

EVALUATING THE BENEFITS OF MUNICIPAL AND INDUSTRIAL WATER SUPPLIES FOR THE SANTEE INDIAN RESERVATION AND NIOBRARA VILLAGE IN KNOX COUNTY, NEBRASKA

Introduction

Assessing the economic feasibility of providing municipal and industrial (M&I) water supplies requires estimation of the benefits and costs associated with the water supply alternatives. If the benefits of an M&I water supply alternative are greater than the costs, then the alternative would be considered economically feasible.

Engineering costs associated with construction or implementation of new technology can usually be estimated in a fairly straight-forward manner. The costs of an M&I project include: 1) engineering costs of construction (engineering design, construction materials, equipment, labor, etc.) 2) annual operation and maintenance costs, and 3) environmental and cultural costs that may result from a project. Environmental and cultural costs related to project construction may be much more difficult to quantify due to uncertain impacts and difficulty in measuring some non-market values.

M&I water benefits are derived from the use of water supplies for residential, commercial, industrial, and public purposes. Due to limited market-based water transaction data the direct benefits of M&I water projects to water users can be very difficult to quantify. In addition, some benefits may also accrue to non-users from the knowledge that an area with inadequate water supplies will receive improved water service. These indirect benefits are even more difficult to quantify than direct use benefits.

A theoretically sound basis for quantifying M&I water use benefits is needed to evaluate economic feasibility. The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G's) provide some guidance on techniques that can be used to estimate M&I water supply benefits. The P&G's state that the conceptual basis for evaluating the benefits from improved municipal and industrial water supplies is society's willingness to pay (WTP) for the increase in the value of goods and services attributable to the water supply (U.S. Water Resources Council, 1983). WTP is the price that an individual or firm is willing to give up or pay to acquire a good or service. Therefore, WTP is the basis for determining the market demand price of a good.

The goods and services attributable to the provision of municipal and industrial water supplies would include water for drinking, washing clothes and dishes, watering lawns and gardens, food processing, various types of production, bathing, etc. It would be very difficult, if not impossible, to measure the value of each of these outputs that are attributable to the provision of water supplies. However, these values are reflected through the willingness to pay of water users for the water necessary to produce these goods and services. Therefore, the WTP for a water supply is the price water users would pay to get various quantities of water and it reflects the demand for M&I water supplies.

A regional demand curve for domestic water supplies is estimated using water supply data for 96 municipalities and water utilities throughout the Western U.S. The results are compared to the results of previous studies to evaluate the reliability of the demand model. The estimated M&I water demand model is then applied to the Santee Indian Reservation and The Village of Niobrara. Representative benefits are estimated using site specific water use, climate, and socio-economic data for the Santee Indian Reservation and Niobrara Village.

Background – Estimating Water Supply Benefits

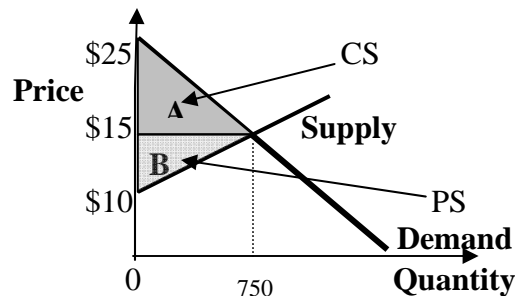
The willingness to pay for M&I water supplies can be measured by asking water users directly what they would pay for water in a hypothetical situation or by using observed water use and payment information that reveal individual preferences and willingness to pay. The technique based on preferences as revealed by actual payments is used in this analysis.

The willingness of consumers to pay for a reliable, good quality water supply depends on the satisfaction or utility they obtain from the service and is reflected through the demand curve for water. Consumer surplus (CS) is the difference between what a consumer would be willing to pay for a good or service and what that consumer actually has to pay. CS is represented as the area under the demand curve and above market price and represents consumer benefits from the good or service.

Economic benefits also accrue to producers of a good or service. For producers the area above the supply curve and below market price is a measure of benefit. This PS is represented as the difference between what a supplier is paid for a good or service and what it costs to supply the good. The sum of CS and PS provides a measure of the total economic benefit of a good or service. This concept is used to estimate the benefits of providing a reliable water supply to the Santee Indian Reservation and to the Village of Niobrara.

The relationship between willingness to pay and the demand curve allows the use of demand curves to measure the benefit (or cost) of a price decrease (increase) to consumers, while the supply curve represents the cost of providing a good or service and can be used measure benefits to producers. Figure 1 below shows the concepts of CS and PS graphically. The values in the figure are for illustrative purposes only.

Figure 1 – Consumer and producer surpluses



The example in figure 1 shows the total benefit for a hypothetical good or service. The supply curve in figure 1 indicates that at a price of \$10 per unit or less there are no producers who would be willing to provide that good or service. The demand curve in figure 1 shows that at a price of \$25 or higher there are no consumers who are willing to pay the price for the good or service. The area of triangles A and B represent CS and PS respectively. CS would be equal to \$10 ($\$25 - \15.00) multiplied by 375 ($.5 \times 750$), or \$3,750. PS would be equal to \$5.00 ($\$15.00 - \10.00) multiplied by 375 ($.5 \times 750$), or \$1,875. Therefore, the total benefits from the provision of this good or service would be \$5,625.

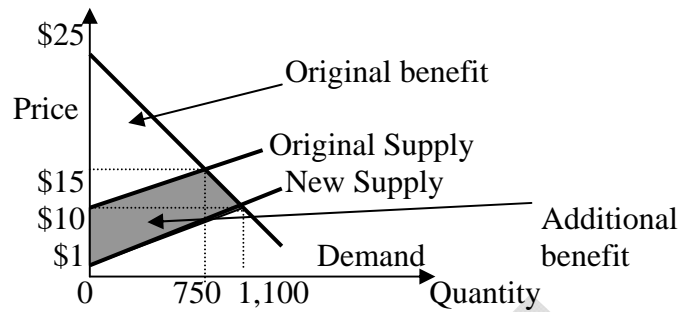
Using measures of CS and PS requires estimation of the supply and demand curves. If we know that at a price of \$25 none of the product will be purchased and at \$15 a total of 750 unit will be sold, then a demand curve can be estimated assuming demand is a linear relationship. However, using only two points to estimate demand will lead to unreliable estimates. The greater the number of observed price-quantity combinations, the more accurate the estimated demand curve.

The supply curve can be estimated in a similar manner, showing price and quantity supplied combinations. It should be noted that the supply curve for M&I water supplies may be nearly horizontal if the per unit cost of providing various quantities of water are very similar. In the case of a horizontal supply curve, the benefits of providing M&I water supplies would be measured solely by the change in CS.

Once the demand and supply curves are both derived, the change in benefits from shifts in supply and demand can be estimated. The demand curve could shift if the quality of the water supply changed and the supply curve could shift if there was a change in water supply technology. Figure 2 shows conceptually the effect of a change in benefits from a shift in the supply curve. In this case, there is some improvement in the provision of a good or service which allows more to be produced at the same cost or the same quantity can be produced at a lower cost.

The initial condition in figure 2 corresponds with the example presented in figure 1, with total benefits of \$5,625. With the assumed shift in supply, producers are willing to produce more of the good at a given price. As a result, additional benefits are realized as shown by the shaded area. The CS with the new supply curve is equal to \$15 ($\$25 - \10) multiplied by 550 ($.5 \times 1,100$), or \$8,250. The PS would be equal to \$9 ($\$10 - \1) multiplied by 550 ($.5 \times 1,100$), or \$4,950. Therefore, the total benefits from the provision of this good or service with the shift in supply is \$13,200. The shift in supply results in a net benefit to society of \$7,575 ($\$13,200 - \$5,625$).

Figure 2 – Change in benefits from a shift in the water supply curve



Supply and demand could both shift outward simultaneously, which would represent a situation where there is an increase in the available water supply and an associated increase in the demand for the improved water supply. The eventual change in price and quantity would depend on the relative magnitude of changes in supply and demand.

Previous Studies

Several studies have been completed which have estimated water supply demand curves. These studies have included a wide variety of variables that explain levels of water use, several different measures of price, different functional forms to model demand, and different supply conditions.

One measure that can be used to compare the results of various studies is the estimated price and income elasticity of demand. Estimates of price and income elasticity of demand for water have been consistently shown to be inelastic in past studies, implying that water demand is relatively insensitive to changes in price and income. Price elasticity of demand is a measure of the change in the quantity of a good or service obtained as a result of a change in the price of the good or service. Income elasticity of demand can be defined as the change in the quantity of a good or service obtained as a result of a change in the income of the individual obtaining the good. A general definition of elasticity is:

(1) $\text{Elasticity} = (\Delta x/x)/(\Delta y/y)$ or the percentage change in x divided by the percentage change in y

For a normal good price elasticity is negative (a higher price results in less purchased) and income elasticity is positive (a higher income results in more purchased). Demand for a good with an absolute value of elasticity greater than 1 is said to be elastic, meaning that the quantity demanded is very responsive to a change in price. An absolute value of elasticity less than 1 is inelastic demand, where a change in price results in a relatively small change in the quantity of a good demanded. Given that water does not have any real substitutes and generally represents a small percentage of total household expenditures and business operating costs, demand would be expected to be price inelastic.

The price elasticity of demand is useful because it can be used to derive generic demand curves when sufficient price and quantity data are not available to estimate a site specific

demand curve. Many water demand models assume a functional form the results in constant elasticities. If the price elasticity of demand for a good is known and is constant and the current quantity exchanged in the market is known, then the effect of relatively small changes in the quantity supplied on prices can be predicted. Alternatively, if a project will lead to a predictable change in prices (rather than quantities), then the price elasticity of demand can be used to estimate the impact a project will have on the quantity demanded. Therefore, price elasticity estimates available on a regional basis could be used to help estimate the benefits of municipal water supplies.

As an example, assume that the price elasticity of demand for domestic water supplies is estimated to be -0.5. In other words, if the price of water increases by 1%, then the quantity of water demanded will decrease by ½%. Also assume that the current water rate is \$5 per 1,000 gallons and that the current water demand for water is 1.0 billion gallons. Assume further that a project is being proposed that would increase the amount of water supplied by 100 million gallons, or a 10% increase. Based on a price elasticity of demand of -0.5, a 10% increase in quantity will result in a 5% decrease in price assuming markets are competitive. The estimated market price would decrease to \$4.75 per 1,000 gallons. The economic value of an increase in domestic water supplies can be estimated using the average of the original price and the new representative “price” with a project, or \$4.87 per 1,000 gallons ($[\$5.00 + \$4.75]/2$).

Another common elasticity measure is income elasticity. Income elasticity of demand measures the relationship between a change in quantity demanded and a change in income. The sign and magnitude of income elasticity depends on the type of good under consideration. Normal goods have a positive income elasticity of demand, indicating that as income rises more is demanded of the good at a particular price level. An income elasticity between 0 and positive 1 (indicating demand is relatively insensitive to a change in income) indicates a good is a necessity. If income elasticity is greater than positive one (indicating demand is very sensitive to a change in income), then the good is considered to be a luxury good. If a good has a negative income elasticity, it is considered to be an inferior good. The demand for an inferior good decreases as income increases because more income makes more desirable goods or services affordable, resulting in reduced purchases of less desirable (inferior) goods. Domestic water supplies would generally be considered a normal good that is a necessity. Therefore, income elasticities for water supplies would be expected to be between zero and one.

Most of the previous studies of domestic water demand have estimated inelastic price and income elasticities. As a result, the demand for domestic water supplies per household tend to be very stable regardless of changes in price and income. Price and income elasticities estimated in previously completed water demand studies are summarized in table 1. Table 1 includes estimates for both short run and long run elasticities. The short run is a time period over which a consumer cannot adjust the level of use of the good under consideration. In the long run consumer can plan ahead and adjust levels of consumption. In general, long run price elasticities are greater than short run elasticities because consumers have more time to adjust to a price change. Results similar to table 1 are expected for the Western United States demand model estimated below.

Table 1 – Price and income elasticities estimated in previous water demand studies

Author(s)	Date	Price elasticities	Income elasticities	Geographic region
Agthe and Billings	1980		1.33 to 2.77	Tucson, AZ
- short run		-0.179 to -0.358	-	
- long run		-0.266 to -0.705	-	
Agthe, Billings, Dobra, Raffiee	1986			Tucson, AZ
- long run		-0.125 to -0.624	-	
- short run		-0.019 to -0.364	-	
Billings and Day	1989	-0.200 to -0.710	0.31 to 0.36	Tucson, AZ
Espey, Espey, and Shaw	1997	-0.51	-	U.S.
Foster and Beattie	1979			U.S.
- Rocky Mountains		-0.226	0.627	
- Southwest		-0.122	0.627	
Gottlieb	1963	-0.656 to -0.680	0.277 to 0.895	Kansas
Howe and Linaweaver	1967	-0.231	-	U.S.
Jones and Morris	1984	-0.14 to -0.44	0.40 to 0.55	Denver, CO
Martin and Wilder	1992	-0.32 to -0.70	-	Columbia, SC
Nieswiadomy	1992	-0.17 to -0.45	0.04 to 0.16	U.S.
Nieswiadomy and Molina	1989	-0.002 to -0.460	0.07 to 0.20	Denton, TX
Nieswiadomy and Cobb	1993			
- increasing block rate structure		-0.64	0.57	U.S.
- decreasing block rate structure		-0.46	-	
Piper	2003	-0.32	0.12	U.S.
Renwick and Archibald	1998			Southern CA
- all water users		-0.33	-	
- less than \$20,000 income		-0.53	-	
- \$20,000 to \$59,999 income		-0.21	-	
- \$60,000 to \$99,999 income		-0.22	-	
- over \$100,000 income		-0.11	-	
Renwick, Green, McCorkle	1998	-0.16 to -0.20	0.25	California
Schneider and Whitlach	1991			Columbus, OH
- residential		-0.110 to -0.262	-	
- commercial		-0.234 to -0.918	-	
- industrial		-0.112 to -0.438	-	
Weber	1989	-0.202	-	Oakland, CA
Williams	1985	-0.05 to -1.09	-	U.S.
Williams and Suh	1986			U.S.
- long run residential		-0.294 to -0.485	.638	
- long run commercial		-0.141 to -0.360	-	
- long run industrial		-0.438 to -0.735	-	
Wong	1972			Chicago area
- Cities over 25,000 people		-0.530	1.025	
- Cities 10,000 to 24,999 people		-0.817	0.840	
- Cities 5,000 to 9,999 people		-0.463	0.476	
- Towns less than 5,000 people		-0.257	0.576	
Young	1973	-0.41 to -0.60	-	Tucson, AZ

A General Demand Model for the Western United States

The data used for the western United States demand curve analysis were obtained from the American Water Works Association 2004 Water and Wastewater Rate Survey. Water use, water cost, and other socio-economic data were obtained for 96 municipalities in the Western United States. Information in the survey includes water and wastewater system

characteristics, water charges, and measures of water service affordability. The water utilities are separated according to location, system size as measured by water sold, and water rate structures. Water charges are further separated into charges to wholesale and residential users. The cost data used in the demand models represent an average cost per gallon which is translated into an average cost per acre-foot. The water use data are aggregated for all users, including residential, commercial, and public uses. The general water use model estimated is:

(1) Water use per connection = f(Cost of water per acre-foot, median household income, average household size, average annual temperature, and average annual precipitation).

Water Use

The water use variable is measured in terms of average gallons used per water user account per month. This variable represents an average use figure for all types of water users, excluding any wholesale accounts. Therefore, the model represents generic water use across all sectors.

Cost of Water

The average cost of water per acre-foot is a measure of the price of water faced by water users. Economic theory suggests that for normal goods people will demand less of a good or service as the price of the good or service increases, assuming other variables such as income and the price of other goods remains constant. Therefore, the cost/price coefficient should be negative. The price variable included in a demand model should be representative of the cost actually faced by water users to purchase water. Ideally, the price included in the model should be a marginal price, indicating the additional cost imposed on the user for obtaining an additional unit of the good or service. However, the model estimated in this analysis is an aggregated model across several different water suppliers, where average use is assumed to be influenced by average price. So, the assumption in this model is that relative differences in the cost of water from site to site will influence the relative level of water use holding all other variables constant. Average use and average cost will capture these relative differences.

Income

The median household income variable is included in the model to capture the financial resources available for water users to purchase water and other goods and services that may contribute to water consumption. A higher income would be expected to contribute to greater water use all other factors held constant. A higher income was also assumed to represent an overall level of economic activity that would support commercial enterprises and increased commercial water use. Therefore, the income coefficient is expected to be positive in the estimated model.

Climate Variables

Previous research results have shown that there is a statistically significant relationship between water use in a geographic region and climate in that region. Average annual temperature and precipitation are climate variables intended to capture the influence of weather variables on outdoor water use. Rainfall has the obvious impact of providing water for lawns and outdoor plants. Therefore, rainfall would be expected to have a

negative impact on water use. High temperatures can lead to the need for more water for irrigation and drinking. As a result, the temperature variable would be expected to have a positive influence on water use. Similar to the average cost variable described, the aggregate nature of the model allows the use of aggregate climate variables to capture the relative difference in climate that affects water use.

Household Size

The water use variable in the estimated model represents annual use per connection. The household size variable is a measure of the average number of people attributable to each water connection. Assuming that most connections are residential, larger households should result in greater levels of water use simply because more people are using each connection for their domestic water use. Therefore, the household size coefficient should have a positive sign.

Potential Missing Variables

The major concern with missing variables is that the absence of these variables will cause bias in the modeling results. The estimated demand equation includes the cost (price) of water, climatic variables for temperature and precipitation, median household income, and household size as variables that influence water use per account. However, other factors would probably influence water use in different cities. For example, differences in water quality and reliability could influence water use. In addition, the estimated model represents water use per account. These accounts include all accounts, residential and commercial. Therefore, commercial variables such as value of goods and services used and type of commercial establishments in the area may influence water use. It is hoped that the income variable is a broad enough measure of overall economic well being to capture some of the commercial influences on water demand. Assuming there is relatively limited variation in water quality from city to city, the omitted water quality variable would not be likely to any systematic bias in the results.

Estimating the Model

Several different types of functional forms could be used to estimate a model of municipal and industrial water demand. The most basic model is a model that is linear in its variables. Two important characteristics of the linear model are: 1) the model has a constant slope and 2) the elasticities of the explanatory variables vary according to the quantity of goods and services purchased. In some cases the linear form may be overly simplistic. Most economic relationships are not linear due to variables that have threshold and saturation effects. For example, a very large change in the price of water at low levels of individual use may lead to a relatively small change in water use because most of current use is for basic necessities such as drinking, cooking, bathing, etc. At relatively high levels of individual use a change in the price of water may lead to a relatively large change in the quantity of water used because a greater proportion of water use is discretionary rather than a necessity. Despite these shortcomings, the linear model does provide a base from which other models can be evaluated.

A model that is frequently used to estimate water demand relationships is called the log-log or double log model. In a double log model, all of the variables are transformed

using the natural log and the transformed variables are then estimated as a linear model. The log-log transformation leads to constant price elasticities and varying slope throughout the range of the dependent variable.

This analysis includes both linear and double log models and the results are compared to evaluate which model performs best. The modeling results are shown below. The results shown in (3) are for the linear model and the results shown in (4) are for the double log model. It should be noted that the coefficients for price and income in the double log model can be interpreted as demand elasticities. The estimated price and income elasticities are very similar to the elasticities reported in the literature, indicating the models estimated in this analysis are consistent with previously estimated models.

$$(3) \text{ AF/HH} = 0.13031 - .000252539 \text{ COST/AF} + .0080699 \text{ TEMP} - .008727 \text{ PRECIP} \\ + .000006346 \text{ INCOME} + .1009461 \text{ HHSIZE}$$

(-3.69)*
(2.61)*
(-4.47)*

(1.29)
(1.44)

where: AF/HH = water use in acre-feet per household per year
 COST/AF = cost of water per acre-foot
 TEMP = average annual temperature
 PRECIP = average annual precipitation
 INCOME = median annual household income
 HHSIZE = average household size

F Statistic = 12.19*
 Adjusted R² = .37
 Observations = 96
 Price Elasticity = -.318
 Income Elasticity = .379

$$(4) \ln \text{ AF/HH} = -4.4528 - .262397 \ln \text{ COST/AF} + .495264 \ln \text{ TEMP} - .266096 \ln \text{ PRECIP} \\ + .378825 \ln \text{ INCOME} + .561974 \ln \text{ HHSIZE}$$

(-4.96)*
(2.50)*
(-5.51)*

(1.59)
(2.47)*

where $\ln \text{ AF/HH}$ = natural log of water use in acre-feet per household per year
 $\ln \text{ COST/AF}$ = natural log of the cost of water per acre-foot
 $\ln \text{ TEMP}$ = natural log of average annual temperature
 $\ln \text{ PRECIP}$ = natural log of average annual precipitation
 $\ln \text{ INCOME}$ = natural log of median annual household income
 $\ln \text{ HHSIZE}$ = natural log of average household size

F Statistic = 18.85*
 Adjusted R² = .48
 Observations = 96
 Price Elasticity = -.262
 Income Elasticity = .379

The numbers in parentheses under the coefficient estimates are t-statistics, which indicate the significance of the variables in explaining water use. Significance is measured in terms of levels of confidence that they are different from zero. A higher level of confidence indicates a greater chance that the coefficient is different from zero. An asterisk (*) indicate a variable is significantly difference from zero at the 99% level of confidence. The F statistic is a measure of the significance of the entire model in explaining a change in the dependent variable. Adjusted R^2 is a measure of the amount of variation in the dependent variable that is explained by the model. A “perfect” model would have an adjusted R^2 of 1.0 and an irrelevant model would have an adjusted R^2 of 0.

The modeling results are generally good, with the double log model performing somewhat better than the linear model as indicated by an additional significant variable and somewhat higher statistical significance. Therefore, the double log model was used to estimate representative water supply benefits. This is similar to the results of previous water demand studies. The insignificance of the income variable in both models was somewhat surprising. This could be due to the fact that the water use data represent residential, commercial, and public sector water users. All of the coefficients had the expected signs.

Benefit Estimation

The benefits associated with the provision of municipal and industrial water supplies can be measured as the area under the demand curve between the relevant prices and quantities for a municipal and industrial water supply. The relevant quantities are represented by the amount of water purchased in the absence of an implemented alternative and the quantity of water after implementing an alternative. The relevant quantities of water with and without an alternative cannot be known with certainty because future population growth, growth in commercial/industrial water demands, and future socio-economic conditions cannot be known with certainty. However, in order to estimate representative water supply benefits some level of use must be assumed.

The quantities of water used in this analysis to evaluate benefits are based on the current estimated water use. Current representative water use rates were estimated using data from a 2004 Santee Indian Reservation Needs Assessment (Bureau of Reclamation, 2004). Average water use for domestic household purposes on the Santee Indian Reservation was estimated to be slightly over 185 gallons per day per household and a little more than 200 gallons per day for the Village of Niobrara. This translates into about 5,625 gallons per household per month for the Santee Indian Reservation and about 6,265 gallons per household per month for the Village of Niobrara. These quantities are use as the base use quantity for each water user group. It was then assumed that if some reliable water source were not made available in the near future, average water use would decrease by 10%. The 10% figure was used to represent some level of hardship that would occur without some type of action. If the potential shortage is greater than 10%, then the estimated benefits would increase. This is a result of the fact that greater scarcity results in higher resource values. These are input into the estimated demand equation to derive an average price per acre-foot under current conditions and under

conditions assuming non-implementation of an alternative would result in lower water use.

M&I water benefits were calculated by integrating equation (4) and solving for the area under the demand curve between the implicit price for current levels of water use and water use at a new level and corresponding price. This calculation is shown below as equation (5).

$$(5) \text{ Area} = 0.144594 * \text{TEMP}^{.495264} * \text{PRECIP}^{-.266096} * \text{INCOME}^{.378825} * \text{HHSIZE}^{.561974} * [(P_1^{(1-.262397)} - P_0^{(1-.262397)}) / (1-.262397)]$$

where:

Area = area under demand curve between P₀ and P₁

TEMP = average annual temperature

PRECIP = average annual precipitation

INCOME = median annual household income

HHSIZE = average household size

P₀ = current price at current level of use

P₁ = price at corresponding level of use that is 10% higher than current use

The above calculations provide the area under the demand curve and to the right of the y-axis. To derive economic benefits the above calculation is adjusted to find the area below the demand curve but above the x-axis. This is done by subtracting the area of the quantity and price change that exists under both prices and quantities.

In order to estimate the benefits per acre-foot of water, representative values for the non-price variables need to be input into equation (4). For this analysis benefits are estimated using socio-economic values for the Santee Indian Reservation and Niobrara Village. The input values for these variables are shown in Table 2.

Table 2 – Variable values used to estimate M&I water supply benefits

Area	Water use per household per month	Annual average Temperature ¹	Annual Precipitation	Median household Income ³	Household Size ³
Santee Res.	5,625	48.9 degrees F	25.47 inches ²	\$20,938	2.98
Niobrara	6,265	48.9 degrees F	23.00 inches ¹	\$26,000	2.06

1 / <http://www.WorldClimate.com>

2 / <http://www.mnisose.org/profiles/santee.htm>

3 / U.S. Bureau of the Census, 2000 Census data.

The estimated benefits per acre-foot of water using the water use, climate, and socio-economic variable values presented in table 2 are presented below in table 3. The range of estimated values are primarily the result of the different original water use estimates. Lower levels of water use (shortage) correspond with higher values for water because greater scarcity is reflected by higher values.

Table 3– Estimated annual M&I water supply benefits for the Santee Indian Reservation and Niobrara Village

Area	Western U.S. model
Santee Reservation	\$630/af/year
Niobrara	\$300/af/year

Summary

The estimates of average water supply benefits presented in this analysis could be used to evaluate the economic feasibility of alternatives designed to improve water supplies in the Santee and Niobrara region. The quantity of water in acre-feet provided by a particular alternative on an annual basis multiplied by the estimated annual benefits per acre-foot would represent an average economic benefit of the alternative. If these benefits are greater than the costs, the alternative would be considered economically feasible. The benefit estimates for a specific alternative could be estimated more precisely if the change in water use is known rather than using an average change of 10%. It should be noted that the implementation of a regional model to a specific site creates the potential for error due to the fact that the relationships between variables on a regional level may not apply precisely to a specific site.

The benefit estimates presented in this analysis would change if different quantities of household water use were applied to the model. The estimated demand curve is used to derive corresponding water prices with and without implementing an alternative. Given that lower levels of use correspond with higher prices, all other variables held constant, lower use rates translate into higher estimated benefits. This makes economic sense because resources become more valuable as they become scarcer. Therefore, more precise water use estimates would be needed to complete a full feasibility study.

This analysis provides an estimate of average benefits per acre-foot from a change in water supply assuming average water supply conditions exist. However, during a period of drought/shortage the benefits are likely to be much higher than during average years. Water supply studies indicate that water users are willing to pay very high water prices during periods of drought and price elasticity tends to be relatively low during drought (an increase in price has little effect on quantity demanded). So, a decrease in the quantity of water available during a drought will result in a much larger loss in water supply benefits than during a non-drought year. As a result, the benefits of avoiding a shortage with a water supply project in place during drought conditions will be much larger than the average benefits associated with an increased water supply during normal conditions. It should also be noted that the benefit per acre-foot estimated in this analysis represents an average benefit for all types of water use.

The economic benefits estimated for M&I water should not be confused with the price of water charged to consumers or the price of water that you would typically see charged for water on a per acre-foot basis. In many cases, the price charge for water covers the cost of supplying water and is not representative of the actual willingness to pay for water. For example, at a discount rate of 4.875% the present value of water supply benefits at \$600 per acre foot annually would be approximately \$12,300 per acre foot in perpetuity.

This value is considerably higher than the price of water for a permanent water right in most of the western U.S. However, the estimated benefits represent the actual social benefit generated by the water resource.

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