) is a coalition of municipal and rural water systems based in Sioux Falls, South Dakota that was formed in part to develop water supply alternatives that would meet growing future water needs in the area. The LCRWS has proposed a surface water system that would divert water from the Missouri River to a central water treatment plant. The water would be delivered through a branching pipeline distribution network to each of the member utilities.

There are currently 15 municipalities and seven rural water systems included in the system. The member utilities are generally small, with the exception of the City of Sioux Falls, South Dakota. Part of the justification for the project is the generation of substantial benefits to water users in the region from improved water quality and supply reliability.

The Black Hills region includes six counties in western South Dakota (Butte, Lawrence, Meade, Pennington, Custer, and Fall River) and three in eastern Wyoming (Crook, Weston, and Niobrara). The population of the area has grown rapidly over the last two decades and is projected to continue to grow into the future. This growth combined with business and industrial development has created a requirement to develop additional sources of municipal water to meet future needs. Proposals under consideration include wastewater reuse and construction of water storage and treatment facilities.

The same general ability to pay methodology is applied to both of these sites. However, site specific data from communities similar to the study communities were used for the LCRWS analysis, while national level data were used for the Black Hills analysis. The procedures used to estimate ability to pay for each study area are presented in detail below.

Lewis and Clark ability to pay

Water use and water rate data were collected for 109 South Dakota water systems outside the LCRWS boundaries and in the eastern portion of the state. Therefore, similarity was defined in terms of location in the same geographic/political boundaries. Average water bill data were available for most of the rural systems from the South Dakota Association of Rural Water Systems (1992) and average water bills were estimated for the municipalities by multiplying the appropriate water rate by average use per household connection (South Dakota Municipal League, 1991).

Income and median home values were obtained from 1990 US Bureau of the Census data by place or county if data for a specific municipality was not available (US Department of Commerce, 1990). The cost of housing was estimated by calculating the monthly mortgage needed to pay a loan equal to the average value of a home in the city or county of the water supplier. A 30-year loan at a 9.0% interest rate was assumed.

The local tax adjustment represents tax payments which cannot be avoided and, therefore, represents funds that are not available for water payments. Average annual per capita local taxes paid were obtained from the US Bureau of the Census by county. These were multiplied by the average household size to estimate total taxes paid per household. This amount was then subtracted from household income. Federal taxes were not included in the census data and the State of South Dakota does not currently impose a state income tax. The insurance cost adjustment represents average payments made toward health insurance for households in the United States (US Department of Commerce, 1992).

Ability to pay factors were estimated for all 109 of the South Dakota municipalities and water districts evaluated. Two ability to pay factors are estimated, a top 10% factor and a one standard deviation above the mean factor. The ability to pay factors ranged from US$32.07 per US$1,000 of income for each household to US$40.02 per US$1,000 income. These factors were then applied to the residual household income for water utilities in the LCRWS area. The residual income estimates for each of the LCRWS entities are presented in Table 2.

The ability to pay of each municipality and rural water district is calculated by multiplying the estimated annual residual income in thousands by the ability to pay factors and this product by the number of households connected to the system. For example, the ability to pay of Beresford is estimated to range from US$514.82 to US$642.44 annually per household, or US$386,115 to US$481,830 annually for the municipality. Total ability to pay is estimated to range from US$38.95 million per year to US$48.61 million per year using the data in Table 2.

The total ability to pay estimates cannot be directly used as the ability to pay for the proposed LCRWS because some of the current costs associated with distribution systems to households and businesses will remain if the project is constructed. The proposed pipeline provides water to the utility, but it would remain the responsibility of the individual utilities to provide water to individual households and businesses.

Therefore, it is assumed in this analysis that the current level of revenues from water sales would be needed to maintain the facilities necessary for each member entity to distribute water to its customers. As a result, the net ability to pay for a new water supply system is estimated to be the total ability to pay using the data in Table 2 minus current water charges. If the total estimated ability to pay of a utility is less than current water charges, then the total ability to pay of that utility is estimated to equal current water charges and the net ability to pay is estimated to be zero. The net ability to pay of LCRWS households is estimated to range from about US$26.2 million to US$35.9 million annually.

Table 2. Residual income calculations for the Lewis and Clark project area

Utility	Monthly cost of water (US$)	Number of connections	Average income (US$)	Insurance and pensions (US$)	Taxes per household (US$)	Annual housing cost (US$)	Residual income (US$)
Beresford	9.30	750	23,843	3,100	1,041	3,650	16,053
Centerville	18.63	350	22,005	3,100	1,101	2,124	15,680
Harrisburg	13.72	220	30,846	3,100	1,398	5,108	21,240
Lennox	9.95	740	24,800	3,100	1,139	3,534	17,027
Madison 24.00	24.00	2,500	26,690	3,100	1,117	3,795	18,679
Parker	18.61	370	20,860	3,100	1,136	2,665	13,959
Sioux Falls	13.00	28,600	34,023	3,100	1,202	5,697	24,025
Tea	31.25	251	30,722	3,100	1,381	4,924	21,318
Boyden, IA	4.00	245	27,418	3,100	815	3,495	20,008
Hull, IA	28.50	660	27,494	3,100	927	3,659	19,807
Sheldon, IA7	16.50	2,000	27,522	3,100	878	4,133	19,412
Sibley, IA	15.78	1,160	31,784	3,100	1,068	3,138	24,479
Sioux Center, IA	13.00	2,000	31,793	3,100	1,084	5,591	22,019
Luverne, MN	14.21	1,730	28,144	3,100	701	3,862	20,481
Worthington, MN	21.10	4,020	27,962	3,100	844	4,779	19,239
Lincoln County RWS, SD	30.17	980	34,023	3,100	1,232	4,625	25,066
Minnehaha CWC, SD	39.80	2,250	34,116	3,100	1,190	5,619	24,207
South Lincoln RWS,SD	49.28	1,215	34,023	3,100	1,232	4,625	25,066
Clay County RWS, IA	36.40	1,350	30,299	3,100	1,151	3,968	22,080
RWS #1, IA	65.20	875	30,219	3,100	945	4,345	21,829
Lincoln-Pipestone, MN	67.60	1,310	24,212	3,100	697	2,192	18,223
Rock County RWS, MN	39.85	515	29,388	3,100	781	3,630	21,876

Black Hills ability to pay

The ability to pay factors used for the Black Hills study region are based on household expenditure data from the Bureau of the Census 1993 American Housing Survey (US Department of Commerce, 1993). Unlike the Lewis and Clark example, using the national level data reflects no attempt to group communities from which the ability to pay factors are estimated to similar communities in the study region. The national survey included 394 sample areas covering 878 counties and cities in all 50 states and the District of Columbia. A total of 1,678 observations included all the income and housing expenditure data needed to derive ability to pay factors.

The ability to pay factor that separates the top 10% of the estimated factors from the bottom 90% using the national 1993 data was US$19.32 per US$1,000 of residual income per household. The ability to pay factor which represents one standard deviation above the mean of all factors in the national data was US$17.04 per US$1,000 of residual income.

Residual income was estimated for the Black Hills region on a county level basis. The data used to estimate residual income is presented in Table 3. The number of households in each county is based on 1990 US Bureau of the Census estimates, income is average household income in 1989 as reported in the 1990 Census, home ownership costs are average annual costs from the 1990 Census, and energy costs are based on estimates from the US Energy Information Administration for South Dakota in 1991.

The same general procedure was used to estimate total ability to pay in the Black Hills region as for the LCRWS. The residual income per household is multiplied by the ability to pay factors, and the product is multiplied by the number of households. Using the national level ability to pay factors and the residual income and number of households information in Table 3, the total ability to pay of households in the Black Hills region for water supply improvements ranges from US$23.4 million to US$26.5 million annually.

Water rate and payment data from the South Dakota Municipal League (1991) and water use data from the US Geological Survey (1993) are used to estimate an average household's water payments for the study area. Average household water costs in the region for 1990 are estimated to range from about US$18 per month to about US$33 per month.

Table 3. Estimates of Black Hills residual household income

Census area	Households	Average household income (US$)	Home costs (US$)	Energy costs (US$)	Residual household income (US$)
South Dakota Counties					
Butte County	3,065	25,050	3,970	1,150	19,930
Custer County	2,370	27,660	4,680	1,160	21,820
Fall River County	2,926	26,420	4,090	1,120	21,210
Lawrence County	7,977	29,190	5,130	1,155	22,905
Meade County	7,081	28,440	5,500	1,380	21,560
Pennington County	30,634	31,700	6,570	1,180	23,950
Wyoming Counties					
Crook County	1,940	28,070	4,340	1,150	22,580
Niobrara County	1,020	28,300	2,760	1,030	24,510
Weston County	2,452	29,350	3,770	1,120	24.460

Households in rural counties generally pay more, on average about US$30 per month.

Using the number of households in each county as a weight, the average water cost for the study area is estimated to be about US$26 per month. Based on a total of 56,465 households in the region, total water payments are estimated to be about US$18.55 million annually. Assuming all of current water payments would be needed to operate and maintain current water sources and distribution systems, the net ability to pay for water supply improvements ranges from US$4.85 to US$7.95 million annually.

Limitations of the ability to pay methodology

It is important to recognize that the above ability to pay estimates are based on the assumption that water bills actually paid by households in South Dakota or the national level water costs paid reflect the amount households within the project area can pay for water, with adjustments made for differences in income, housing costs and taxes paid. However, the amount actually paid for a water bill is not necessarily the same as the ability to pay for water. It is possible that some actual payments are greater than the amount some people could pay for water, given other expenses in the household budget that must be paid. It is also possible that some people could pay more for water but do not have to pay more.

Ability to pay estimates assume that water bills actually paid by households in South Dakota or the national level water costs reflect what households in the project area can pay, with adjustments for differences in income, housing costs and taxes

It is also important to realize the shortcomings of using ability to pay as a measure of the financial viability of a water supply project. Ability to pay theory traditionally applies to the area of taxation and is based on the belief that tax payments should be determined by the ability of an individual to pay a tax (Pearce, 1994). The theory is based on equal sacrifice, where the sacrifice is a loss of utility which is incurred when tax payments are made. The validity of ability to pay theory depends on the ability to make interpersonal comparisons of utility and is a major limitation of the theory. The theory is applied in this analysis by assuming the interpersonal relationships outside the LCRWS and Black Hills regions are representative of the expected relationships within the study areas.

Last, the ability to pay methodology and estimates presented above do not account for the ability to pay of businesses and industry. Because of the wide variety of businesses located in a region and limited data availability, the budgeting method used for households would not work well for business and industry. One possible adjustment would be to increase ability to pay by the proportion of total non-residential water payments to household payments. For example, if business and industry account for 50% of total water payments and residential use accounts for the other 50%, then ability to pay could be doubled to account for business and industry. However, there is little basis for assuming non-residential users could pay the same proportion of current water payments in higher water costs.

Willingness to pay applications

Two household willingness to pay applications are presented. The first is a contingent valuation based analysis for the LCRWS and the second is a benefits transfer based analysis for the North Central Montana Regional Water Supply System (North Central Montana) near Havre, Montana. Details of the LCRWS study are presented in Piper and Martin

(1997) and the North Central Montana study details are presented in Piper (1998). The general methods and results of the analyses are presented below to demonstrate applications of the techniques.

Lewis and Clark willingness to pay

The LCRWS willingness to pay data were obtained through a household and business mail survey conducted by LCRWS staff during the summer of 1992. A copy of the household questionnaire can be obtained from the authors. The survey included questions about: the willingness to pay for reliable good quality water; socio-economic issues which may affect willingness to pay and also to verify the representativeness of the survey; water quality; and topics that would help identify potential survey bias.

The household questionnaires included both open-ended and dichotomous choice (yes/no) questions asking how much a household was willing to pay above current water costs for a water supply system that would help ensure a reliable and good quality water supply in the future. The willingness to pay for water above the current water bill is an estimate of the position of an individual demand curve at a particular quantity. Combining individual estimates, the average willingness to pay for the proposed system can be estimated.

The average willingness to pay of Lewis and Clark households surveyed was US$59 per household per year and the average willingness to pay of rural Lewis and Clark households was US$57 per year. Although the average willingness to pay of rural water system users is somewhat less than urban residents, the average cost of water for rural water users (US$588 per year) is higher than for urban users (US$250 per year). Therefore, lower willingness to pay for rural users would be expected.

The analysis by Piper and Martin (1997) presented a variety of willingness to pay models. Ordinary least squares, tobit, and logit models were all estimated. The ordinary least squares and tobit models were based on the open-ended willingness to pay data and the logit models were based on the dichotomous choice responses. As a result of potential bias associated with the ordinary least squares estimates, only the tobit and logit results are presented here.

The logit models were used to estimate willingness to pay based on procedures outlined by Hanemann (1984) and by Cameron and James (1987). The willingness to pay modeling resulted in a range of willingness to pay from US$64 to US$1,446 per household per year for the urban households and US$53 to US$120 per year for the rural LCRWS households.

There are an estimated 45,600 urban households and 8,500 rural households in the LCRWS area. The population of the study area has grown an average of about 1.36% a year since 1960 (South Dakota State Data Center, 1991). This translates into an average annual population that is approximately 42% higher than the current population by the year 2040.

Using the adjusted household willingness to pay estimates and the average annual population level, the total household willingness to pay for improved water supplies ranges from about US$5.0 million to US$10.0 million per year. It should be recognized that water quality and reliability could become worse in the future, which would affect future willingness to pay.

Business willingness to pay for the LCRWS

In addition to the household survey, the LCRWS surveyed a small number of businesses. The business questionnaire included questions related to: perceived water quality and supplies; the importance of water quality and supply reliability to output; the willingness to pay for improved water supplies; and the size and type of business. A copy of the business questionnaire is available on request from the authors. The business surveys are used as an indication of the possible magnitude of water supply improvement benefits to businesses in the project area.

A total of 200 surveys were mailed to randomly selected businesses in the project area during the summer of 1992. Unlike the household survey, the business survey did not include reminder letters, follow-up questionnaire mailings, or contact with non-respondents. A total of 46 business surveys were returned, resulting in a response rate of 23%.

Because of the wide variety of business types and size and the small number of survey responses, a business willingness to pay model similar to the household models could not be estimated. The purpose of the business survey was to get a general idea of how important water quality is to individual businesses and the magnitude of willingness to pay for water supply improvements.

Although the survey response rate was fairly low, there was a sufficient number of responses to observe general trends in business attitudes and how much they would pay for good quality water supplies. The responses indicated water quality and adequate supplies are important to businesses in the area and that there is concern that water supplies are inadequate. Approximately 70% of the business responses indicated water quality is important or very important and 80% indicated adequate supplies are important or very important. Of those businesses responding, 43.5% perceived adequate current supplies but inadequate future supplies, and 26.1% perceived inadequate current and future supplies.

An average of 100 people were employed for each business surveyed, compared to an average of almost 17 employees for Minnehaha County (US Department of Commerce, 1995). Minnehaha County lies within the Lewis and Clark boundaries and includes Sioux Falls. Over 50% of the businesses which were surveyed are wholesale, retail, or service businesses, which is consistent with the business patterns in Minnehaha County (US Department of Commerce, 1995).

The average number of employees per business surveyed is much higher than estimated by the Department of Commerce, so firm's willingness to pay is probably over-estimated, but it is a sector that has a strong interest in water supply improvements

Removing protest responses for those who did not believe they should have to pay for new supplies or did not have enough background to answer, 56.1% of businesses were willing to pay for improved supplies. The average willingness to pay, not including protest responses, was US$28.93 per account per month or about US$350 per account per year. As a percentage of the average bill indicated in the surveys, willingness to pay from businesses was 9.4% of the average annual business water bill.

Data are not available to estimate average water payments for all businesses in the study area. However, the Department of Commerce estimated that there was a total of 4,454 businesses in Minnehaha County, South Dakota in 1992 (US Department of Commerce, 1995). Assuming the average willingness to pay from the business survey can be applied to all businesses in the study area and the number of businesses in Minnehaha County alone account for most of the businesses in the study area, the total business willingness to pay would be about US$128,900 per month or US$1.55 million per year under current conditions.

Assuming business revenues and growth in the number of establishments will be the same as the growth in household income and population, the business willingness to pay over the next 50 years is estimated to be about US$2.42 million annually. Given the average number of employees per business of those surveyed is considerably higher than the average estimated for the area by the Department of Commerce, business willingness to pay is probably over-estimated. However, the business estimate is an attempt to include a sector of the economy that would have a strong interest in water supply improvements.

North Central Montana willingness to pay

A coalition of state, tribal, and local officials has proposed a pipeline that would bring water to the Rocky Boy's Indian Reservation located approximately 230 miles northwest of Billings, Montana and would also deliver water to existing non-tribal water systems, including the cities of Havre and Conrad, Montana. The system would provide good quality water to a large rural area and would provide water for municipal, rural, and industrial uses. There is concern that the current groundwater supplies will not support future economic growth in the area and many systems are faced with potentially high costs of providing safe drinking water from current supplies in the future.

The model used for this benefits transfer application is based on survey data obtained from four different regions in the western USA and is presented in Piper (1998). The model includes several independent variables, which improves its flexibility. The willingness to pay model used for transfer to the North Central Montana site is:

$$\text{Willingness to pay} = f(\text{hhsize, cost, age, income, haul, ceremony}) \quad (4)$$

where:

hhsize = number of people in household,
cost = monthly cost of water to household,
age = age of respondent,
income = gross household income,
haul = household hauls water for domestic supplies (1=yes, 0=no),
ceremony = household participates in ceremonies that require water (1=yes, 0=no).

Four different models were estimated with varying levels of econometric sophistication. Weighted models were estimated to account for potential heteroskedasticity problems. Tobit models were estimated to correct problems created by a large number of zero responses.

The estimated variable coefficients from the willingness to pay regressions are presented in Table 4. The variable values used to estimate household willingness to pay for good quality water supplies in the North Central Montana study area and the willingness to pay estimates using benefit transfer are presented in Table 5.

Comparing costs with ability/willingness to pay

As an illustration of the potential use of ability to pay and willingness to pay information, the costs of the proposed LCRWS project are presented and compared to ability and willingness to pay. The proposed LCRWS water supply project includes a diversion system at Lewis and Clark Lake in the southern portion of the project area, a water treatment system, a distribution system, an environmental enhancement component, acquisition of land and easements, and other engineering and administrative costs. The costs of the project can be separated into two categories: construction costs; and operation, maintenance, and repair (OM&R) costs.

Annual OM&R includes all costs associated with water treatment, maintenance of distribution pipelines, and equipment costs. Typical OM&R items would include labor, electrical power, chemicals, equipment repair and replacement, and any administrative costs. The total OM&R costs of the LCRWS project are estimated to be US$4.707 million each

Table 4. Willingness to pay models used for benefits transfer

Variables	Coefficients			
	Ordinary least squares	Weighted least squares	Tobit	Weighted tobit
Household size	0.21501	0.56524	0.39963	0.87753
Water cost	0.027961	0.026304	0.01754	0.01487
Age	0.02543	0.010241	0.09166	0.06769
Income	0.00005212	0.00003661	0.0001136	0.0000983
Haul water	6.5487	6.2499	9.4052	9.9653
Ceremonial use	5.4301	6.1324	6.5031	7.1392
Constant	3.4718	1.0068	0.34105	4.3824

year (Banner Associates Inc, 1993). An increase in the population served would be expected to increase OM&R costs. Therefore, OM&R is expected to increase at the same rate as population to an average annual cost of US$6.68 million.

The capital costs of the project are annualized by determining the equal annual payments that are required to pay off US$282.9 million over 50 years, which is a conservative estimate of the useful life of a water supply facility. The interest rate used was 7.75%, which is the fiscal year 1995 rate used by federal water agencies for planning purposes (Department of the Treasury, 1994). The annualized capital cost of the project is estimated to be US$23.02 million per year. Adding this to the OM&R cost, the total annual cost of the project is estimated to be US$29.7 million, translating into about US$550 per household per year.

The net household ability to pay for the LCRWS was estimated to range from US$26.2 million to US$35.9 million annually, or US$485 to US$665 per household per year. The ability to pay estimates do not include businesses. Therefore, the true ability to pay of all water users in the Lewis and Clark area is greater than the household ability to pay. In any case, it appears that water users in the LCRWS area are financially capable of paying for the project.

The willingness to pay estimates indicate the household benefits from an improved water supply range from US$5.0 million to US$10.0 million annually. Business benefits are estimated to be about US$2.4 million a year. The total benefit of the project is estimated to be as high as US$12.4 million a year, which is a little less than half the annualized project costs. Therefore, from a purely economic perspective the Lewis and Clark project is not justified based on a comparison of benefits and costs. However, the benefits to businesses and potential benefits to households outside the survey area need to be examined more closely and the potential errors associated with the benefit estimates need to be recognized.

The desirability of the project can also be examined by looking at the per household cost of the project compared to current water payments. The average cost of the project would be approximately US$550 per connection per year or US$46 per month. The weighted average water bill in the Lewis and Clark area is about US$20 per month or US$240 per year. Therefore, the cost of the proposed project represents a three-fold increase in household water costs. However, it should be recognized that water costs represent a small percentage of total household expenditure. A large percentage increase in water costs reflect a fairly small percentage increase in overall household expenses.

Policy implications

This paper presents methodologies that water utilities, consultants, and government analysts can use to evaluate the financial and economic viability of a rural water supply project. Using these procedures, the desirability of investing in rural water improvements can be analyzed. The Lewis and Clark, Black Hills, and North Central Montana applications illustrate how ability and willingness to pay estimates can be used to assess the financial and economic viability of a project. If ability to pay exceeds costs, then the water users can pay for the project. If willingness to pay

Table 5. Values used to estimate household willingness to pay

Group	Household size (no)	Age (years)	Mean household income (US$)	Households hauling water (%)	Native American population (%)	Range of willingness to pay (hh/year) (US$)
Rural	2.78	47.4	30,000	9.8	9.5	65 – 96
Urban	2.55	45.8	29,650	0.1	6.0	49 – 90

exceeds costs, then the project is economically justified.

The application indicated that the benefits generated by the proposed Lewis and Clark system are about one-half of project costs while the ability of households to pay for the project are likely to exceed the costs. As a result, LCRWS water users would be able to pay for the project through increased rates and the project appears to be financially feasible. However, based on the CVM results the LCRWS water users do not appear to receive enough benefit to justify the project on economic grounds.

The LCRWS includes a relatively large municipality (Sioux Falls, South Dakota), which reduces the cost per user compared to other rural water project areas that are less densely populated. Therefore, the costs of rural water system improvements in other sparsely populated rural areas are likely to exceed the benefits. The LCRWS analysis indicates meeting water quality goals does not ensure net economic benefits even if the water users can afford the costs of the improvement.

Demand side management alternatives, such as conservation pricing or the use of water conserving devices, can be used to reduce current and future water demands when expanding the available supply is not economically justified. Reduced demand may allow water quality and reliability goals to be met without an expensive water supply project. Some LCRWS member utilities have periodically enacted lawn watering restrictions during high water use months and have encouraged wise water use. However, additional measures could be taken to reduce per capita water use. The LCRWS household survey indicated 58% of the rural households surveyed and 71% of the urban households would be willing to practice water conservation techniques to reduce water use (Piper, 1996).

Previous work on conservation pricing and conserving water use indicate that these two options can be effective in delaying or eliminating the need for expanding water supplies (National Regulatory Research Institute, 1994). Based on the apparent willingness of Lewis and Clark water users to participate in water conservation programs, these two options may be a realistic alternative to expanding water supplies. Water conservation pricing can reduce peak periods of use and can reduce overall use while generating revenues for future improvements. Water saving fixtures and appliances can also reduce peak use and overall use, which would reduce the need for future water supply expansion.

Several willingness to pay studies for domestic water supplies have also been conducted in developing countries (see Whittington *et al*, 1989; Briscoe *et al*, 1990; Whittington *et al*, 1990; Whittington *et al*, 1991; Altaf *et al*, 1992; Griffin *et al*, 1995). The primary focus of the international literature has been on the relatively high cost of water supply projects. In many cases water systems are too expensive for many households and the need for good quality water supplies remains unmet (Whittington *et al*, 1993). The problem of building expensive and unused water supply systems can be addressed by understanding how much the prospective water users are willing to pay for water (Whittington *et al*, 1993).

A water utility that considers only the financial feasibility of an improvement project is likely to reach a different conclusion from a utility considering the economic feasibility of a project. Water users in the LCRWS have the resources to pay for a water supply project, but they are not willing to pay all its costs. Based on this analysis, the LCRWS water supply project should be modified to reduce the cost per household served, or demand side management alternatives should be evaluated.

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