EVALUATING THE PERSISTENCE OF RESIDENTIAL WATER CONSERVATION: A 1992-1997 PANEL STUDY OF A WATER UTILITY PROGRAM IN DELAWARE

YOUNG-DOO WANG, JAE-SHUCK SONG, JOHN BYRNE, AND SUN-JIN YUN

Made in United States of America
Reprinted from JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
Vol. 35, No. 5, October 1999

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
VOL. 35, NO. 5 AMERICAN WATER RESOURCES ASSOCIATION OCTOBER 1999

EVALUATING THE PERSISTENCE OF RESIDENTIAL WATER CONSERVATION: A 1992-1997 PANEL STUDY OF A WATER UTILITY PROGRAM IN DELAWARE[1]

Young-Doo Wang, Jae-Shuck Song, John Byrne, and Sun-Jin Yun[2]

ABSTRACT: This study systematically evaluates residential consumer responses to a utility conservation initiative based on an econometric analysis of a sample of 510 households served by Artesian Water Company, Inc. (New Castle County of Delaware). Using a panel study approach covering the period from 1992 to 1997, this study shows that Artesian's water conservation program has had statistically significant and persistent impacts on residential water consumption.
(KEY TERMS: economics; water conservation; water demand; water management; water resources planning.)

INTRODUCTION

Water service is becoming more costly, especially in jurisdictions with high summer peak use and where drought conditions frequently appear. Many researchers (Schultz and Hornbogen, 1997; Lund *et al.*, 1995; Beecher, 1995; Fiske and Dong, 1995; Child and Armour, 1995; Beecher and Stanford, 1993; Weber 1993; Vickers, 1993, 1991; Vickers and Markus, 1992; Beecher *et al.*, 1991; Little and Moreau, 1991) are encouraging states, municipalities and private water utilities to adopt an Integrated Water Resource Planning (IWRP) approach in which Demand-Side Management (DSM) options are employed in conjunction with conventional supply activities to address water shortage problems.

The success of DSM will depend upon how water consumers respond to policy initiatives. Quantitative analysis of consumer responses to conservation-oriented rates and other DSM initiatives by water utilities can provide valuable information on the effectiveness and persistence of such programs. The objective of this paper is to evaluate the impacts of selected DSM measures on residential water conservation. For this purpose, household-level data were gathered by survey from a random sample of Artesian Water Company customers (Wang *et al.*, 1998).

A stratified random sample by water consumption subgroup was drawn for this analysis. Three subgroups were used – small, medium and large consumption – with consumption levels defined according to the residential tariff in use by Artesian. The sample size of each subgroup was based on the mean and standard deviation of water consumption during the summer of 1991 by each target subgroup. The initial survey was conducted during the spring of 1993, incorporating questions involving 87 variables relating to water consumption and conservation behavior. Artesian is an investor-owned water utility serving western New Castle County, Delaware. With the overriding concern in DSM research on the persistence and reliability of conservation performances (Nadel, 1993; Vine, 1993), a household-based panel analysis for the period 1992-1997 is used to estimate conservation impacts.

ARTESIAN'S WATER DSM PROGRAM

Beginning in 1990, Artesian took several steps to improve management and operations and to address specific concerns expressed by the Delaware Public Service Commission (DPSC). A new board of directors and management team were appointed. In

[1]Paper No. 98067 of the *Journal of the American Water Resources Association*. **Discussions are open until June 1, 2000.**
[2]Respectively Associate Professor, Research Associate, Professor, and Research Associate, Center for Energy and Environmental Policy, College of Human Resources, Education and Public Policy, University of Delaware, Newark, Delaware 19716 (E-Mail/Wang: youngdoo@udel.edu).

conjunction with these changes, Artesian adopted a long-range strategic plan in 1992 which set a goal of becoming a leader in encouraging residential conservation. According to direct testimony before the DPSC by the president of Artesian, the Company proposed a three-part conservation plan consisting of an information campaign, a conservation technology promotion program, and a revision of residential water pricing to include a conservation incentive (Artesian Water Co., 1992, Vol.1: 3).

Information Campaign

The Company launched a comprehensive campaign to publicize its active commitment to water conservation. Artesian used "a kick-off" meeting and various media messages to encourage its employees and customers to learn about the Company's conservation efforts. It reinforced its campaign by publishing water conservation-related information in an in-house newsletter and in a newsletter mailed to customers as a bill insert.

In addition, water conservation was the theme of the Company's 1992 annual report which was printed in greater quantities and distributed to a wider audience. Artesian became active in *Water Week* celebrations supporting employee participation, providing displays of conservation equipment and furnishing publicity for the event. Artesian also promoted its conservation initiatives to the Customer Advisory Program (CAP) in 1991 to improve communication with customers, to keep them up to date on issues affecting them and to learn of their needs and concerns. The members of CAP are delegates from active civic associations in Artesian's service territory.

Conservation Technology Promotion

With support from Delaware's Department of Natural Resources and Environmental Control (DNREC), Artesian also launched a Customer Conservation Program (CCP) in September 1992. The costs of water conservation kits (including flow restrictors, toilet dams, and leak detection equipment) and ultra-low consumption toilets were financed by DNREC in an effort to provide incentives to program participants to retrofit their homes with water conservation technology and to educate them on water conservation techniques.

Through this program, Artesian offered its customers conservation hints and strategies, installed water-saving fixtures, and checked for costly leaks. On request, Artesian's conservation team performed a water audit and installed conservation devices in customer's homes that included faucet aerators, low-flow shower heads, and toilet dams. Artesian also sent its residential customers leaflets attached with a reply card, asking them to sign up for free conservation devices. This service was free to the first 2,000 customers who returned the reply card. To the second 2,000 customers responding, the Company offered a customized conservation kit at a 50 percent discount and a free water audit. After this offer expired, customers could purchase the kits at the Artesian Water Company.

Conservation Pricing

On January 31, 1992, Artesian filed a petition with the DPSC seeking to increase water sales revenues by 14 percent. On August 25, 1992, the DPSC approved a rate increase, raising the Company's revenue requirement by 9 percent, which included Delaware's first rate structure designed to encourage water conservation. Converting to an inclining block rate structure from a flat rate structure, the Company sought to send "price signals" to residential customers who have large discretionary demands to reduce water use through improved use-efficiency, especially during the summer. In May of 1995, Artesian raised the rates again, enhancing the conservation signal of its inclining block structure. The effect of these rate changes was to increase the cost to high-volume residential customers (who typically use 30,000 gallons of water during the summer) by a little more than 15 percent (from $86.45 to $99.70).

ECONOMETRIC ANALYSIS

Artesian provided quarterly water consumption data for the sample households during the summer months (third quarter) from 1992 to 1997. Third quarter 1992 water consumption was used as the control quarter for evaluating the conservation impact of the Company's DSM measures, since the information, technology promotion, and rate reform initiatives were put into effect after this period. As a means of evaluating the statistical performance of variables, preliminary analyses were first conducted using the t-test (for dichotomous independent variables) and Pearson's correlation (for numerical independent variables). These tests were designed to examine bivariate relationships between actual water consumption growth rates between the two years $[(Q_1 - Q_0) / Q_0]$

and variables that were expected to influence water-using activities.

Correlation analyses of changes in water consumption (1992-1993, 1992-1994, 1992-1995, 1992-1996, and 1992-1997 cases) and 12 independent variables revealed that only change in price $[(P_1 - P_0) / P_0]$ was statistically related to water consumption change in all five cases (as expected, the relationship was found to be inverse). In November 1994, a supplementary survey was conducted to obtain information on changes in factors affecting water consumption since the last survey in early 1993. Through the late-1994 survey, changes in household income and household size (ΔHHSIZE) were identified. The correlation between ΔHHSIZE and water consumption growth was found to be statistically positive. However, ΔHHSIZE was not included in the analysis because information on changes between 1992 and 1993 and also after 1995 was not available. Neither the indoor appliance usages nor outdoor water activities were found to be statistically significant in all five periods.

Fourteen dichotomous variables were used in t-tests to identify possible predictions of change in water consumption. Only two variables were statistically significant in all five cases. Those customers who obtained water conservation devices provided by Artesian showed a significantly lower water consumption growth rate compared to those who did not receive the devices. Also, those who were aware of both Artesian's DSM efforts and conservation tips through bill inserts or pamphlets had a significantly lower water consumption growth rate compared to their counterparts.

To quantitatively evaluate Artesian's water DSM impacts, a regression model of water demand was built using a proportional change measure of price and consumption instead of a single-year cross-sectional model. In case where a consumer faces a price schedule such as an increasing block-rate, a two-part price variable has been recommended to estimate price elasticity: the price of the marginal block and the total water bill minus what would have been paid if all water was sold at the marginal rate (see Billings and Agthe, 1980). Griffin and Martin (1981) commented, however, that Billings and Agthe's estimated price elasticity is biased because the explanatory variables, marginal price and difference, are not independent of the disturbance term. Some researchers recognized the possible bias and proposed alternative approaches using, for instance, a set of instrumental variables representing marginal price and difference (Billings, 1982) or using a three equation system in which water consumption, marginal price and difference are simultaneously determined (Agthe *et al.*, 1986).

In our proportional change model, however, we used growth in average prices between the two years (ΔPRICE), reflecting the assertion that consumer responds to his/her bill and rarely knows what his/her marginal rate is (see Wilder and Willenborg, 1975; Foster and Beattie, 1981). It is also noteworthy that the simultaneity bias of ΔPRICE is perhaps insignificant because of our proportional approach.

Proportional changes between 1992 and each subsequent year to 1997 for water prices and consumption were used to estimate five separate regressions. For this model, the independent variables which were conceptually and statistically significant in the preliminary t-tests and correlation analyses were included in the regression analysis. In these cases, the dependent variable was the rate of water consumption growth between two years with 1992 as a reference year (ΔWATER). The statistically-significant independent variables included in the equation were: the growth rate of real average water price (ΔPRICE); customer awareness of both the water conservation efforts undertaken by Artesian and conservation tips supplied through bill inserts or pamphlets (INFORM); and use of water conservation devices supplied by Artesian as part of the Customer Conservation Program (DEVICES). Since our panel study has a six-year duration from 1992 to 1997, it is necessary to adjust for inflation in water prices. Consumer price indexes for 1992-1997 for the Philadelphia-Wilmington-Trenton CMSA were used to adjust water prices from 1993 through 1997. The variable PRICE is the real average price paid for summer water consumption by each individual customer.

For consistency, the same variable specification was adopted in the water consumption growth equations of 1993 through 1997. The dependent variable ΔWATER and the independent variable ΔPRICE were entered in the equation in proportional change forms between the two years, while INFORM and DEVICES were inserted as base-year dummy variables. Weather conditions were treated in two ways: as part of the dependent variable by adjusting water consumption for maximum temperatures and as one of the independent variables (WEATHER).

Weather adjustment was made on the basis of the sum of the current year's maximum daily temperatures during a summer quarter compared to the average sum of daily maximum temperatures during summer quarters in the past 29 years (starting with 1969). This means that if the 1997 summer quarter is hotter, for example, than the average summer quarter of the past 29 years, then water consumption in 1997 would be adjusted downward to normalize its volume with the last 29 years. We found that the adjusted R^2 of the temperature-adjusted equation (i.e., weather included as part of the dependent variable) was higher than that for the temperature-as-independent-variable equation. Both temperature $[(T_1 - T_0) / T_0]$ and rainfall $[(R_1 - R_0) / R_0]$ were introduced as independent variables in the model with proportional price and consumption changes (Hansen and Narayanan, 1981). But no significant improvement in statistical performance resulted. In subsequent analyses, therefore, a temperature-adjusted water consumption equation was used without rainfall as an independent variable. The general form of the equation was as follows:

$$\Delta WATER = a_0 + a_1 \Delta PRICE + a_2 INFORM + a_3 DEVICES + e$$

where ΔWATER = proportional changes in day- and weather-adjusted water consumption during the summer months between two periods $[(Q_1 - Q_0) / Q_0]$; ΔPRICE = proportional changes in real (inflation-adjusted) average prices of water during the summer months between two periods $[(P_1 - P_0) / P_0]$; INFORM = consumers with higher levels of water conservation information provided by Artesian = 1 and consumers with lower levels of information = 0; DEVICES = customers who used water conservation devices provided by Artesian =1 and customers who did not = 0; and e = error term.

PERSISTENCE OF CONSERVATION IMPACTS

As shown in Table 1, the estimated five equations show the F-values far greater than the critical F-value of 2.965, indicating that these equations are statistically significant at the 0.05 level. The R^2s of all five equations range from 0.173 to 0.311. All the signs of the estimated coefficients conformed with prior expectations. No problem with heteroscedasticity nor multicollinearity existed. INFORM was significant at the 0.05 level only in the 1992-1995 equation, whereas DEVICES was significant in all equations except in the 1992-1995 and 1992-1996 equations. Overall, the results of our regression analysis indicate that water conservation impacts have persisted since the price reforms and new DSM initiatives were implemented in 1992.

Impact of Conservation Rates

Artesian's water conservation rates appear to have had a statistically significant impact on water conservation in the summer. ΔWATER and ΔPRICE were constructed in such a way that the estimated coefficient of ΔPRICE is equivalent to the price elasticity of water demand. Using differential calculus, it can be shown that dΔWATER / dΔPRICE is equal to

TABLE 1. Results of Regression Models for Water Demand Based on Real Prices (1992-1997).

Equation	Variable			Constant	Statistics		
	PRICE (R)	INFORM	DEVICES		R^2	F Value	Cases
1992-1993	-0.50821**	-0.02844	-0.20400**	0.20391**	0.173	35.216	510
	(-9.546)	(-0.795)	(-3.379)	(7.613)			
1992-1994	-0.69716**	-0.05054	-0.14693**	0.20957**	0.311	76.271	510
	(-14.243)	(-1.661)	(-3.200)	(9.293)			
1992-1995	-0.63295**	-0.08723*	-0.09605	0.18390**	0.208	44.315	510
	(-10.445)	(-2.216)	(-1.667)	(6.213)			
1992-1996	-0.58896**	-0.06906	-0.10676	0.15225**	0.214	45.876	510
	(-11.011)	(-1.824)	(-1.909)	(5.289)			
1992-1997	-0.53255**	-0.04835	-0.15999*	0.16795**	0.206	43.777	510
	(-11.016)	(-1.117)	(-2.487)	(5.268)			

Note: The figures in the parentheses are t-statistics.
* denotes a statistical significance at the level of 0.05.
** denotes a statistical significance at the level of 0.01.

$(dWATER_1 / dPRICE_1) * (PRICE_0 / WATER_0)$, the elasticity of water with respect to $price_0$. The price elasticities range from -0.508 to -0.697, relatively higher than elasticity estimates based on yearly data used in nearly all of the studies summarized in Table 2. This is explained by our focus on summer water use where discretionary demand tends to be greatest. Indeed, outdoor water use has been found in the literature to be particularly sensitive to price increases, especially during the high-demand summer months (Rhodes *et al.*, 1992).

It is interesting to note that the magnitudes of the price elasticities, as shown in Table 1, have weakened since 1994, from -0.697 in the 1992-1994 equation to -0.533 in the 1992-97 equation. The test of the equality of two regression coefficients showed that the two elasticities are statistically different (the calculated t- statistics of 2.393 compared to the critical t value of 1.965). It may be interpreted that the price responsiveness on the part of residential customers has dwindled over time. However, ΔPRICE is still the most significant policy variable in this model as shown by the magnitude of the t-values. Based on the price elasticity of -0.533 in the 1992-1997 equation, it was estimated that water consumption in 1997 was 8 percent less than in 1992 attributable to the 15 percent increase in water prices between 1992 and 1997.

TABLE 2. Estimated Price Elasticities for Residential Water Demand: Selected Studies Conducted Between 1985 and 1998.

Investigator	Year Published	Type of Analysis	Price Elasticity
Wang, Byrne, Song, and Chen	1998	510 households, Delaware Panel Study, 1992-1997 (Summer)	-0.508 to -0.697
Dandy, Nguyen and Davies	1997	320 households, Australia Panel Study, 1979-1992 (Summer)	-0.36 to -0.86
Espey, Espey and Shaw	1997	24 U.S. Studies Reviewed Short-Run Range Long-Run Range	 -0.03 to -2.23 -0.10 to -3.33
Hansen	1996	Copenhagen, Annual Per Capita Time Series, 1981-1990	-0.1
Hewitt and Hanemann	1995	121 Households, Texas Panel Study, 1981-1985 (Summer)	-1.57 to -1.63
Stevens, Miller, and Willis	1992	85 Massachusetts Communities, Cross-Sectional	-0.10 to -0.69
Woo	1992	Hong Kong, Monthly Per Capita Time Series, 1973-1984	-0.384
Nieswiadomy	1992	430 Water Utilities, AWWA Data Cross-Sectional	-0.29 to -0.45
Rizaiza	1991	563 Customers, Saudi Arabia, Cross-Sectional	-0.40 to -0.780
Nieswiadomy and Molina	1991	101 Customers, Summer, Texas 1976-1980, DBR Period* 1981-1985, IBR Period*	 -0.11 to -0.94 0.78 to -0.295
Weber	1989	12 zones, East Bay Municipal Utility District, California Time Series and Cross-Sectional	-0.10 to -0.25
Metzner	1989	City of San Francisco 1974-1986, Time Series	-0.25
Billings and Day	1989	3 Water Utilities, Arizona, Time Series and Cross Sectional	-0.720
Palencia	1988	Metropolitan Manila, Time Series, 1970-1981	-0.287
Martin and Thomas	1986	Five Arid Cities (U.S., Kuwait, and Australia), Cross-Sectional	-0.500
Narayanan, Larson and Hughes	1985	33 Utah Communities, 1976-1977, Cross-Sectional	-0.07 to -0.09

Note: *DBR denotes declining block rates, and IBR denotes inclining block rates.

Impact of Conservation Devices

Artesian's delivery of water conservation devices was also found to contribute to water conservation. The estimated coefficients of DEVICES were negative and statistically significant in the 1992-1993 equation, in the 1992-1994 equation and in the 1992-1997 equation. These results indicate that those customers who received conservation devices provided by Artesian as part of CCP experienced a significantly lower growth rate in water consumption than those who did not participate in the program. More specifically, those who received the devices reduced their consumption by approximately 15-20 percent compared to those who did not (as shown in the estimated coefficients of DEVICES of -0.147 in the 1992-1994 equation and -0.204 in the 1992-1993 equation). This magnitude of savings is impressive compared with other research results, such as those for the San Jose residential retrofit kit program which achieved a 10 to 11 percent reduction in indoor water use (Vickers, 1991). Even though those who received Artesian's water conservation devices reduced their consumption by 16 percent in 1997 compared to 1992, overall water savings were estimated to be only 2 percent due to the small number of participants in this program (15 percent participation rate in our sample).

Efficiency improvements in water appliances combined with consumer behavior changes can make significant contributions to water conservation. According to a four-year study conducted by the University of Arizona, a residential water conservation experimental and demonstration home which was retrofitted with water conservation techniques and technologies consumed only 34 percent of the average residential water consumption in Arizona. At the demonstration home, the average water usage was 49 gallons per capita per day (gpcd) compared to the Arizona average of 145 gpcd, creating savings also in terms of reduced energy consumption for heating water, treating sewage and purifying water (Karpiscak *et al.*, 1990).

Impact of Information

Artesian's information campaigns through bill inserts and pamphlets have made a modest contribution to the overall water conservation effort, according to our analysis. Even though information was not statistically significant at the 0.05 level except for the 1992-1995 equation, the estimated coefficients in all equations had negative signs, indicating that residential customers with higher levels of water conservation information (supplied by Artesian) tended to consume less water than those who had lower levels of conservation information. The magnitude of reduction during the summer months between 1992 and 1997 was about 5 percent (as shown in the estimated coefficient of INFORM of -0.048 in the 1992-97 equation). Based on our sample, 51 percent of residential customers were classified as "more informed." Overall water savings from Artesian's information campaigns were estimated to be 2 percent in 1997 compared to 1992.

Few studies are available which deal with the impact of INFORM on water conservation. The studies that have analyzed this factor are based on aggregate data and on regions significantly different from New Castle County, Delaware. Using the American Water Works Association (AWWA) survey of 430 U.S. water utilities, Nieswiadomy (1992) estimated the impacts of public education programs on water conservation for four different regions of the United States – North Central, Northeast, South and West. His results showed that public education programs, which urge people to conserve water, significantly reduce water demand only in the West.

A study of southern Arizona's campaign showed that publicity about water problems had a small impact on water conservation, with an average elasticity of -0.05 (Billings and Day, 1989), suggesting that a 10 percent increase in the amount of publicity about the need to conserve water would produce a 0.5 percent reduction in water use. Several formulations were estimated by Billings and Day for this variable, "but none showed a significant lagged effect of publicity, thus indicating that the effect of publicity exists only as long as the publicity continues" (Billings and Day, 1989:63).

An interesting result with regard to conservation information was found by Bruvold and Smith (1988). Their research indicates that the variable representing a customer's knowledge of water consumption was statistically significant, but the belief variable, represented by attitudes toward long range water conservation, turned out not to be statistically significant, although the outcome was in the predicted direction. They concluded that "an inclining block rate structure coupled with an informational program designed to inform consumers of their consumption under each block will have a synergistic impact" (Bruvold and Smith, 1988:661).

POLICY IMPLICATIONS

The estimated impacts of Artesian's DSM measures were based on five years of experience (1992-97). Our research indicates that these measures have resulted in a statistically measurable, persistent conservation effect. Thus, our work tends to support to the conclusion that water conservation programs can be designed which can have lasting impacts on water users' behaviors. The policy implications of our findings can be summarized as follows:

- Water utilities, in collaboration with state and local governments, can play an active role in the dissemination of quality information on the water supply situation and conservation needs for reduction in discretionary water consumption. The most critical matter is to get customers to take the message seriously enough to change their behavior. The information should be clear and understandable to customers and motivate them to take actual conservation measures. Information campaigns should be also be ongoing to be most effective.
- Our analyses and engineering estimates (Postel, 1986; Vickers, 1989, 1991, 1993) generally indicate that efficient water fixtures can significantly reduce water consumption. Fully realizing such potential water savings available from higher-efficiency fixtures necessitates their widespread adoption. Water utilities might consider combined strategies of information and pricing reform (including utility rebate programs) to promote installation of conservation devices by customers.
- Pricing policy is essential for ensuring that water utilities and customers alike weigh efficiency alternatives properly in their water supply and demand decisions. The most costly water supply problem faced by water utilities is peak summer demand. To be most effective, pricing structures need to be designed in such a way that discretionary water use in the summer months is targeted (Espey *et al.*, 1997). Customers who are the principal source of peak demand should shoulder proportionally higher costs. Seasonal and inclining block pricing reflects these higher costs.
- A policy that combines the strategies of conservation pricing, consumer education and the promotion of conservation devices can ensure adequate water supplies while also minimizing adverse environmental impacts. Such a policy benefits consumers by reducing wasteful water use, contributing to the preservation of the natural environment, and assisting utilities in meeting water needs more cost-effectively. An intelligent water conservation policy can produce win-win outcomes for all.

ACKNOWLEDGMENTS

The authors wish to thank Ms. Dian C. Taylor, President, and Mr. David Spacht, Vice President, Artesian Water Company, Inc., who sponsored this project; Mr. Stewart Lovell, Manager of the Water Supply Section of the Delaware Department of Natural Resources and Environmental Control, who initiated our water conservation impact study and gave insightful comments throughout this project; and Dr. Shih-Jung Hsu, Dr. Vijay Ramakrishna, Mr. Wenyao Hu, Mr. Leigh Glover, Ms. Zhu Lee, Ms. Amy Clineburg Pfeufer, Ms. Yingxia Chen and Mr. Kyung-Jin Boo, research associates of the Center for Energy and Environmental Policy, who contributed to this five-year study. Last, but not the least, the authors greatly appreciated critical comments by Dr. Myong-Keun Yoon, Center for Composite Materials, University of Delaware and three anonymous referees of the Journal of the American Water Resources Association. The authors bear sole responsibility for the contents of the paper.

LITERATURE CITED

Agthe, D. E., R. B. Billings, J. L. Dobra, and K. Raffiee, 1986. A Simultaneous Equation Demand Model for Block Rates. Water Resources Research 22(1):1-4.

Artesian Water Company, 1992. Application of Artesian Water Company, Inc. for a Revision of Rates, Filed before the Public Service Commission of the State of Delaware, Volumes 1 and 2, 1992.

Beecher, J. A., 1995. Integrated Resource Planning: Fundamentals. Journal AWWA (June), pp. 34-48.

Beecher, J. A., J. R. Landers, and P. C. Mann, 1991. Integrated Resource Planning for Water Utilities. The National Regulatory Research Institute, Columbus, Ohio.

Beecher, J. A. and J. D. Stanford, 1993. Integrated Water Resource Planning: Discussion Paper. The National Regulatory Research Institute, Columbus, Ohio.

Billings, R. B., 1982. Specification of Block Rate Price Variables in Demand Models. Land Economics 58(3):386-394.

Billings, R. B. and D. E. Agthe, 1980. Price Elasticities for Water: A Case of Increasing Block Rates. Land Economics 56(1):73-84.

Billings, R. B. and W. M. Day, 1989. Demand Management Factors in Residential Water Use: The Southern Arizona Experience. Journal AWWA (March).

Bruvold, W. H. and B. R. Smith, 1988. Developing and Assessing A Model of Residential Water Conservation. Water Resources Bulletin 24(3).

Child, M. and A. Armour, 1995. Integrated Water Resource Planning in Canada: Theoretical Considerations and Observations from Practice. Canadian Water Resources Journal 20(2).

Dandy, G., T. Nguyen, and C. Davies, 1997. Estimating Residential Water Demand in the Presence of Free Allowances. Land Economics 73(1):125-139.

Espey, M., J. Espey, and W. D. Shaw, 1997. Price Elasticity of Residential Demand for Water: A Meta-Analysis. Water Resources Research 33(6):1369-1374.

Fiske, G. and A. Dong, 1995. IRP: A Case Study from Nevada. Journal AWWA (June), pp. 72-83.

Foster, H. S. and B. R. Beattie, 1981. On the Specification of Price in Studies of Consumer Demand Under Block Price Scheduling. Land Economics 57(4):624-629.

Gujarati, Damodar N., 1988. Basic Econometrics (Second Edition). McGraw-Hill, Inc., New York, New York.

Griffin, A. H. and W. E. Martin, 1981. Price Elasticities for Water: A Case of Increasing Block Rates: Comment. Land Economics 57(2):266-275.

Hansen, L. G., 1996. Water and Energy Price Impacts on Residential Water Demand in Copenhagen. Land Economics 72(1):66-79.

Hansen, R. D. and R. Narayanan, 1981. A Monthly Time Series Model of Municipal Water Demand. Water Resources Bulletin 17(4):578-585.

Hewitt, J. A. and W. M. Hanemann, 1995. A Discrete/Continuous Choice Approach to Residential Water Demand Under Block Rate Pricing. Land Economics 71(2):173-192.

Karpiscak, M. M., K. E. Foster, and N. Schmidt, 1990. Residential Water Conservation: Casa del Agua. Water Resources Bulletin 26(6):939-948.

Little, K. W. and D. H. Moreau, 1991. Estimating the Effects of Conservation on Demand During Droughts. Journal AWWA (October).

Lund, J. R., M. Jenkins, and O. Wilchford, 1995. Integrated Planning and Management for Urban Water Supplies: Considering Multiple Uncertainties. Research Report, University of California Water Resources Center.

Martin, W. E. and J. F. Thomas, 1986. Policy Relevance in Studies of Urban Residential Water Demand. Water Resources Bulletin 22(6).

Metzner, R., 1989. Demand Forecasting: A Model for San Francisco. Journal AWWA (February), pp. 56-59.

Nadel, S., 1993. Utility Demand-Side Management Experience and Potential: A Critical Review. LBL Advance IRP Seminar, Vol. 1.

Narayanan, R., D. T. Larson, and T. C. Hughes, 1985. Effectiveness of Drought Policies for Municipal Water Management. Water Resources Bulletin 21(3):407-416.

Nieswiadomy, M. L., 1992. Estimating Urban Residential Water Demand: Effects of Price Structure, Conservation, and Education. Water Resources Research (March).

Nieswiadomy, M. L. and D. J. Molina, 1991. A Note on Price Perception in Water Demand Models. Land Economics, November.

Palencia, L. C., 1988. Residential Water Demand in Metro Manila. Water Resource Bulletin 24(2):275-279.

Postel, Sandra, 1986. Increasing Water Efficiency. State of the World 1986. W. W. Norton and Company, New York, New York, pp. 40-61.

Rhodes, S. L., K. A. Miller, and L. J. MacDonnell, 1992. Institutional Response to Climate Change: Water Provider Organizations in the Denver Metropolitan Region. Water Resources Research 28(1):11-18.

Rizaiza, O. S. A., 1991. Residential Water Usage: A Case Study of the Major Cities of the Western Region of Saudi Arabia. Water Resources Research (May), pp. 667-671.

Schultz, Gert A. and Martin Hornbogen, 1997. Integrated Anticipatory Planning of a Regional Water Resources System. IAHS Publication, Vol. 240.

Stevens, T. H., J. Miller, and C. Willis, 1992. Effects of Price Structure on Residential Water Demand. Water Resources Bulletin 28(4):681-685.

Vickers, A., 1989. New Massachusetts Toilet Standard Sets Water Conservation Precedent. Journal AWWA (March).

Vickers, A., 1991. The Emerging Demand-Side Era in Water Management. Journal AWWA (October).

Vickers, A., 1993. The Energy Policy Act: Assessing Its Impact on Utilities. Journal AWWA (August).

Vickers, A. and E. J. Markus, 1992. Creating Economic Incentives for Conservation. Journal AWWA (October).

Vine, E. L., 1993. Persistence of Energy Savings: What Do We Know and How Can It Be Ensured? LBL Advanced IRP Seminar, Vol. 1.

Wang, Y-D, J. Byrne, J. Song, and Y. Chen, 1998. The 1992-97 Panel Study of Residential Water Conservation Impact: Persistence of Conservation Performances of Demand-Side Management Programs. Sponsored by Artesian Water Company, Inc., Center for Energy and Environmental Policy, University of Delaware, Newark Delaware.

Weber, J. A., 1989. Forecasting Demand and Measuring Price Elasticity. Journal AWWA (May).

Weber, J. A., 1993. Integrating Conservation Targets into Water Demand Projections. Journal AWWA (August).

Wider, R. P. and J. F. Willenborg, 1975. Residential Demand for Electricity: A Consumer Panel Approach. Southern Economics Journal 42(2).

Woo, C-K., 1992. Drought Management, Service Interruption, and Water Pricing: Evidence From Hong Kong. Water Resources Research 20(10).