Exhibit No.:	______________
Issues:	Rate Design-Income/ Consumption Correlation
Witness:	Thompson
Type of Exhibit:	Rebuttal Testimony
Sponsoring Party:	Missouri Gas Energy
Case No.:	GR-2001-292

MISSOURI PUBLIC SERVICE COMMISSION

MISSOURI GAS ENERGY

CASE NO.

GR-2001-292

REBUTTAL TESTIMONY OF

PHILIP B. THOMPSON

Mt. Pleasant, Michigan

May 22, 2001

REBUTTAL TESTIMONY OF PHILIP B. THOMPSON

CASE NO. GR-2001-292

May 2001

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. Philip B. Thompson, RT Associates, 1777 Rose Marie Lane, Mt. Pleasant, Michigan, 48858.

Q. ON WHOSE BEHALF ARE YOU APPEARING IN THIS PROCEEDING?

A. I have been retained by Missouri Gas Energy (MGE).

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL AND EMPLOYMENT BACKGROUND.

A. I have a B.A. in Economics from Kent State University and a Ph.D. in Economics from the University of Arizona. From 1982-1984 I was an instructor at Texas A&M University. From 1984-1986 I was a Public Utility Economist with the Missouri Office of the Public Counsel, and from 1986-1994 served as Public Counsel's Chief Economist. From 1994-2000 I was an Assistant Professor of Economics at the University of Missouri-Rolla, and since August 2000 I have been a Temporary Assistant Professor of Economics at Central Michigan University.

Throughout my career I have made presentations at many conferences and published papers in peer-reviewed journals and in other publications, mostly on topics related to utility and energy economics, including the influence of household income on residential natural gas consumption. My vita is attached to this testimony as Schedule PBT-1.

Q. HAVE YOU EVER TESTIFIED BEFORE THIS COMMISSION?

A. Yes. I filed written testimony in numerous cases while employed by the Office of the Public Counsel, and in two other cases while working as a consultant. In many of these cases I also appeared for cross-examination at a hearing.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. I will present the results of a study I performed in an effort to ascertain the relationship between residential gas consumers' income levels and their usage of natural gas in MGE's service territory. This is in response to (and in disagreement with) the testimony of Public Counsel witness Roger Colton, which includes a statement (p. 64, Schedule RDC-4) to the effect that low income customers use only 90% of the overall average residential gas usage. My discussion also responds to the direct testimony of Staff witness Beck and Public Counsel witness Hong Hu insofar as they appear to recommend that the Commission look first to increasing volumetric charges, as opposed to fixed monthly charges, for the residential customer class to recover the revenue increase in this case.

Q. WHY IS THE INCOME-CONSUMPTION RELATIONSHIP FOR NATURAL GAS CONSUMERS IMPORTANT?

A. Residential natural gas rate structures typically consist of a monthly fixed charge, known as the customer charge, and a rate applied to each volumetric unit of consumption, also sometimes called the commodity or energy charge. In some rate structures the fixed charge includes a charge for the first units of usage each month, in which case the volumetric charge is not levied on that usage.

When rates for the residential class are increased, a decision must be made concerning how to apportion the increase between the fixed and volumetric charges. The greater the proportion of the rate increase collected through the volumetric charge, the greater the increase in bills for customers with above-average usage, and the smaller the impact on below-average users.

In deciding how to apportion a class revenue increase between the rate components, this Commission has traditionally used cost-of-serve studies as a starting point, but has considered other factors in its final rate determinations. These factors include "*consumption characteristics (effect on low income customers)*, economic factors, current rate structures, value of service, *rate affordability*, customer service quality, historical rates, the concept of gradualism to avoid or minimize potentially disruptive rate shifts or rate shock, and the magnitude of the required increases or the overall rate impact of the increase in the revenue requirement." (*Re: Missouri Gas Energy*, Report and Order, GR-96-285, issued February 1, 2001, Missouri Public Service Commission, pp. 40-41, emphasis added, footnotes deleted.)

In order to consider the impact of a particular fixed/volumetric charge apportionment on low income customers, we must first have information about the income-consumption relationship. For example, if low income consumers use less than the average amount of gas (within the residential class), a larger relative increase in the fixed charge will increase the burden of such customers relative to other customers. On the other hand, if low income customers use *above*-average quantities, rate increase impacts on such customers would be reduced by putting a greater portion of the increase into the fixed charge and a smaller portion into the volumetric charge.

The Commission has in two recent cases considered both possibilities. In Case No. GR-2000-512 the Commission approved a Stipulation and Agreement settling the case, which included an increase in AmerenUE's monthly fixed charge for residential customers from $8 to $9. But three Commissioners (Chair Lumpe and Vice Chair Drainer in a Concurring Opinion, and Commissioner Schemenauer in his Dissenting Opinion) expressed concern that an increase in the customer charge is regressive, meaning that it results in larger bill increases for low income customers.

The Commission has also recognized the alternative possibility in its Report and Order in Case No. GR-96-285 (February 1, 2001, p. 41, footnote 12), stating that "frequently lower income customers use more gas for heating because the homes they heat are often older and more poorly insulated, thereby causing those people who can least afford it, to consume more gas to achieve the same degree of heating as newer, better insulated homes." Finally, advocacy agencies for low income customers often argue that such customers are below-average users who would be harmed disproportionately by a revenue increase apportionment weighted heavily toward the fixed charge.

Which view is correct? Both arguments have theoretically sound underpinnings. The question therefore becomes an empirical one: What is the income-consumption relationship?

Q. YOU SEEM TO BE SUGGESTING THAT THERE ARE TWO POSSIBILITIES: CONSUMPTION IS LOW AT LOW INCOME LEVELS AND INCREASES WITH INCOME, OR THAT USAGE STARTS HIGH AT LOW INCOMES AND DECLINES WITH INCOME. IS THAT CORRECT?

A. Those are two possibilities, but there is a third. In a sense, both sides of the argument may be correct. That is, usage may be high at low income levels and fall as income increases, but then reaches a minimum and begins to climb again after a certain income level. If we imagine a graph with income on the horizontal axis and monthly usage per customer on the vertical, the relationship I have just described would have "U"-shape; see Schedule PBT-2 for examples. I believe, based on an econometric study of residential natural gas consumption determinants, that the relationship between income and consumption in MGE's service territory is of this "U"-shaped type.

Q. HOW MIGHT SUCH A "COMBINATION" RELATIONSHIP BE EXPLAINED?

A. Simply as a combination of the two explanations for the individual relationships. At the lowest income levels, families live in homes that are inefficient in their gas use. Their homes are older, not well insulated, and lacking energy-efficient doors and windows. Their furnaces may be older and not well maintained, especially if the home is rented.

As incomes rise above the very lowest levels, families obtain the wherewithal to improve the thermal integrity of their residences and the efficiency of their furnaces, and usage declines. But at some income level usage begin to rise once again as the household gas bill becomes a smaller factor in the family budget and as more gas appliances (e.g., swimming pool heaters) are added.

Q. PLEASE DESCRIBE THE CONTENTS OF SCHEDULE PBT-2.

A. Schedule PBT-2 contains a report to MGE that I authored to present and explain the results of my econometric study. It includes a general overview section and a technical section. The remainder of this testimony will provide the highlights of the study results, but a more complete description of the results appears in the report.

Q. PLEASE PROVIDE A BASIC DESCRIPTION OF THE STUDY YOU CONDUCTED.

A. The study explains the way in which average monthly usage in MGE's residential customer class varies across geographic units and over time. The geographic units employed are zip codes. The time periods are the entire two-year period under examination (October 1998 through September 2000), referred to as "annual" models, and each individual month during that period, the "monthly" models. (Note: A "model" is simply a single regression equation containing a specific set of explanatory variables.)

The annual models take average monthly usage in a zip code over the entire two-year period as the *dependent* variable, or the variable whose behavior we wish to explain. Various combinations of *independent* or *explanatory* variables are used to determine the causes of variations in usage across zip codes and the contribution of each explanatory variable. These included weather, income, housing characteristics (e.g., age), and household characteristics (e.g., employment history). Data for a total of 182 zip codes in MGE's service territory were used.

The monthly models have average monthly usage *for each month in the period* as the dependent variable. Thus, instead of only 182 observations (one for each zip code), there are 4,368 (24 for each zip code). A very similar set of explanatory variables is examined, with the addition of a price variable.

Q. WHERE DID YOU GET THE DATA YOU USED?

A. The raw data and the variables derived from it are described in Schedule PBT-2. Data on customer usage and the number of bills by zip code or census tract, by month; and data on the weather were provided by MGE. Data on population and housing variables were taken from the 1990 Census.

Q. WHY DID YOU USE 1990 CENSUS DATA?

A. The zip code and census tract level data from the 2000 census will not be available for several more months. That would be better data to use because it would more closely match the study period for the MGE data. But there is no reason to believe that differences in 1990 and 2000 data would be such that the quantitative results would be greatly affected or that the qualitative conclusions would be any different.

Q. PLEASE SUMMARIZE THE RESULTS.

A. I will first present the results of some simple calculations indicating that low income customers use above-average amounts of natural gas. The sum of total usage over the period over all 182 zip codes divided by the total number of bills, also summed across months and zip codes, yields an average usage per bill of 72.01 Ccf (hundred cubic feet). The same calculation performed using only the 37 zip codes with the lowest average household income (approximately one-fifth of the total, or the lowest income quintile) yields an average usage per bill of 84.51 Ccf , 17% higher than the overall average. It is interesting to note that if we first calculate average usage per bill within each zip code, and then calculate the unweighted average of these averages, the results are nearly the same for the overall group (69.8 Ccf) and the low income group

(69.0 Ccf). The contrast between these two comparisons can be explained by a closer examination of the zip code average usage figures, which reveal that in the lowest income quintile, the zip codes with the largest number of bills also have the highest usage per bill, with some exceeding 100 Ccf per bill.

Regression analysis allows us to more closely examine whether it is income or other factors that drive these differences in consumption, and whether the income-consumption relationship is "U"-shaped. As I suggested earlier, the results of my econometric study strongly suggest that the income-consumption relationship in MGE's service territory does indeed have a "U"-shape, so that average monthly consumption at first declines as income rises, then turns upward with further increases in income. There is <u>no</u> evidence that consumption increases steadily from lowest incomes to highest incomes. Schedule PBT-2 contains detailed support for these conclusions.

For the annual models, depending on which model is examined, the bottom of the "U" occurs at annual income levels ranging from $44,559 to $67,319 (1999 dollars), when the estimated relationship is evaluated at the means of the other explanatory variables. In addition, the low-income section of the "U" crosses the average usage level at incomes ranging from $24,599 to $41,125. This means that consumers with incomes below these levels consume above-average amounts of gas.

For the monthly models, the bottom of the "U" occurs at annual income levels ranging from $59,683 to $73,534 (1999 dollars), again when the estimated relationship is evaluated at the means of the other explanatory variables. The low-income section of the "U" crosses the average usage level at incomes ranging from $22,836 to $40,154.

Q. YOU STATED EARLIER THAT YOU EXAMINED OTHER VARIABLES IN ADDITION TO INCOME AS DETERMINANTS OF RESIDENTIAL USAGE. PLEASE EXPLAIN THE RESULTS OF YOUR STUDY IN THIS REGARD.

A. All of these other variables contributed to gas usage in the anticipated direction. Colder weather, measured as an increase in Heating Degree-Days (HDD), increases usage. An increase in the median age of homes in a zip code increases average usage in that area, all else equal. An increase in the size of a home (measured as the average number of rooms) also increases usage.

A variable measuring the proportion of persons over 15 years of age who did not work in the previous year also has a positive affect on gas usage. That is, the greater the proportion of persons in a zip code who did not work, the higher the gas consumption. An interpretation of this result is that not working is associated with a greater proportion of the time in which at least one family member is at home, which is likely to result in higher average thermostat settings. That is, many consumers turn down the thermostat during the day if nobody is home, but not if someone is home.

A variable measuring the proportion of homes that are owner-occupied is negatively related to usage in some model specifications. This conforms to the view that homeowners have a greater incentive than renters to adopt energy efficiency measures.

Some interesting results with respect to price variables were obtained. If only the current period price is used (e.g., January's price is used to predict January usage), the relationship is positive. At first this would appear to run counter to the so-called law of demand, which holds that, all else equal, higher prices cause lower consumption. But a possible explanation for this result may be simply that higher prices tend to coincide with colder weather. When a price variable that is lagged one period is also included in a model (e.g., both the January and February prices are used to explain February's usage), the current month's price is negatively related to usage, but the lagged price has a positive impact. The reason for this result is unclear, but it may be caused by the fact that consumers generally are unaware of the price of natural gas at the time of consumption, at least in the same sense that they are aware of the price of a gallon of gasoline or milk. In any event this result does not affect the overall performance of the models with respect to the other variables; a model that does not include a price performs very much like those that do with respect to the other explanatory variables.

Schedule PBT-2 also includes some discussion of the performance of other variables, such as using persons per household as a "house size" variable and some interaction variables, which, for example, allow us to examine the effect of changes in income on the impact of weather on consumption. Please refer to Schedule PBT-2 for the details.

Q. DO THE RESULTS OF YOUR STUDY INDICATE THAT INCREASING THE FIXED MONTHLY CHARGE FOR MGE WOULD HAVE A REGRESSIVE IMPACT ON LOW INCOME CUSTOMERS?

A. No. In fact, the results of my study indicate that, because low income customers in MGE's service territory consume higher than average volumes, increasing the *volumetric* charge would have a regressive impact on low income consumers.

Q. PLEASE STATE YOUR OVERALL CONCLUSIONS.

A. In my opinion, there is no evidence that increases in the monthly customer charge (proportionally larger than increases in the volumetric charge) are regressive. The results of my study indicate that the income-consumption relationship for residential natural gas usage in MGE's service territory is mildly "U"-shaped: above-average at the lowest income levels, declining through middle incomes, and then rising again to above the average at higher income levels.

Q. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

A. Yes.

BEFORE THE PUBLIC SERVICE COMMISSION

OF THE STATE OF MISSOURI

In the Matter of Missouri Gas Energy's Tariff Sheets Designed to Increase Rates for Gas Service in the Company's Missouri Service Area.	))))	Case No. GR-2001-292

AFFIDAVIT OF PHILIP B. THOMPSON

STATE OF MICHIGAN)
) ss.
COUNTY OF ISABELLA)

Philip B. Thompson, of lawful age, on his oath states: that he has participated in the preparation of the foregoing Rebuttal Testimony in question and answer form, to be presented in the above case; that the answers in the foregoing Rebuttal Testimony were given by him; that he has knowledge of the matters set forth in such answers; and that such matters are true and correct to the best of his knowledge and belief.

Philip B. Thompson

PHILIP B. THOMPSON

Subscribed and sworn to before me this 16th day of May 2001.

Faye L. Cole

Notary Public

My Commission Expires: 5/2/2005

Faye L. Cole, Notary Public
Montcalm County, Michigan
Acting In Isabella County Michigan
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EDUCATION

Ph.D., Economics, University of Arizona, May, 1988.
Dissertation: *The Spatial and Temporal Distribution of Risks Associated with Low-Level Radioactive Waste Disposal* (Advisor: David E. Pingry)

B.A., Economics, Magna Cum Laude, Kent State University, June, 1976

EMPLOYMENT EXPERIENCE

August 2000 to present	Temporary Assistant Professor of Economics, Central Michigan University
August 1998 to August 2000	Assistant Professor of Economics, University of Missouri-Rolla, *Teaching:* Principles of Microeconomics and Macroeconomics, Intermediate Microeconomics, Industrial Organization, and Energy Economics. *Research:* Hazardous/Radioactive Waste economics, energy demand, energy efficiency, airline pricing, sports economics *University Outreach and Extension:* Quarter-time academic year and full-time summer appointment, consulting research economist conducting projects including industry studies for the Center for Competitive Analysis, energy efficiency, and community economic development.
August 1994 to May 1998	Visiting Assistant Professor of Economics, University of Missouri-Rolla
August 1994 to present	Principal, RT Associates, consulting on Public Utility, Regulatory, and Antitrust Economics
May 1986 to August 1994	Chief Public Utility Economist, Office of the Public Counsel, State of Missouri.
May 1984 to May 1986	Public Utility Economist, Office of the Public Counsel, State of Missouri

August 1982 to May 1984 — Visiting Instructor, Department of Economics, Texas A&M University, teaching Principles and Money & Banking.

NATIONAL OFFICES: Member, Gas Technology Institute Advisory Council, 1993 - present, and GRI Advisory Council Science and Technology Committee, 1999-present.

National Association of State Utility Consumer Advocates, Chair, Economics and Finance Committee, 1990 - 1994.

PUBLICATIONS

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Riordan, C.A., L.M. Manning, A. Daniel, S.L. Murray, P.B. Thompson, and E. Cummins, 1999. "If I Knew Then What I Know Now: A Portable Mentor for Women Beginning Professorial Careers in Science and Engineering," *Journal of Women and Minorities in Science and Engineering*, v. 5, 29-52.

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OTHER SCHOLARLY ACTIVITIES

CONFERENCE PARTICIPATION

Thompson, Philip B., presenter, "New Faculty Mentoring: Getting a Good Start," Western Economic Association International 75th Annual Conference, Vancouver, BC, July, 2000.

Thompson, Philip B., presenter, "Writing a Microeconomics Principles Textbook: Process, Problems, and Positives," 11th Annual Teaching Economics: Instruction and Classroom Based Research, Robert Morris College, Pittsburgh, PA, February, 2000.

Session Chair and Discussant, Western Economic Association International, Midwest Economic Association, and Missouri Valley Economic Association conferences, various years

Thompson, Philip B., presenter, "Consumer Theory, Home Production, and Energy Efficiency," Western Economic Association International 74th Annual Conference, San Diego, CA, July, 1999.

Thompson, Philip B., presenter, "Modeling Cost-Risk Tradeoffs Associated With Low-Level Radioactive Waste Disposal Systems," Midwest Economic Association International 63rd Annual Meeting, Nashville, TN, March, 1999.

Thompson, Philip B., presenter, "Low-Level Radioactive Waste Disposal: Cost-Risk Tradeoffs," Western Economic Association International 73rd Annual Conference, Lake Tahoe, July, 1998.

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Thompson, Philip B., presenter, "Consumer Theory, Discounting, and Energy Conservation," Missouri Valley Economic Association meetings, St. Louis, Missouri, February, 1997.

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Respondent, Gas Research Institute Energy Seminar, *Electric Utility Restructuring and its Impact on the Gas Industry*, Asheville, North Carolina, August, 1995.

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Thompson, Philip B., presenter, "Appropriate Pricing Policies Toward Bypass: An Application of Natural Monopoly Theory With Spatial Considerations," at the Eighth National Association of Regulatory Utility Commissioners Biennial Regulatory Information Conference, National Regulatory Research Institute, Columbus, Ohio, September 1992. Won Honorable Mention (second place) in Conference prize competition.

CONFERENCE PARTICIPATION (continued)

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Thompson, Philip B., presenter, "The Non-Gas Component of Local Distribution Company Rates," at National Association of State Utility Consumer Advocates, Annual Meeting, Orlando, Florida, November 1990.

Thompson, Philip B., presenter, "Competitive Pricing of Local Distribution Company Service in Missouri: the Recent Experience," at Assessing the Competitiveness of the Natural Gas Marketplace, a conference sponsored by the Center for Regulatory Studies, Illinois State University. Chicago, Illinois, October 1990.

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Thompson, Philip B., presenter, "The Spatial and Temporal Distribution of Risks Associated with Low-Level Radioactive Waste Disposal," Western Economics Association, San Francisco, California, July, 1981.

OTHER SCHOLARLY PRESENTATIONS

Thompson, Philip B., presenter, "An Economic Analysis of U.S. Policy for Low-Level Radioactive Waste Management," UMR College of Arts and Sciences Humanities-Social Sciences Lecture Series, April, 1999.

TESTIMONY

Missouri General Assembly, Joint Interim Committee on Telecommunications and Energy Sources, testimony on behalf of the University of Missouri containing comments on the Public Service Commission Task Force Report on Retail Electric Competition, September, 1998.

Missouri Public Service Commission: Written testimony in over sixty docketed cases before the MPSC between 1984 and 1996, and oral cross examination on that testimony in approximately half of those cases.

TESTIMONY (continued)

Missouri Senate, Commerce and Consumer Protection Committee, testimony regarding changes in Missouri law relating to telecommunications, March 1992.

DISSERTATION AND THESIS COMMITTEES

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Lu, Chaoyuan, Ph. D. in Engineering Management, Colin O. Benjamin, Committee Chair. *Managing Risk and Uncertainty on Research and Development Projects*. 1995-6 .

Almasqué-Cain, Judith, M.S. in Electrical Engineering, E. Keith Stanek, Committee Chair. *Developing a Compliance Plan for a Coal-Fired Utility Under "The 1990 Clean Air Act"*, 1994-5.

SCHOLARLY AWARDS

Honorable Mention (second place), Conference prize competition, Eighth National Association of Regulatory Utility Commissioners Biennial Regulatory Information Conference, National Regulatory Research Institute, The Ohio State University, Columbus, Ohio, 1992.

SERVICE ACTIVITIES

Department Representative, various College of Arts and Sciences committees, University of Missouri-Rolla, 1995-present .

Advisor for Undergraduate Economics Majors, University of Missouri-Rolla, 1995- present.

Member, University Advisory Board, University of Missouri and Network Resources, Inc., Richard L. Wallace, Project Director and Vice President for Academic Affairs, *Study of Missouri's Telecommunications Infrastructure Development*, 1994.

PROFESSIONAL SOCIETY MEMBERSHIPS

American Economics Association

Midwest Economics Association

Association of Environmental and Resource Economists
Western Economic Association International
International Association for Energy Economics
Missouri Valley Economic Association
Industrial Organization Society

REFERENCES

Available on Request

The Relationship Between Household Income and Natural Gas Consumption in Missouri Gas Energy's Service Territory: A Report to MGE

Philip B. Thompson, Ph.D., Principal, RTAssociates, Mt. Pleasant, MI

I. Introduction

An important consideration in deciding how to apportion a given total dollar increase in residential rates between the fixed monthly customer charge and the volumetric rate is how the apportionment will affect customers at various income levels. Raising the volumetric rate by a larger percentage than the customer charge has a larger impact on above-average users than on those whose usage is below the average. The impact on customers in different income groups therefore depends on the relationship between household income and natural gas consumption.

There are two distinct theoretical possibilities regarding this relationship. The first is that natural gas usage is positively related to income: as household income rises, so does gas consumption, as households add more gas-using appliances such as gas hearths and swimming pool heaters. Alternatively, consumption may increase as income decreases below a certain level because of the tendency for lower income families to live in older homes that are less well insulated and that have less efficient heating equipment. In addition, families at the low end of the income spectrum are more likely to live in rental housing, which yields fewer incentives for efficiency. Landlords are less likely to invest in energy efficiency measures such as efficient furnaces and windows and doors because they typically do not pay tenants' utility bills. Renters are less likely than homeowners to invest in such measures because their tenure in a given housing unit tends to be shorter than the payback period for those investments. Even low-income homeowners may find it difficult to afford the up-front costs associated with efficiency investments and unable to find lenders willing to help.

A third possibility is a combination of the two. At lower income levels consumption decreases as income rises because households' ability to pay for efficiency retrofits and to afford newer, better-insulated housing rises. At some income level usage reaches a minimum and then begins to increase as more appliances are added and as families come to afford higher levels of comfort. This possible outcome is depicted graphically as a "U"-shaped curve, with income on the horizontal axis and usage per month on the vertical. As will be discussed in greater detail below, this study finds that the income-consumption relationship for Missouri Gas Energy's (MGE's) service territory is of this third type.

The purpose of this report is to present the results of a study I performed to investigate the income-consumption relationship in MGE's service territory. In the next section I provide a general overview of the results, and the third section consists of a discussion of the more technical aspects of the study. The report ends with a summary and conclusions.

II. General Overview of Models and Results

There are two basic parts to this study, both of which are based on the same data. In the portion I refer to as the annual study, the basic units of observation are the zip codes in MGE's service area. MGE provided me with monthly total usage figures for its residential customers in each zip code it serves, for the entire 24-month (October 1998 through September 2000) period of the study. These data are used as presented for the second ("monthly") part of the study, but for the annual part the 24 months of usage data within each zip code are summed. The summed usage data, measured in Ccf (hundred cubic feet, the volumetric unit of measurement employed by MGE in metering and billing its residential customers), are then divided by the sum of the bills issued in each zip code over the period to obtain a usage per bill figure for each zip code. This average usage per bill, which I call CCF, is used as the dependent variable in the annual regression models. (Variable names as used in the regression analysis appear in all capital letters throughout this report.)

The independent variables discussed below in connection with either the annual or monthly model groups were selected initially because of their theoretical roles as determinants of residential gas consumption. Several other variables were used in some trial models but are not discussed because they turned out not to be significant determinants of gas usage, or because some other, similar variable performs just a bit better in the models. For example, the number of persons per household was used instead of the average number of rooms as representing the "size" of a home, and while the former did help explain gas usage, it did not do so as well as the latter. Similarly, the proportion of homes built before a particular year was used in place of median home age, but the latter appeared to work a little better. The proportion of homes occupied by the owner did not seem to explain gas usage in the annual models as well as in the monthly models. These similarities in performance between two related variables are largely due to similar patterns of variation (in the statistical sense) across zip codes. The remaining discussions are largely confined to those model specifications that performed better, but in many cases the improvement in model performance offered by a particular independent variable were modest.

Returning to the annual model, the independent variable HDD, or heating degree-days, is derived in a manner slightly similar to CCF. That is, monthly HDD are calculated for each month and zip code, using a bill-cycle weighting process described in the technical section below, and then are summed across months to get the total HDD over the period. It is reasonable to expect the regression coefficient on HDD to be positive—colder weather (higher HDD) leads to increased gas consumption.

Other independent variables used in the annual models are taken from or calculated using 1990 U.S. Census of Population data. The variable AGEMED is the median age of housing units in a zip code, and is calculated by subtracting the census data's "Median Year Built" from 1999. Median age of housing is used as a proxy variable for the energy efficiency of homes (degree of insulation, quality of windows, efficiency of heating equipment, etc.). Theory predicts that the regression coefficient on AGEMED will be positive—that older homes consume more gas, all else equal. The independent variable RMAVG is the average number of rooms in a zip code's housing units and is a proxy for home size. The coefficient on this variable is also expected to be positive, because heating larger homes requires more gas.

Another factor that would tend to affect gas usage is whether someone is at home during normal working hours. Many homes are kept at lower temperatures when nobody is home for several hours. The variable PCTNOWRK is the proportion of persons aged 16 and over who did not work in 1989, and is a proxy for the proportion of households in which someone is at home during the day. The regression coefficient on this variable is expected to be positive since it is unlikely that the thermostat in such a home would be lowered during the day.

The income variable used is mean household income for a zip code. The census data reports 1989 data. To adjust these figures to 1999 income levels, the 1989 data is multiplied by 1.544, which is the ratio of per capita personal income in 1999 to that for 1989 for the state of Missouri. The adjusted variable is denoted MNHSY99 (mean household income in 1999). To test for the existence of a "U"-shaped income-consumption relationship, the square of this variable, denoted MNHSY992, is also included. If the relationship is in fact "U"-shaped, adding the square of income will improve the performance of a model, measured by its R^2 coefficient. In addition, the coefficient on the squared income variable will be positive and statistically significant, and the coefficient on income variable will be negative and statistically significant.

The impacts of two interaction variables are also examined in two of the annual models. The first is AGEINCMN, the product of AGEMED and MNHSY99. The sign of the coefficient on AGEINCMN will be negative if higher household income dampens the effect of older housing on consumption. The logic is that higher income gives a homeowner a greater financial ability to invest in energy efficiency measures such as a more efficient furnace, new windows, and the retrofitting of insulation. The second interactive variable is AGEOWN, which is the product of AGEMED and PCTOWNOC, or the proportion of homes in a zip code that are owner occupied. The coefficient on AGEOWN will be negative if home ownership dampens the effect of older housing on gas usage, which would be the case if home ownership provides a greater incentive for investment in energy efficiency measures.

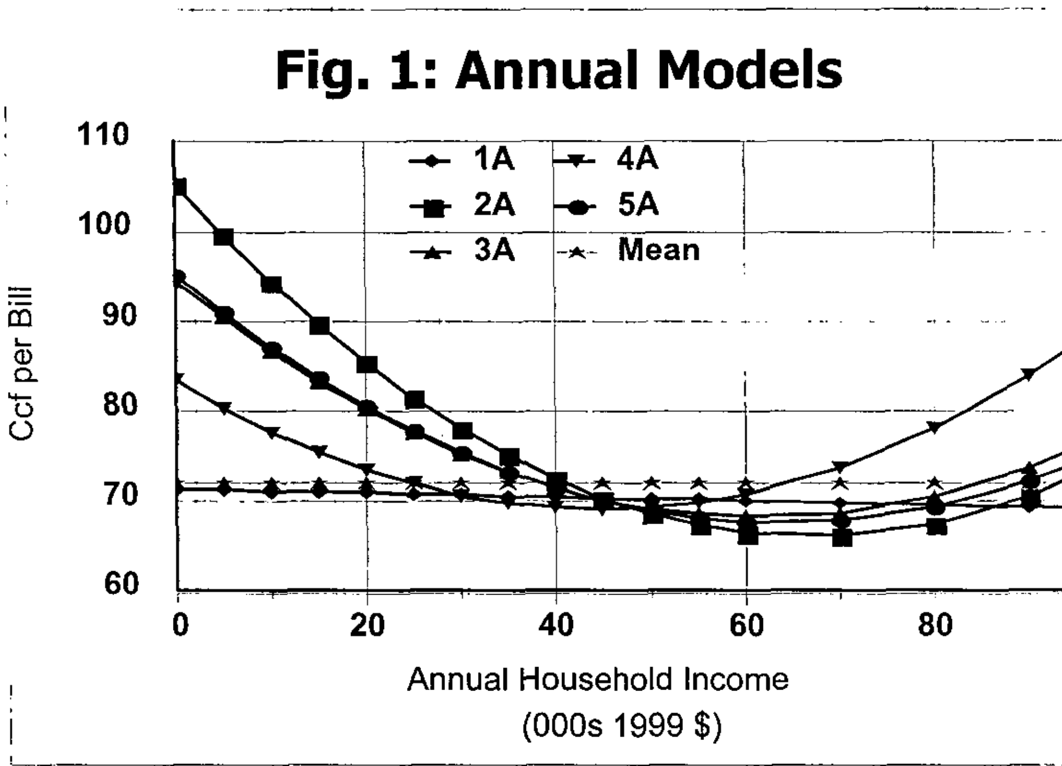
Estimation of the annual models employs a technique known as weighted ordinary least squares. The results of the models that generally perform the best are presented in Table 1. In each model the dependent variable is CCF. Each model is designated with a number along with the letter A to signify the annual set of models. More complete information about each model, including t-statistics, is presented in the next section. If a cell in the table is blank, the corresponding independent variable was not used in that model. A graph of the income-consumption relationships shown in Table 1 appears in Figure 1.

Model 1A is presented to show what happens when no squared income term is included. Although income (MDHSY99) has a negative influence on consumption in that model, its coefficient is not statistically significant (see Section III below for t-statistics). Clearly the addition of the squared income variable MDHSY992 in the other equations 2A-5A improves the fit of the regression to the data. This can be seen from the improvement in the R^2 statistic, which measures how well the model fits the data; R^2 must lie between 0 and 1, and a higher value indicates a better fit. In addition (see Section III.), both income variables are statistically significant. The conclusion from these annual models is therefore that the income-consumption relationship is indeed U-shaped. This conclusion in turn implies that relatively larger increases in the customer charge will result in lower bills for customers at the lowest income levels than if the volumetric rate were increased by a larger percentage. Table 1 also includes two lines that show 1) the household income level (1999 dollars) at which monthly usage is at a minimum, and 2) the income level at which usage equals the average, and below which usage is above average.

TABLE 1: Regression Results from Annual Models

Dependent variable = CCF (mean = 72.01)	Coefficients on Variables in Model No.:				
Variable Names	1A	2A	3A	4A	5A
HDD	0.0036446	0.005416	0.0055903	0.0049121	0.0053369
AGEMED	0.78212	.52737	0.48646	0.79024	0.62519
RMAVG	11.764	10.279	10.101	9.8508	13.244
MNHSY99	-.000021102	-0.0011627	-0.00084637	-0.00063704	-0.00085643
MNHSY992		8.636×10^{-9}	6.848×10^{-9}	7.148×10^{-9}	6.702×10^{-9}
PCTNOWRK			35.43	34.755	40.805
AGEOWN					-0.28937
AGEINCMN				-5.403×10^{-6}	
CONSTANT	-52.251	-15.906	-35.99	-41.644	-49.946
R^2	0.6665	.7324	.7494	.7575	.7557
Income level at bottom of "U"	N.A.	$67,319	$61,797	$44,559	$63,898
Income level below which usage exceeds the average	N.A.	$41,125	$38,363	$24,599	$38,234

The coefficients listed in Table 1 are interpreted as follows, using model 4A as an example. The coefficient on AGEMED is 0.79024, which implies that a 10-year increase in the age of a housing unit increases gas consumption by approximately 7.9 Ccf per month, or by more than 10% of the average consumption level of 72.01 Ccf per month. Similarly, we see that the coefficient on RMAVG equals roughly 9.85, which means that a house with one more room will use an additional 9.85 Ccf per month, on average, all else held constant. The impacts of other variables can be similarly calculated. See Table 3 in Section III below for a list of the mean values for all variables to get an idea of how large each variable is, and therefore what can be thought of as a reasonable change in its size.



The estimation of the monthly models is carried out using a technique known as pooled cross-section time series analysis. In this instance the "cross-sections" are the zip codes, and "time series" refers to the 24 months of data for each zip code. There are a total of 4,368 (24 months x 182 zip codes) observations. The dependent variable CCF varies both across zip codes and months. HDD varies across months, and because different zip codes are on different (combinations of) bill cycles and are in different geographic regions (3 in total), HDD also varies to some extent across zip codes. The same can be said about the price variables, PRICE (current month's non-gas margin plus gas cost) and PLAG1 (PRICE lagged one month), that are included in the monthly models. Data taken from the U.S. Census (all variables except for CCF, HDD, and the price variables) varies across zip codes but not across months. That is, a given zip code is assigned the same income (or AGEMED, RMAVG, etc.) value for each of the 24 months in the study period. Table 2 below presents the results of five monthly models. Figure 2 at the end of this report graphically depicts the income-consumption relationships for these models.

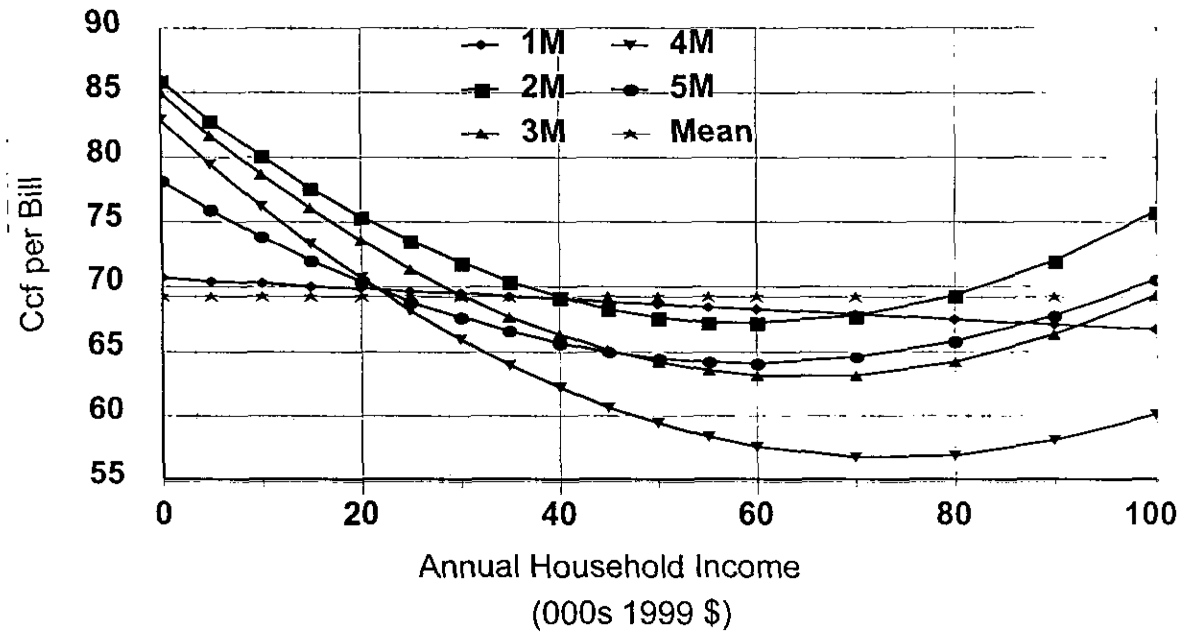
There are several explanatory variables used in the annual models that are also used in the monthly models: HDD, AGEMED, RMAVG, and PCTNOWRK. The variation in consumption within a zip code across months is considerably greater than the variation across zip codes either within a given month, or, with reference to the annual models discussed above, across zip codes for the entire study period. The vast majority of the *monthly* variation in usage is driven by HDD. Indeed, a trial model including only HDD as an explanatory variable performed very well, and adding the other independent variables increased the performance of the models only marginally.

TABLE 2: Regression Results from Monthly Models

Dependent variable = CCF (mean = 69.17)	Coefficients on Variables in Model No.:				
Variable Names	1M	2M	3M	4M	5M
HDD	0.15187	0.15192	0.13962	0.14001	0.13898
AGEMED	0.36739	.34391	0.31452	0.3084	0.30704
RMAVG	6.7431	6.7472	8.1829	8.7361	7.6827
PRICE	-15.364	-16.791	-16.974	-17.228	-16.263
PLAG1	69.302	71.18	71.04	70.694	70.291
MNHSY99	-.00003966	-0.00063042	-0.00067686	-0.00071125	-0.00047284
MNHSY992		5.334 x 10^{-9}	5.206 x 10^{-9}	4.836 x 10^{-9}	3.960 x 10^{-9}
PCTNOWRK			9.4545	9.6659	9.296
PCTOWNOC			-6.1137	-3.657	-2.2335
PCTBACH				14.346	
PCTHPAST					32.556
HDDINCMN			2.490 x 10^{-7}	2.424 x 10^{-7}	2.595 x 10^{-7}
CONSTANT	-58.586	-42.639	-45.126	-49.375	-53.516
R^2	0.9784	.9794	.9790	.9790	.9784
Income level at bottom of "U"	N.A.	$59,683	$65,014	$73,534	$59,704
Income level below which usage exceeds the average	N.A.	$40,154	$30,551	$22,836	$23,909

This does not mean that the other variables are not important determinants of gas usage. Regression analysis allows us to answer the question, "What is the impact of a particular variable, assuming all of the other variables are held constant?" By including HDD in the regression equation, we effectively examine the impacts of the other variables after extracting the impact of weather. Even though variations in these other factors do not cause as much variation in usage per customer as weather over the study period, regression analysis allows us to isolate the separate impacts of the other variables in terms of usage variations across zip codes. Put another way, weather is the most important determinant of month-to-month variations in usage, while the other explanatory variables are important in explaining usage variations across zip codes.

Fig 2: Monthly Models



As was the case in the annual models, the coefficients on weather (HDD), housing age (AGEMED), housing size (RMAVG), and our proxy for occupation of the home during the day (PCTNOWRK) all have the expected signs and are statistically significant. In addition, both the income variables are statistically significant and each has the sign that yields a "U"-shaped income-consumption relationship: negative for MNHSY99 and positive for MNHSY992. The improvement in R^2 resulting from the addition of the squared income variable is not as large as in the annual models, but this is because (as discussed above) weather variations already explain such a large portion of the variation in usage. (Compare the results for Models 1M and 2M.)

An explanatory variable that was not statistically significant by itself in the annual regressions but becomes so in the monthly models is PCTOWNOC, the proportion of homes occupied by the owner. The coefficient on this variable is negative, which is consistent with the notion that homeowners are more likely than renters to invest in energy efficiency measures. The interaction variable HDDINCMN, which is the product of HDD and MNHSY99, has a negative and statistically significant impact on usage, implying that weather has a smaller (but still positive) effect on consumption at higher income levels, *holding housing age and size constant.* This is supportive of the idea that higher income households tend to invest more in efficiency measures, so that colder weather causes a smaller increase in usage for such households than for low income households.

The results regarding the impact of price (PRICE and PLAG1) is more difficult to explain. When included as the current month price only (PRICE), the price variable has a positive and statistically significant coefficient. It becomes negative when the lagged price

(PLAG1) is added, but PLAG1 has a positive coefficient. While this is somewhat troubling from the standpoint of pure microeconomic theory--both price variables should have a negative coefficient—the rather unique case of utility pricing in which consumers are rarely aware of the marginal price of an additional unit of consumption helps explain it. Indeed, while consumers should reasonably be expected to be are aware that they use more gas in cold weather, they generally cannot determine *how much* more until they receive a bill, by which time they are already halfway into the next billing month. In addition, increases in price (which more frequently result from gas cost increases rather than margin rate increases) tend to occur during colder weather periods. Furthermore, the short run demand for gas is relatively unresponsive to price. A model (not shown here) that does not include price performs nearly as well as those that do, and the "U"-shaped income-consumption relationship remains clear whatever combination of price variables is used.

An additional monthly model investigated included the variable PCTBACH, which is the proportion of persons over 25 years old in a zip code who have at least a bachelor's degree. I expected the coefficient on this variable to be negative, reasoning that more educated people would have a better understanding of energy efficiency principles and would therefore have lower usage, all else equal. But the result was a positive relationship. This result is somewhat puzzling, but could perhaps be explained by the possibility that better educated people may own more gas operated appliances, such as gas hearths or swimming pool heaters, even when income is held constant. The addition of this explanatory variable does not change the general "U"-shape of the income-consumption relationship, although it does result in the highest "bottom of the 'U'" income level of all the models and the lowest income level at which consumption crosses from above average to below average as income increases. The inclusion of PCTBACH also makes the coefficient on PCTOWNOC statistically insignificant.

A variable equal to the proportion of households that received some form of public assistance income, PCTHPAST, was included in the final model shown in place of PCTBACH. It did have a positive effect, which is the expectation if one subscribes to the theory that households that receive public assistance income live in less energy efficient housing. The inclusion of this variable did not, however, have a large impact on any of the other coefficients.

What conclusions can be reached from the annual and monthly models? First, that the income-consumption relationship in MGE's service territory is indeed "U"-shaped, and that proportionally larger increases in the fixed customer charge are *not* regressive. Second, as would be expected, older, larger homes use more gas than newer, smaller ones. Third, the presence of non-working adults in a household tends to increase gas consumption, and the characteristic of home ownership tends to reduce it. And fourth, higher income levels mitigate, if only slightly, the impact of weather on consumption, perhaps because higher income households have a greater financial ability to invest in energy efficiency measures.

III. Technical Details: Variable Calculations and Regression Techniques

This section describes the data used and provides additional discussion of the regression analyses. An initial issue was determining the zip codes to include in the analysis. MGE provided me with a list of 226 zip codes. Forty-four of these could be eliminated because either 1) usage in the zip was either 0 in all 24 months or fewer than 24 months of data were available; or 2) they are new since the 1990 census. In some cases I determined that a new zip code was formerly part of a 1990 zip code; in those cases the sum of usage, etc., in the "new" and "old" zip codes was then associated with the "old" zip code data from the census files. The eliminated zip codes accounted for less than 2% of MGE volume sales over the study period. After eliminating these 44, there were 182 zip codes remaining.

Table 3 lists the names of variables used in the study, their respective mean values, and a brief definition of each. Some are discussed at greater length following the table. Note that all data with monthly values (CCF, HDD, PRICE, PLAG1, HDDINCMN) covers the period October 1998 through September 2000. If two numbers appear under "Mean," the first is for the annual models, and the second is for the monthly models. Some variables are used in both sets of models, while others are used in just one (annual or monthly); see Tables 1 and 2 for a list of which variables were used in each model.

Table 3: Variable Means and Definitions

Name	Mean	Description
CCF	72.01/69.17	Usage per bill, MGE residential class
HDD	8382.1/349.25	Bill-cycle weighted heating degree-days, 65° basis
AGEMED	35.797	Median age of housing in zip, 1999
RMAVG	5.53	Mean number of rooms per housing unit
PRICE	0.48784	MGE's residential non-gas margin plus volumetric gas rate
PLAG1	0.4792	PRICE, lagged on period
MNHSY99	48,581	1989 mean household income, adjusted to 1999 dollars
MNHSY992	2.5822×10^9	MNHSY99 x MNHSY99
PCTNOWRK	0.28936	Proportion of persons over 15 who did not work in previous year
PCTOWNOC	0.71676	Proportion of housing units that are owner-occupied
PCTBACH	0.17939	Proportion of persons over 24 who have at least a bachelor's degree
PCTHPAST	0.060852	Proportion of households with public assistance income
AGEOWN	25.114	AGE x PCTOWNOC
AGEINCMN	1.6663×10^6	AGE x MNHSY99
HDDINCMN	4.1219×10^8/ 1.7175×10^7	HDD x MNHSY99

Values for CCF were computed from data provided by MGE on total volumes recorded by month and zip code and the corresponding number of bills. For annual data, the mean shown is the 24 month total of usage divided by the 24 month total bills. For monthly data, that same calculation is carried out using individual CCFs for each month, and the mean is the sum of these monthly figures divided by 4,368, the number of observations. The difference is simply the result of using a weighted regression approach for the annual models.

Values for HDD were calculated in a standard way. First, HDD for each month, billing cycle, and weather region in MGE's service territory were calculated. This yielded 1,512 HDD values (24 months x 21 billing cycles x 3 weather stations–Kansas City, Joplin, and St. Joseph). This calculation involved summing the daily HDD figures across the days in a month/billing cycle/weather region. Then, if a given zip code had only one bill cycle, the simple sum was used. But if a zip code had multiple billing cycles, the monthly HDD figure for that zip code is a weighted sum of the bill cycle HDD, with the weights equal to the proportion of total monthly volumes for a zip code recorded for each bill cycle.

AGEMED and RMAVG were calculated from the Census data. AGEMED is equal to 1999 minus the median year built as recorded in the census data. RMAVG is the total number of rooms in the zip code divided by the number of housing units.

The price variables were calculated in a manner similar to HDD and were based on the prices (residential non-gas margin plus volumetric gas price) in effect for MGE on each day of the study period. PLAG1 is simply PRICE lagged one month.

The remaining variables were calculated as described in Table 3.

A note on the income data is warranted. The 1990 Census reports household income for 1989. In order to convert these figures to 1999 levels, I multiplied the 1989 values by 1.544, which is the ratio of 1999 per capita personal income for Missouri to the same figure for 1989. Per capita income data for Missouri for 1989 and 1999 are taken from the web site of the Bureau of Economic Analysis of the U.S. Department of Commerce, http://www.bea.doc.gov/bea/regional/spi/action.cfm.

The regressions were done using SHAZAM version 7.0. The annual regressions used SHAZAM ordinary least squares "weight" option, with the weights being the number of bills in each zip code. The monthly regressions used SHAZAM's "pool" command. This approach assumes that the error terms are cross-sectionally heteroskedastic and time-wise autorgressive (i.e., serially correlated), but that the errors for different cross sections are independent.

The regression results and some calculations based thereon are presented below in Table 4 (annual models) and Table 5 (monthly models) below. The additional calculations include usage at various income levels based on a particular model and on the overall means of all other variables, and a similar set of calculations based on the means of values for only the lowest income quintile. Also appearing are the calculations of income elasticities at various income levels (based on the overall means of all other variables). Finally, for those models including the squared income term, the value of income at the minimum of the "U" is also shown.

Table 4: Annual Model Results (t-statistics in italics below coefficients)

VARIABLE	ESTIMATED COEFFICIENTS				
NAME					
MODEL NO.	1A	2A	3A	4A	5A
HDD	0.0036446	0.005416	0.0055903	0.0049121	0.0053369
	4.30	*6.74*	*7.17*	*6.07*	*6.87*
AGEMED	0.78212	0.52737	0.48646	0.79024	0.62519
	15.13	*8.79*	*8.22*	*6.10*	*7.53*
RMAVG	11.764	10.279	10.101	9.8508	13.244
	7.70	*7.41*	*7.52*	*7.44*	*7.04*
MNHSY99	-2.1102E-005	-1.1627E-003	-8.4637E-004	-6.3704E-004	-8.5643E-004
	-0.37	*-6.52*	*-4.37*	*-3.08*	*-4.48*
MNHSY992		8.6357E-009	6.8480E-009	7.1482E-009	6.7015E-009
		6.68	*5.09*	*5.38*	*5.04*
PCTNOWRK			35.43	34.755	40.805
			3.59	*3.58*	*4.08*
AGEOWN					-0.28937
					-2.35
AGEINCMN				-5.4026E-006	
				-2.62	
CONSTANT	-52.251	-15.906	-35.99	-41.644	-49.946
	-5.17	*-1.51*	*-3.09*	*-3.57*	*-3.86*
ADJUSTED R-SQ.	0.6665	0.7324	0.7494	0.7575	0.7557
F	4138	4306	3942	3566	3539
Income at minimumCcf		67,319	61,797	44,559	63,898

1 Table 4, continued

MODEL NO.	1A	2A	3A	4A	5A
Income elasticity@					
$5,000	-0.001	-0.054	-0.043	-0.047	-0.043
10,000	-0.003	-0.105	-0.082	-0.088	-0.083
15,000	-0.004	-0.151	-0.115	-0.123	-0.118
20,000	-0.006	-0.191	-0.143	-0.148	-0.146
25,000	-0.007	-0.224	-0.163	-0.164	-0.168
30,000	-0.009	-0.248	-0.174	-0.170	-0.181
35,000	-0.010	-0.260	-0.176	-0.165	-0.185
40,000	-0.012	-0.260	-0.167	-0.149	-0.179
45,000	-0.013	-0.246	-0.148	-0.122	-0.163
50,000	-0.015	-0.218	-0.117	-0.083	-0.135
55,000	-0.017	-0.174	-0.075	-0.035	-0.096
60,000	-0.018	-0.114	-0.022	0.023	-0.046
70,000	-0.021	0.049	0.114	0.162	0.084
80,000	-0.024	0.260	0.283	0.321	0.249
90,000	-0.027	0.500	0.472	0.489	0.436
100,000	-0.030	0.750	0.669	0.658	0.634
Predicted consumption (ccf per month per customer) at various income levels, calculated at the overall means of other variables:					
MODEL NO.	1A	2A	3A	4A	5A
$0	71.360	105.221	94.401	83.355	94.958
5,000	71.255	99.623	90.340	80.349	90.844
10,000	71.149	94.457	86.622	77.700	87.064
15,000	71.044	89.723	83.246	75.408	83.620
20,000	70.938	85.421	80.213	73.474	80.510
25,000	70.833	81.551	77.522	71.897	77.736
30,000	70.727	78.112	75.173	70.677	75.297
35,000	70.622	75.105	73.167	69.815	73.193
40,000	70.516	72.530	71.503	69.311	71.424
45,000	70.411	70.387	70.181	69.163	69.990
50,000	70.305	68.675	69.202	69.374	68.891
55,000	70.200	67.395	68.566	69.941	68.127
60,000	70.094	66.547	68.271	70.866	67.698
70,000	69.883	66.147	68.710	73.788	67.846
80,000	69.672	67.473	70.518	78.140	69.334
90,000	69.461	70.527	73.696	83.922	72.162
100,000	69.250	75.308	78.244	91.133	76.330

Table 4, continued

Predicted consumption at various income levels, calculated at the means of other variables, lowest income quintile only:					
MODEL NO.	1A	2A	3A	4A	5A
$5,000	68.980	95.274	88.597	82.350	88.554
10,000	68.875	90.108	84.879	79.701	84.775
15,000	68.769	85.374	81.503	77.409	81.330
20,000	68.664	81.071	78.469	75.475	78.221
25,000	68.558	77.201	75.778	73.898	75.447
30,000	68.453	73.762	73.430	72.678	73.007
33,835	68.372	71.417	71.860	71.985	71.364
40,000	68.242	68.180	69.760	71.312	69.134
45,000	68.136	66.037	68.438	71.165	67.700

As can be seen from the table, all coefficients with the exception of that on income in Model 1A, and the constant term in 2A, are statistically significant and of the expected sign. Also note that when usage is predicted by income level using the means of variables for the lowest income quintile (as compared to the overall means of variables), predicted usage is slightly lower. Given the difference in performance between Model 1A and all other annual models, it is clear that the income-consumption relationship is "U"-shaped. That is, the R^2 value improves and the coefficients on MNHSY99 and MNHSY992 are statistically significant and of the required sign to yield the "U"-shaped income-consumption relationship.

Table 5: Monthly Model Results (t-statistics in italics below coefficients)

VARIABLE	ESTIMATED COEFFICIENTS				
NAME	*(t-statistics in italics)*				
MODEL NO.	1M	2M	3M	4M	5M
HDD	0.15187	0.15192	0.13962	0.14001	0.13898
	390.60	*399.70*	*101.30*	*101.30*	*99.29*
AGEMED	0.36739	0.34391	0.31452	0.3084	0.30704
	16.08	*15.61*	*12.50*	*12.23*	*11.94*
RMAVG	6.7431	6.7472	8.1829	8.7361	7.6827
	8.01	*8.41*	*8.53*	*9.09*	*8.13*
PRICE	-15.3640	-16.7910	-16.974	-17.228	-16.263
	-5.06	*-5.56*	*-5.56*	*-5.65*	*-5.32*
PLAG1	69.302	71.18	71.04	70.694	70.291
	14.81	*15.28*	*15.09*	*15.01*	*14.89*
MNHSY99	-3.966E-005	-6.3042E-004	-6.7686E-004	-7.1125E-004	-4.7284E-004
	-1.47	*-6.35*	*-6.82*	*-6.74*	*-4.28*
MNHSY992		5.2814E-009	5.2055E-009	4.8362E-009	3.9599E-009
		5.66	*6.71*	*6.00*	*4.71*
PCTNOWRK			9.4545	9.6659	9.296
			2.06	*1.92*	*2.06*
PCTOWNOC			-6.1137	-3.657	-2.2335
			-2.27	*-1.25*	*-0.80*
PCTBACH				14.346	
				3.62	
PCTHPAST					32.556
					3.60
HDDINCMN			2.4903E-007	2.4243E-007	2.5947E-007
			8.95	*8.67*	*9.20*
CONSTANT	-58.586	-42.639	-45.126	-49.375	-53.516
	-13.01	*-8.82*	*-7.99*	*-8.49*	*-9.04*
BUSE R-SQ.	0.9784	0.9794	0.979	0.979	0.9784
F	47072	45420	32338	29813	28136
Income at minimum CCF		$59,683	$65,014	$73,534	$59,704

Table 5 (continued)

	Predicted consumption (ccf per month per customer) at various income levels, calculated at the overall means of other variables:				
MODEL NO.	1M	2M	3M	4M	5M
$0	70.638	85.966	84.987	82.887	78.208
$5,000	70.440	82.945	81.733	79.452	75.943
$10,000	70.241	80.189	78.739	76.258	73.876
$15,000	70.043	77.698	76.006	73.306	72.007
$20,000	69.845	75.470	73.532	70.596	70.336
$25,000	69.646	73.506	71.319	68.128	68.862
$30,000	69.448	71.806	69.366	65.902	67.587
$35,000	69.250	70.371	67.674	63.918	66.510
$40,000	69.051	69.199	66.242	62.175	65.631
$45,000	68.853	68.291	65.070	60.674	64.949
$50,000	68.655	67.648	64.158	59.415	64.466
$55,000	68.457	67.269	63.507	58.398	64.181
$60,000	68.258	67.153	63.115	57.622	64.094
$70,000	67.862	67.715	63.114	56.797	64.513
$80,000	67.465	69.333	64.154	56.939	65.725
$90,000	67.068	72.007	66.234	58.048	67.728
$100,000	66.672	75.738	69.356	60.124	70.523

MODEL NO.	1M	2M	3M	4M	5M
Income elasticity@					
$5,000	-0.003	-0.035	-0.033	-0.036	-0.023
$10,000	-0.006	-0.065	-0.062	-0.069	-0.041
$15,000	-0.008	-0.091	-0.086	-0.099	-0.055
$20,000	-0.011	-0.111	-0.104	-0.123	-0.064
$25,000	-0.014	-0.125	-0.116	-0.141	-0.067
$30,000	-0.017	-0.131	-0.120	-0.153	-0.064
$35,000	-0.020	-0.130	-0.117	-0.158	-0.055
$40,000	-0.023	-0.120	-0.105	-0.154	-0.040
$45,000	-0.026	-0.102	-0.084	-0.142	-0.018
$50,000	-0.029	-0.076	-0.054	-0.120	0.011
$55,000	-0.032	-0.040	-0.015	-0.089	0.046
$60,000	-0.035	0.003	0.033	-0.048	0.087
$70,000	-0.041	0.113	0.154	0.062	0.187
$80,000	-0.047	0.248	0.303	0.207	0.306
$90,000	-0.053	0.400	0.472	0.378	0.439
$100,000	-0.059	0.562	0.651	0.567	0.581

Table 5 (continued)

	Predicted consumption (ccf per month per customer) at various income levels, calculated at the means of other variables for the lowest mean income quintile				
MODEL NO.	1M	2M	3M	4M	5M
$5,000	65.774	78.154	76.274	73.104	71.829
$10,000	65.575	75.398	73.281	69.911	69.761
$15,000	65.377	72.906	70.547	66.959	67.892
$20,000	65.179	70.678	68.074	64.249	66.221
$25,000	64.981	68.714	65.861	61.781	64.748
$30,000	64.782	67.014	63.908	59.555	63.472
$35,000	64.584	65.579	62.215	57.570	62.395
$40,000	64.386	64.407	60.783	55.827	61.516
$45,000	64.187	63.500	59.611	54.327	60.835

As can be seen from Table 5, all coefficients with the exception of that on income in Model 1M, and on PCTOWNOC 4M and 5M, are statistically significant and generally of the expected sign. See section II above for a discussion of these coefficients. Also note that when usage is predicted by income level using the means of variables for the lowest income quintile (as compared to the overall means of variables), predicted usage is slightly lower. Given the difference in performance between Model 1M and all other monthly models, it is clear that the income-consumption relationship is "U"-shaped. That is, the R^2 value improves slightly (except for 5M) and the coefficients on MNHSY99 and MNHSY992 are statistically significant and of the required sign to yield the "U"-shaped income-consumption relationship.

IV. Summary and Conclusions

This study has used two approaches (cross section and pooled cross section-time series) to investigate the relationship between usage and a number of independent explanatory variables. Regression coefficients with few exceptions are statistically significant and of the correct (i.e., predicted or expected) sign. Most important, there is no evidence that usage and household income are positively related through all levels of income. Rather, the relationship between usage and income has a "U"-shape. At lower income levels, usage increases as income falls, and at the lowest income levels is greater than the overall average usage. The relationship becomes positive at higher income levels—beyond some income level, usage increases with income. The implication for ratemaking is that larger proportional increases in the fixed monthly customer charge are not regressive. That is, increases in the customer charge do not harm low income users disproportionately. In fact, effecting a residential rate increase by disproportionately increasing the volumetric charge would have a greater harmful impact on such customers.