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THE CONCORD WATER SURVEY

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TECHNICAL COMPLETION REPORT

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ABSTRACT

The city of Concord, New Hampshire, experienced a serious water shortage in 1980-81. An energetic conservation campaign was evidently successful, as city-wide use declined by some fifteen percent during the shortage. This study uses data from a mailed survey questionnaire, combined with information from Water Department billing records, to examine the predictors of water conservation in a random sample of 431 Concord households.

The most important single predictor of household conservation is baseline, pre-shortage water use. The greater the pre-shortage use, the greater the use reduction, in both absolute and in percentage terms. This effect remains strong even with more than twenty other variables in the model. The most important steps taken to conserve water are indoors, behavioral changes such as less flushing of toilets, shorter showers, shallower baths, etc. Reductions in outdoors water use were almost universally claimed by these households, so this variable cannot account for within-sample variations in conservation. The indoors, behavioral changes are most closely related to idealistic, rather than economic, motives for saving water. Idealistic motives are highest among younger, more affluent, and better-educated households. Economic motives, in contrast, are higher among less affluent and educated households, with larger numbers of children. People citing economic motives may actually have conserved less water than others.

This study represents the first attempt to construct a full causal model for household water conservation. The findings have implications both for water-conservation program design, and for the direction of possible future research.

ACKNOWLEDGEMENTS

Some of the pilot work for this project has been described in "Response to Water Conservation Campaigns: An Exploratory Look," in Evaluation Review (October, 1982). That paper was also presented at the 1982 meetings of the American Sociological Association. Two other papers based on this work have been submitted for publication: "Self-Reported and Actual Savings in a Water Conservation Campaign," and "Saving Water: A Causal Model of Household Conservation." The latter will be presented at the 1983 meetings of the American Sociological Association as well. In addition, a fourth paper, summarizing the policy implications of findings in the Concord Water Survey, is presently being prepared.

Support for this study was provided by the Department of Interior, Office of Water Research and Technology grant A-061-NH, administered by Gordon L. Byers, Chairman, Water Resource Research Center, University of New Hampshire.

John Forrestall, Director of the Concord Water Department, was extremely helpful in providing information about the shortage and conservation campaign, access to Water Department records, and a press release and cover letter which contributed to the survey's high response rate. Larry Labelle aided in setting up the computerized mailing system for the survey. Assistance with data collection, coding, and analysis was provided by Leslie Hamilton, Kim Vogt, Dan Santoro, and Susan Frankel. I am also grateful to Gordon Byers, who encouraged this work in its early stages, and to Gayle Dorsey, who typed the final manuscript and tables.

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I. THE CONCORD WATER SHORTAGE

Concord is a city of 30,400, located on the Merrimack River in south-central New Hampshire. Population growth has been slow in recent years, up only 1.3 percent from 1970 to 1980. Despite the nearly stable population, water use increased substantially over this same period. This increasing demand, coupled with a period of low rainfall beginning in 1979, brought about a serious crisis of water supply. In the face of this crisis, city officials mounted a strenuous campaign to persuade citizens to use less water. This campaign was evidently successful, as water use subsequently dropped by some fifteen percent, and has still not regained its pre-crisis level. This report describes an investigation into just how and why such conservation occurred, focussing on the level of the individual household.

A Chronology

The history of Concord's water consumption is shown graphically in Figure 1, which plots monthly water use in millions of gallons for the period 1975-1981. The trend from the early part of the decade onward was one of fairly steady, year-by-year increases. This is most evident in the upper plot of Figure 1, where the data have been "smoothed" by an iterative nonlinear method which removes much of the jaggedness of random fluctuations. (The method, called "4253H, twice", is described in an article by Velleman, 1982.) The trend of gradual yearly increases was dramatically reversed in late 1979, as shown in Figure 1.

In October of 1979, a rate increase went into effect (indicated by a vertical line in Figure 1) to raise money for capital improvements. It was not particularly intended to save water as there was no evident crisis at that time. Subsequently, it was seen that due to low rainfall,

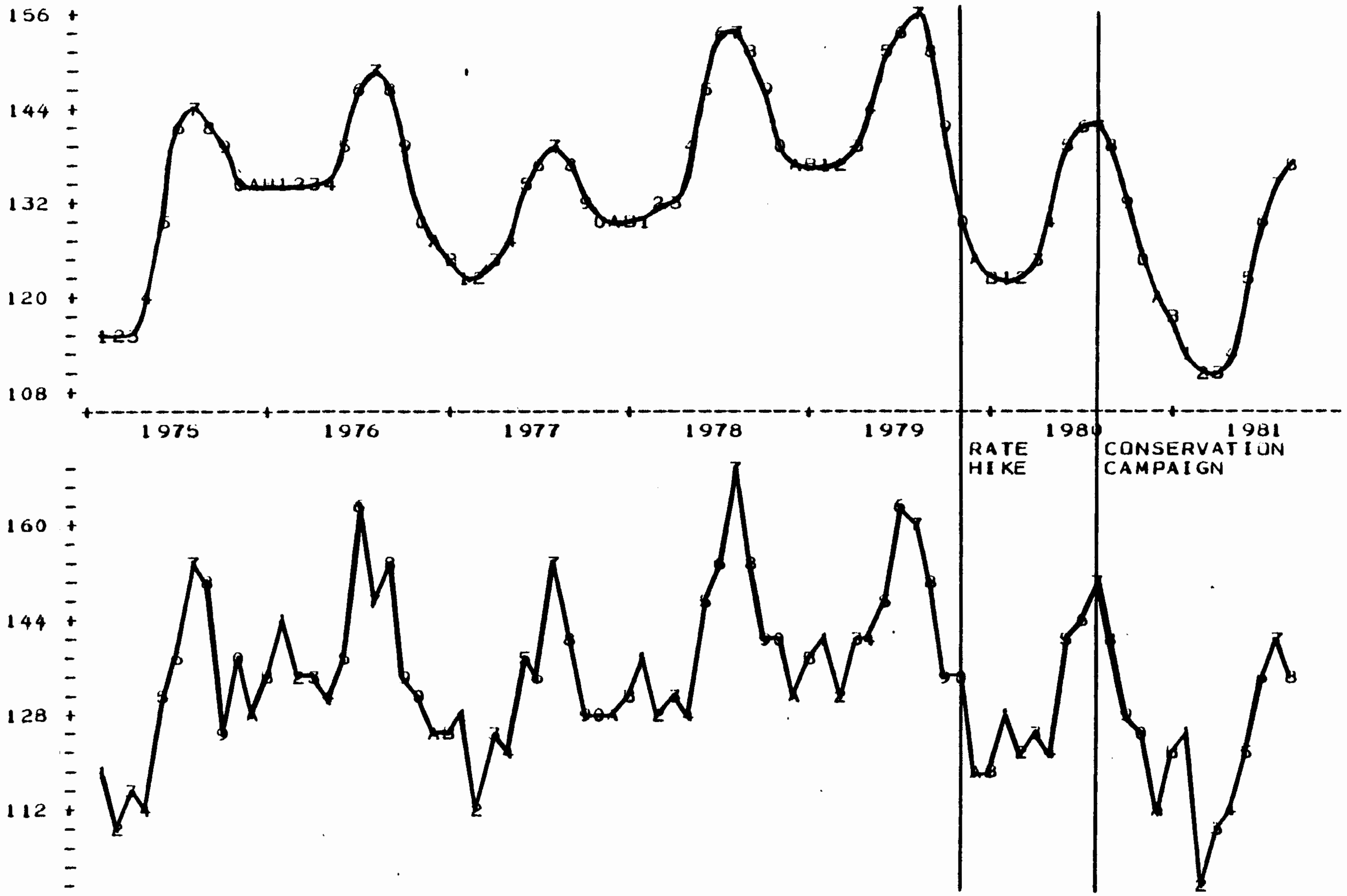

FIGURE 1: MONTHLY WATER USE FOR CONCORD, NEW HAMPSHIRE, 1975-1981, IN MILLIONS OF GALLONS. RAW DATA (BOTTOM), AND DATA SMOOTHED BY 4253H, TWICE (TOP; SEE TEXT FOR DESCRIPTION OF THIS METHOD). TIMING OF RATE HIKE (10/79) AND CONSERVATION CAMPAIGN (7/80) ARE SHOWN.

the level of the lake supplying Concord's water was dropping. The Concord Water Department began to request consumers to voluntarily conserve water and in late July 1980 the local news media were hit with stories describing the seriousness of the problems. This event is also marked by a vertical line in Figure 1.

In late November of 1980, rainfall had still not materialized and conservation publicity was intensified. This publicity included newspapers, radio talk shows, and educational efforts in the public schools. Quizzes and materials for "environmental education" classes were prepared for schoolchildren, who were also taught about how to inspect for leaks and how to spot family members who were inadvertently wasting water. Children were given booklets and posters to take home and stick on refrigerators, etc. All levels of the Concord public schools were involved in these efforts.

In April 1981, mandatory restrictions on outdoor water use were put into effect. These were removed on May 28th, so were not in effect during the peak summer months. Flyers describing the shortage were also sent out for posting in hotel rooms. The local newspaper printed a number of pictures showing the low water level in Long Pond, the city's main water source. Many residents saw the evidence for themselves, as they drove past the reservoir.

By late fall 1981, the shortage had eased due to a combination of the conservation efforts and supply expansion. The new supply arrangements removed the threat of imminent water shortage, but did so at considerable economic and environmental cost. For these reasons both the Concord Water Department and its customers have incentives to continue their conservation efforts.

In the wake of the 1979 rate hike and the 1980-81 conservation campaign, there was a noticeable drop in water demand. This drop could not be attributed to the weather, which was drier than normal during this period; indeed, the dryness was a major cause of the shortage in the first place (see Hamilton, 1982, for actual time plots of precipitation over this period). It is therefore reasonable to attribute it to the rate hike and/or the conservation program. But given the variety and timing of these events, it is impossible to use aggregate data such as those in Figure 1 to evaluate which aspects of the conservation program were most and least effective, or for which residents, or to assess the relative impacts of economic (rate hike) and idealistic (voluntary conservation appeals) motives. It is also impossible to judge just how water was conserved; what steps were followed, what conveniences were foregone. These questions must instead be addressed at the level of individual water consumers.

Responses of Large and Small Users

The Concord Water Department's conservation efforts were directed at all types of users. Large industrial, commercial, and institutional users had strong economic incentives to reduce their consumption and could respond with such measures as equipment retrofitting, leak repair, and drilling their own wells. Any changes made by a large-scale user such as a hospital or a cement factory could have a significant impact on the city's overall supply. Small household users, on the other hand, were also a major part of the demand picture. Household users might be reached by quite different sorts of appeals, and employ quite different conservation tactics, than the large industrial and commercial users. These small users are the focus of this study.

The drop in city-wide water consumption shown in Figure 1 was brought about by broad reductions in the usage of both household and industrial consumers. This is illustrated in Figure 2, a stem-and-leaf display of changes in cubic feet of water used, summer 1981 minus summer 1980, for a random sample of 310 Concord water customers. Stem-and-leaf displays (Tukey 1977) are a modification of the sample histogram which permits retention of individual data values. Figure 2 records change in use, to the nearest 100 cubic feet, for each of the 310 cases in this sample. For example, a user who reduced consumption by 1400 cubic feet would be displayed as -1F 4; a user who increased consumption by 600 cubic feet would appear as +0S 6. See Hamilton (1982), and Velleman and Hoaglin (1981), for other conventions.

Positive values in Figure 2 represent users who increased their water consumption following the conservation campaign; negative values represent those whose use decreased. The display shows that there was a very general reduction in water use, made up both of a handful of large reductions (i.e., the 24 cases displayed as LO outliers) and of many smaller reductions. The latter give the change distribution in Figure 2 its overall negative location. More specifically, the 33 users trimmed as outliers in Figure 2 made a net reduction of 149,650 cubic feet (59% of the total reduction in this sample); the remaining 277 users who made more modest changes achieved a net reduction of 104,152 cubic feet (41% of the total).

From Figure 2 and similar displays from other samples, it is apparent that small changes by individual households were a major component of the conservation program's success. It is also apparent that there was considerable household-to-household variation in response to this program, and not all households reduced their use as requested. A fifteen percent overall reduction clearly does not mean that everyone reduced

	LO	-545, -413, -133, -132, -82, -78, -65, -63, -58, -53, -47, -42, -42, -30, -30, -29, -26, -26, -24, -23, -23, -23, -23, -21	
26	-2*	00	
32	-1.	999999	
36	-1S	7776	
48	-1F	555555554444	
60	-1T	333333222222	
71	-1*	11111000000	
88	-0.	99999988888888888	Decreased Use
109	-0S	777777777666666666666	
151	-0F	555555555555555555555444444444444444444444	
(54)	-0T	333333333333333333333333333333222222222222222222222222	
105	-0*	11111111111111111111111110000000000	
70	+0*	000000000111111111111111	
46	+0T	2222223333333333	
30	+0F	44444555	
22	+0S	677	Increased Use
19	+0.	88999	
14	1*	01	
12	1T	222	
	HI	17, 18, 20, 21, 22, 39, 107, 110, 218	

Figure 2: Stem-and-Leaf Display of Changes in Cubic Feet of Water Used, Summer 1981 Minus Summer 1980, for 310 Users in Concord, New Hampshire.

NOTE: Leaf digit unit = 100 cubic feet; a user who reduced consumption by 1400 cubic feet would be displayed as -1F 4; a user who increased consumption by 600 cubic feet would be displayed as +0S 6. See text for other conventions.

their use by about fifteen percent; some did much more, and others did much less. The chapters that follow describe work done in an effort to explain household-to-household variation in responses to this water conservation campaign.

II. DATA COLLECTION

The Concord Water Department keeps quarterly records of water use and water bills for over 5000 individual meters or accounts. These records contain information on meter readings and amounts billed, and also an "availability charge", which is a function of the tax-assessed value of the buildings at that address. It is possible to recover the building values directly as a linear transformation of the availability charge, so the billing records provided us with both water use and building values for each case in the population. Unfortunately, the records do not distinguish between different classes of water users such as residences, factories, stores, etc.

Summer 1980 billing records were used as the sampling frame for this study. We systematically selected every sixth case from these records, noting water use, availability charge, and owner's name and address. Systematic sampling from such a list should provide a random sample of the population, with statistical properties as good or better than those of a simple random sample (Schaeffer et al. 1979). We then obtained water use data for the same cases for the summers of 1979 and 1981 as well. This phase of the data collection, completed by May 1982, provided us with the original sample, mailing list, and measures of the principal dependent variable, water use over three summers including the crisis period. A paper describing preliminary analysis of these data, and the innovative statistical methods used, has been published in Evaluation Review (Hamilton 1982).

The Mailed Survey

The next step in data collection was to obtain survey questionnaires from as many of these same water-users as possible. Since our interest was strictly with residential users, cases with obviously non-residential names were omitted, and the remaining 870 names were coded onto a computer mailing list. Each case on this list was assigned a number for identification.

A questionnaire was designed to measure variables identified in the literature as possible predictors of water use or conservation behavior. This questionnaire, designed along the lines set forth in Labaw's (1980) Advanced Questionnaire Design, is included as Appendix A. Opinion and attitude questions on the survey were adapted from the Berk et al. (1981) study of water conservation programs in California. The questionnaires were each numbered, to permit matching of questionnaire responses with water-use data. Mr. John Forrestall, Director of the Concord Water Department, wrote an introductory cover letter which went out with the questionnaires. He also prepared a press release, picked up by the local newspaper and radio station, briefly describing the purposes of the study and encouraging people to respond.

Questionnaires were mailed out with postage-guaranteed return envelopes, using computer-generated mailing labels. As questionnaires were returned, their data were coded and computer-stored, and the fact of response was noted in the mailing-list file. Two weeks after the initial mailing, a second mailing of reminder postcards (Appendix B) was sent out to all those who had not yet responded. Two weeks after the postcards, a third and final mailing was sent out. This consisted of a replacement questionnaire, return envelope, and a second explanatory cover letter (Appendix C). Each of these follow-up mailings resulted in a new surge of returned questionnaires.

The original sample consisted of 870 addresses, all for water accounts still current as of summer 1981. However, since the survey was conducted in late spring 1982, we were not surprised to find that many respondents had moved, died, or otherwise become unavailable in the interim. Also, some non-residential accounts had remained undetected among these 870 cases. For these reasons, 106 questionnaires were returned to us as undeliverable. To the best of our knowledge, the remaining 764 questionnaires reached their destinations. Of these, 516 were returned, for a very gratifying completion rate of 67%. This was particularly important not only for this study, but because it demonstrated that high response rates are attainable in water-conservation research. Prior to doing this survey, some reviewers had expressed doubts about this possibility. It seems clear that the two follow-up mailings, and the pre-survey press release, were probably very important factors in generating this response. Also, the success of Concord's water conservation efforts had been well publicized in local news media, and was probably a matter of civic pride to many people.

Babbie (1972:165) described response rates of at least 60% as "good", and 70% as "very good", but went on to note that "a demonstrated lack of response bias is far more important than a high response rate". We know that the original sample of 870 accounts was random; data on the 516 accounts for which questionnaires were returned can be tested against this sample to judge the extent of response bias. Both water use (for the summers of 1979-1981) and house value (from the "availability charge") can be used to perform this test.

Table 1 summarizes the results of these tests. Because the Concord billing records are divided into three geographical zones (here called Concord A, B, and C), we performed the tests separately for each zone and across all four variables, providing twelve possible sample-respondent comparisons. Medians were calculated for both the original sample and for

TABLE 1

TESTING FOR RESPONSE BIAS: WATER USE AND HOUSE VALUE

SAMPLE/date	SAMPLE MEDIAN	RESPONDENT MEDIAN*
Concord A: summer 1981 water use	2150	2000 ± 221
Concord A: summer 1980 water use	2300	2100 ± 239
Concord A: summer 1979 water use	2800	2600 ± 288
Concord A: house value	26,493	26,319 ± 1623
Concord B: summer 1981 water use	2100	1800 ± 189
Concord B: summer 1980 water use	2500	2300 ± 227
Concord B: summer 1979 water use	2600	2400 ± 241
Concord B: house value	25,275	24,986 ± 1159
Concord C: summer 1981 water use	2100	2100 ± 189
Concord C: summer 1980 water use	2300	2400 ± 255
Concord C: summer 1979 water use	2300	2400 ± 274
Concord C: house value	24,116	24,580 ± 1159

*Respondent medians are given with their approximate 95% confidence limits, calculated as $\pm$ 1.58 $(\frac{dH}{\sqrt{n}})$. Only one of the twelve comparisons (Concord B, summer 1981) shows a sample median that is not well within these limits.

the actual respondents, and 95% confidence intervals constructed for the respondent medians. (Medians, rather than means, are used in this comparison because of the former's more efficient performance in contaminated, skewed distributions (Mosteller and Tukey 1977:206).) The confidence intervals were found using the approximation described by Velleman and Hoaglin (1981:74). Sample medians within the 95% confidence intervals established from respondent medians indicate that there is no significant bias. For eleven of the twelve comparisons in Table 1 this is indeed the case, and sample and respondent medians are often quite close. This finding supports the belief that, at least on these crucial variables, the sets of households which returned questionnaires are not significantly different from the original random sample.

Coding and Cleaning

As the questionnaires were returned, they required extensive coding work. First, the questionnaires' numerical answers were coded into a computer file. There were also many open-ended questions on the questionnaire, and these too had to be carefully read and assigned numerical codes by the researchers. One question, asking for the head of household's occupation, was coded in terms of occupational prestige, using the scales developed by Trieman (1977) and Duncan (in Reiss, 1961). Next, the survey variables for each case were matched with the billing record variables for that case, and a single combined data file constructed. Each step of this procedure presented numerous possibilities for mistakes, so results were carefully checked. As a final check, the complete computer data set was printed out, and each case in this data set was checked against the raw data from questionnaires and billing records. Because of these precautions, we are confident that no coding errors remain in the data.

III. VARIABLE DISTRIBUTIONS

The combined survey and billing-record data set contains information on six types of variables: household demographic characteristics, household water use, ways in which water is used, opinions about the water shortage, respondents' sources of information about the shortage, and self-reports of what water-saving steps were taken. For purposes of comparison with other studies, and to lay the groundwork for the multivariate analyses that follow, the univariate distributions of these variables are described in some detail below.

Demographic Characteristics

Two types of respondents were set aside in the early stages of this analysis: those living in apartments, and those with swimming pools. Apartment dwellers often do not know how much water they are using, or have any way of knowing or influencing the water use of other tenants or the building's owners. Thus they would have difficulty in answering many items on the questionnaire, and theoretical propositions developed for residential households would not apply to them. Although apartment dwellers are an important water-consuming group, they cannot easily be incorporated in this particular research design.

There were 31 swimming-pool owners in the original sample. Because a swimming pool requires a great deal of water, the timing and method of fill-ups tended to dominate all other variables in predicting these households' water use. It was therefore judged to be a mistake to mix these highly atypical cases, representing 6% of the original sample, in with the others. When swimming-pool owners and apartment dwellers were omitted, we were left with 431 cases. The analyses that follow, unless otherwise specified, refer to this subset of 431 residential households without swimming pools.

Household sizes ranged from zero to ten occupants, with a median of three. These included up to six school-aged children, although the median was none. Both household size and number of school-age children are positively skewed variables, the latter much more so. Their distributions and univariate statistics are shown in Figure 3.

Total household incomes ranged from less than $5,000 to $90,000 dollars, with a median of about $20,000. As might be expected, the income distribution had a marked positive skew. The median education level of household heads was 13 years, but there were many people with college and graduate degrees. Income, education, and their respective univariate statistics are shown in Figure 4.

Water Use

Because summer is the time of highest water use, highest discretionary water use, and the main period of crisis for this study, summer-months water use was selected as the principal dependent variable. The Concord Water Department records water use, in cubic feet, at three-month intervals by reading meters. As with many other economic variables, these water-use distributions turned out to be positively skewed, with a long tail of high-use cases. The range was from 200 to over 10,000 cubic feet. Median water use during the summer of 1980, before the crisis, was 2200 cubic feet. Median use the following summer, after conservation appeals had been going on for nearly a year, was down dramatically to only 1900 cubic feet. The mean water use dropped even more sharply. These statistics and the relevant histograms are shown in Figure 5.

How Water Was Used

The survey included a checklist of possible ways in which a household might use water. The list was based on previous researchers' findings

NUMBER OF PEOPLE LIVING IN HOUSEHOLD

```
EACH * REPRESENTS   5 OBSERVATIONS

MIDDLE OF    NUMBER OF
INTERVAL     OBSERVATIONS
    0.          4     *
    1.         67     **************
    2.        141     *****************************
    3.         82     *****************
    4.         76     ****************
    5.         38     ********
    6.         12     ***
    7.          5     *
    8.          5     *
    9.          0
   10.          1     *      MEAN=2.89   MEDIAN=3.00   S.D.=1.55   N=431
```

NUMBER OF SCHOOL-AGE CHILDREN

```
EACH * REPRESENTS  10 OBSERVATIONS

MIDDLE OF    NUMBER OF
INTERVAL     OBSERVATIONS
    0.        303     *******************************
    1.         52     ******
    2.         50     *****
    3.         20     **
    4.          4     *
    5.          0
    6.          2     *      MEAN=0.56   MEDIAN=0.00   S.D.=1.01   N=431
```

FIGURE 3: NUMBER OF PEOPLE, NUMBER OF SCHOOL-AGE CHILDREN IN HOUSE.

```
TOTAL HOUSEHOLD INCOME (THOUSANDS)

    EACH * REPRESENTS    5 OBSERVATIONS

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
        0.           5      *
       10.         100      ********************
       20.         134      ***************************
       30.         121      *************************
       40.          54      ***********
       50.          11      ***
       60.           4      *
       70.           1      *
       80.           0
       90.           1      *       MEAN=22.7   MEDIAN=20.0   S.D.=12.4   N=431
```

```
HEAD OF HOUSEHOLD EDUCATION (YEARS)

    EACH * REPRESENTS    5 OBSERVATIONS

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
        6.           1      *
        7.           1      *
        8.          14      ***
        9.           7      **
       10.          10      **
       11.           7      **
       12.         135      ***************************
       13.          49      **********
       14.          59      ************
       15.           4      *
       16.          66      **************
       17.           2      *
       18.          25      *****    MEAN=14.1   MEDIAN=13.0   S.D.=3.1   N=431
       19.           1      *
       20.          50      **********
```

FIGURE 4: HOUSEHOLD INCOME AND HEAD-OF-HOUSEHOLD EDUCATION.

```
HOUSEHOLD WATER USE, SUMMER 1980 (CUBIC FEET)

    EACH * REPRESENTS    5 OBSERVATIONS

    MIDDLE OF     NUMBER OF
    INTERVAL      OBSERVATIONS
         0.        10       **
      1000.       101       *********************
      2000.       141       *****************************
      3000.        80       ****************
      4000.        55       ***********
      5000.        18       ****
      6000.        13       ***
      7000.         4       *
      8000.         6       **
      9000.         3       *       MEAN=2547   MEDIAN=2200   S.D.=1582   N=431
```

```
HOUSEHOLD WATER USE, SUMMER 1981  (CUBIC FEET)

    EACH * REPRESENTS    5 OBSERVATIONS

    MIDDLE OF     NUMBER OF
    INTERVAL      OBSERVATIONS
         0.        16       ****
      1000.       120       ************************
      2000.       156       ********************************
      3000.        84       *****************
      4000.        38       ********
      5000.         6       **
      6000.         4       *
      7000.         5       *
      8000.         1       *
      9000.         0
     10000.         1       *       MEAN=2119   MEDIAN=1900   S.D.=1297   N=431
```

FIGURE 5: HOUSEHOLD WATER USE, SUMMER 1980 AND SUMMER 1981.

about important predictors of domestic water use. Responses to this checklist are shown in Table 2. Most households had clothes washing machines (94%), and more than half participated in outdoors summer activities like lawn and garden-watering or washing cars. Concord's climate is not ideal for swimming pools, so it is not surprising that only a small fraction (6%) of these households had them.

Attitudes and Beliefs

The questionnaire included a number of attitude, belief, and motivation questions. Many of these were based upon the five social-psychological beliefs that Berk et al. (1981) identified, on the basis of experimental and theoretical studies, as being likely to affect conservation behavior. These questions were phrased to allow 5-point responses, from strongly agree to strongly disagree. Two open-ended questions, asking for people's motives in taking whatever conservation steps they took (or did not take), were coded by the researchers for volunteered economic or idealistic motives. Economic motives were coded (0,1), for absent or present. Only 36.2% of the sample expressed such motives, and many went out of their way to deny them. Some sort of idealistic motive (e.g., to help the community, conserve resources, etc.) was mentioned by 83.6% of the sample. The nature of these responses was more variable than those for economic motives. Some people merely wrote that they saved water "to help the community." Others made a more complete statement of their reasoning, while some showed evidence that they had strongly held opinions and had given the matter considerable thought. These varied "idealistic" responses we coded as 0 (if absent), 1 (if present but perfunctory), 2, and 3 (increasingly strong statements). Responses to all these attitude and belief items are shown in Table 3.

TABLE 2

WAYS IN WHICH WATER IS USED

Item	Percent "Yes"
Dishwashing Machine	43.5
Clothes Washing Machine	94.0
Lawn Watering	51.5
Tree and Garden Watering	57.9
Swimming Pool *	6.0
Car Washing	56.3
Garbage Disposal	36.3
Number of Bathrooms	(Median: 1.2)

* These cases excluded from subsequent analyses.

TABLE 3

ATTITUDES AND BELIEFS

Item *		Response %				
		Agreed Strongly	Agreed	Neutral	Disagreed	Disagreed Strongly
Q14:	Shortage serious	28.8	59.9	6.2	1.2	0.2
Q16:	People not respond	1.8	16.3	18.9	57.1	5.9
Q17:	Save us money	8.1	41.3	17.8	28.7	4.2
Q18:	Not Serious	1.4	44.2	24.1	27.2	3.2
Q19:	Moral responsibility	34.1	62.6	2.2	1.0	0.2
Q20:	Improve situation	28.3	64.4	6.1	1.0	0.2
Q21:	Too inconvenient	0.8	11.5	13.5	59.9	14.3
Economic motives		(Mentioned by 36.2%)				
Idealistic motives		(Mentioned: 83.6%, Statement: 66.9%, Long statement: 6.0%)				

* Items Q14, etc. are numbered as they appear in the original questionnaire, Appendix A. Economic motives is a two-point scale based on whether or not such motives are mentioned in the open-ended questions 33 and 34. Idealistic motives, from the same questions, are coded 0 if not mentioned, 1 if mentioned very briefly, 2 if supported by a complete statement, and 3 if this statement was long or showed evidence of strongly held beliefs.

Sources of Information

Another open-ended item on the questionnaire asked for respondents' sources of information about the crisis. This was included to provide information of the effectiveness about the city's campaign to persuade its citizens. Considerable efforts went into such diverse tactics as mailed flyers, presentations in the public schools, news releases to the media, and announcements by public officials. Presumably many Concord residents were exposed to all of these appeals. Table 4 shows their responses when asked to name their primary sources of information. The Concord *Monitor*, a local newspaper, was by far the most often-cited source. The second most frequently-cited source was visual inspection of the city's reservoir; this was accessible to many residents and apparently provided very graphic and persuasive evidence. As one respondent put it: "Who believes bureaucrats? I could see the low water level for myself." The third important source of information was local radio stations. Concord does not have its own television stations, which may partly account for the low saliency of this source. Only a small fraction of the respondents cited mailed flyers (2.1%) or children in school (1%) as their source. Although it seems likely that more people got *some* information from these sources, it did not stick in their minds to the extent that newspaper, visual inspection, and radio reports did. The latter three may have played a very important role in convincing people that the crisis was real.

Steps to Conserve Water

All survey data must be interpreted with caution, and this is especially true, in this case, of the questionnaire items asking respondents what steps they took to save water. Ten such items were included in a checklist on the questionnaire, and responses to these items are summarized in Table 5. High percentages of respondents

TABLE 4

SOURCES OF INFORMATION

Source *	Percent Mentioning
Newspapers	67.1
Saw reservoir	33.3
Radio	29.3
Television	6.4
Mailed flyers	2.1
Kids in school	1.0

* Respondents were asked to volunteer their primary sources of information about the crisis; many people listed more than one source.

TABLE 5

WATER-SAVING STEPS

Step	Percent "Yes"
Water-saving device: toilet	24.2
Water-saving device: shower	34.0
Water lawn less	71.3(97.0) *
Water trees/garden less	59.4(82.0) *
Wash car less	63.9(87.0) *
Flush toilet less	60.7
Shorter showers, shallow baths	69.9
Other behavioral change	25.0
Repair leaks	58.4
Not fill pool	2.9(48.4)

* Percentages of relevant households given in parentheses. For example, 71.3% of the sample watered lawns less, but this was 97% of the households that actually watered lawns to begin with (see Table 2).

claimed to have taken many of these water-saving steps. In particular, 97% of those with lawns reported watering less, as did 82% of those with gardens and 87% of those who normally washed their own cars. These high compliance rates are not incredible; there was a mandatory ban on outdoors water use for a while, and city-wide water use clearly did drop off substantially. Nonotheless, one can't help suspecting that some of these percentages are inflated by respondents who wish to look good. In the next chapter, however, it will be demonstrated that these water-saving steps have an interpretable factor structure, and that at least some of the steps do explain household-to-household variations in water use.

IV. MEASUREMENT FINDINGS

The assorted quantitative and qualitative variables described in the previous section constitute the study's raw data. Further work with these variables is needed, however, before they can be used directly in multivariate analysis. There are three types of problems with the raw data. First, as noted previously, a number of the quantitative variables have skewed distributions. Skewed distributions cause problems in statistical analyses, and it is often desirable to try to symmetrize such variables before proceeding further. Second, two of the most important demographic variables, income and education, contain a number of "missing values", or cases where the respondents failed to answer these questions. Internal evidence can be used to make reasonable guesses about what those "missing values" should actually be, and thus increase the pool of usable responses. Thirdly, several key concepts--water use, attitudes and beliefs, conservation steps--are represented by multiple items on the questionnaire. Is each of these items really a separate variable, or are some of them measuring some smaller set of underlying dimensions? If the latter is the case, then these dimensions may be identified and estimated, giving us a smaller and more understandable set of variables to work with.

Distributional Transformations

Household income, water use, and house value all have positively skewed distributions, with long right-hand tails made up of high-income, high-use, or high-value households. These tails of the distributions contain outliers that can exert undue leverage on almost every stage of statistical analysis. In addition, such skewed distributions are frequently associated with the problem of heteroskedasticity, which reduces the efficiency of classical parameter estimation strategies. Also, many inferential methods assume that residuals from model fitting have a Gaussian or normal distribution; this assumption is less plausible when key variables have skewed (i.e., radically non-Gaussian) distributions.

For all of these reasons, it is desirable to try to symmetrize skewed variables prior to multivariate analysis. John Tukey (1977) has suggested that we do this by using a "ladder of powers": a set of nonlinear power transformations that retain order, but change distributional shapes. To compensate for positive skew, he suggests trying the square root, logarithm, and negative reciprocal root as increasingly powerful corrections. The "normality" of raw and transformed distributions can be assessed by applying a chi-square test to deviations from a fitted normal curve. The particular fitting and testing algorithms used here are those developed for the "suspended rootogram" by Velleman and Hoaglin (1981).

It was found that for income and domestic water use, the square root transformation resulted in an approximately normal curve; the Gaussian null hypothesis could not be rejected at the .05 level for the square roots of income or water use, in any of the sample tests. Stronger transformations such as the logarithm tended to overcorrect, transforming the positively skewed raw distribution into a negatively skewed logarithmic one. House value, on the other hand, was more skewed than income or water use; the logarithm was the best symmetrizing transformation for this variable.

On the basis of these findings, we decided to use the square root of income, the square root of water use, and the logarithm of house value in subsequent multivariate analyses. Use of these transformed variables should improve the statistical properties of our analyses.

Missing-Value Replacement

About eight percent of the sample left the "education of household head" question blank. More seriously, a quarter of the sample failed to provide reports of household income. Removing these cases with incomplete data would involve a substantial loss of information, and a decrease in the representativeness of the resulting subsample. Fortunately, other variables in the data set were available to provide reasonably good estimates of the missing education and income variables.

The education of household head, for those cases reporting it, is strongly correlated (r=.61) with occupational prestige scores based on Duncan's SEI (from Reiss, 1961). Education could therefore be regressed on prestige to provide a prediction equation for substituting estimates for the missing values of education. The R^2 for this equation is 37%, and careful checks of the correlates of education before and after missing-value replacement showed that this operation did not substantially alter any of education's bivariate relationships. The actual equation used was:

$$\text{Education} = 10.05 + (.08 * \text{Prestige}).$$

There was no single variable which predicted income as well as occupational prestige predicted education; three predictors were required to reach the same level of adequacy. These three were logarithm of house value (objectively recorded in the water-billing records), number of people with full-time jobs, and occupational prestige of household head. The multiple-regression equation relating these variables to income is:

$$\text{Income} = -107.6 + (.176 * \text{Prestige}) + (11.5 * \log(\text{Housev.})) + (4.23 * \text{Emps})$$

These three predictors explained 38% of the variance of income. As with education, the correlates of income were examined before and after subsitution, to assure that the substitution had not altered the pattern of income's relationships with other variables.

Since the missing-value substitutions produced no significant changes in bivariate relationships, and the R^2 for each substitution equation was reasonably high, it was decided to use these new no-missing-value income and education variables in all subsequent multivariate analyses.

Factor Analysis

Three important conceptual areas were measured by multiple items: water use, water-saving steps, and attitudes and beliefs. Using all the separate items individually would produce clumsy and hard-to-interpret analytical results, so it was desirable to reduce this large number of items into a smaller and more manageable number of composite varitables. Some previous researchers have done this by arbitrarily summing items, for example to form a "conservation score" for each household. This procedure will produce valid and reliable composites only to the extent that the combined items are in fact all measuring a single underlying dimension. Factor analysis provides the best method for empirically evaluating the underlying dimensionality of sets of related variables.

Factor analyses were performed for this research using Rao's canonical (maximum likelihood) factor analysis and oblique (oblimin) rotation. Rao's method has optimal statistical properties, and also provides a X^2 test of the factor model's ability to reproduce the sample covariance matrix. A high X^2 indicates a poor fit; a low X^2 indicates that there is no significant difference between the observed covariance matrix, and that implied by the factor model. To check the stability of our results, all analyses were also replicated using several other factoring algorithms, with substantially similar findings.

The questionnaire contained eight questions asking about ways in which water was normally used (see Table 2). 94% of the sample had clothes washing machines, so this nearly constant variable was not included in the factor analysis. Only 6% of the sample had swimming pools; because of the small size of this group, and the huge and highly variable effects that swimming-pool filling had, these cases were eliminated from the general analysis. The six remaining water-use items were: dishwasher, garbage disposal, # of bathrooms, watering lawn, wash cars, and watering trees or gardens. A factor analysis of these six items is shown in Table 6.

Two factors explained 52% of the variance of these six variables, and gave a good fit (as measured by the X^2 test) to the observed covariance matrix. These factors are interpretable as a "kitchen-bathroom" factor, made up of dishwashing machine, garbage disposal, and number of bathrooms; and a "summer-lawn" factor, made up of car-washing and watering trees, lawn, and gardens. The two factors have only a weak positive correlation (r=.14). Factor score coefficients, shown also in Table 6, can be used to construct two composite indexes of water use.

The questionnaire also contained a checklist of ten possible water-saving steps (see Table 5). One of these, not filling pools, was relevant only to those households, already ommitted from the analysis, that had a pool to begin with. A second water-saving step, repairing plumbing leaks, turned out to be completely unrelated to any of the other water-saving steps. A factor analysis of the remaining eight steps is shown in Table 7. Three interpretable factors emerged: a "summer-lawn" factor, similar to the summer-lawn water use factor, involving less car washing, lawn watering, and tree and garden watering; a "device" factor involving water-saving devices in toilets and showers; and a "behavioral" factor, involving shorter showers/shallower baths, flushing toilets less often, and other behavioral changes. These three factors explained 56% of the

TABLE 6

FACTOR ANALYSIS OF SIX WATER-USE ITEMS

Item	Factor 1: Kitchen-bathroom Loading	Factor 1: Kitchen-bathroom Score Coefficient	Factor 2: Summer-lawn Loading	Factor 2: Summer-lawn Score Coefficient
Dishwasher	.64 *	.45	.02	.02
Garbage disposal	.57 *	.34	.02	.01
# Bathrooms	.37 *	.18	-.03	-.02
Water lawn	.23	.15	.52 *	.38
Wash cars	-.04	-.02	.42 *	.23
Water trees	-.07	-.04	.59 *	.41

* Denotes highest loading in each row. Oblique rotation, $r_{12}=.14$; eigenvalues factor 1=2.6, Factor 2=2.0; X^2 for two-factor model is 6.2 with 4 degrees of freedom (.25>p>.10), indicating reasonably good fit.

TABLE 7

FACTOR ANALYSIS OF EIGHT WATER-SAVING STEPS

Step	Factor 1: Summer-lawn		Factor 2: Devices		Factor 3: Behavior	
	Loadings	Score Coefficient	Loadings	Score Coefficient	Loadings	Score Coefficient
Device-toilet	-.02	.02	.57 *	.40	.01	.05
Device-shower	.02	.03	.54 *	.38	.02	.06
Flush less	-.02	.02	-.12	-.05	.50 *	.36
Shorter showers	.04	.05	.08	.07	.41 *	.30
Other behavior	.02	.03	.11	.08	.34 *	.23
Water lawn less	.70 *	.43	.02	.06	-.06	.01
Water trees less	.65 *	.38	-.17	-.11	.05	.10
Wash cars less	.46 *	.23	.18	.15	.06	.09

* Denotes highest loading in each row. Oblique rotation, r_{12}=.17, r_{13}=.30, r_{23}=.22; eigenvalues Factor 1=3.14, Factor 2=2.02, Factor 3=1.55; X^2 for three-factor model is 6.46 with 7 degrees of freedom (.50>p>.25), indicating excellent fit.

cumulative variance, and gave an excellent fit ($p>.25$) to the observed covariance matrix. The summer-lawn and behavior factors had a moderate positive correlation ($r=.30$), while the other two interfactor correlations were weaker.

The attitude and belief items presented the most difficult factor analytic problem, and much work could be done in redesigning these items for future questionnaires. As shown in Table 3, there were nine of these attitude and belief variables, but several of these were almost invariant. Only five of the nine items had interesting patterns of variation and covariation with other variables. These were: agreement that "most people in Concord would not respond to requests to use less water" (Q16); agreement that "it would be too inconvenient or costly for this household to save much water" (Q21); agreement that "using less water would actually save this household a significant amount of money" (Q17); and the researcher-coded measures of idealistic and economic motives described in Chapter III. A factor analysis of these five variables is shown in Table 8.

The results of this factor analysis are weaker than the two shown previously, but they do suggest the existence of two underlying dimensions, interpretable as an "idealistic" and an "economic" dimension. The two-factor model explained 55% of the total variance, and could not be rejected at the .05 level. The "idealistic" factor contains both positive and negative loadings; in order to make this dimension fully intelligible as a measure of idealistic attitudes and beliefs, it is necessary to reverse the coding on the two negatively-worded questions, Q16 and Q20. Then a high "idealistic" factor score would indicate a person who cited extensive idealistic considerations on the open-ended "motives" question, and who disagreed that "people would not respond" or that it would be "too inconvenient or costly" for their own household to save much water.

TABLE 8

FACTOR ANALYSIS OF FIVE ATTITUDE/BELIEF ITEMS

Item	Factor 1: Idealism		Factor 2: Economic	
	Loadings	Score Coefficient	Loadings	Score Coefficient
Q16: People not respond	.44 *	.28	.16	.15
Q21: Too inconvenient	.64 *	.46	-.22	-.09
Idealistic motives	-.47 *	-.27	-.05	-.08
Q17: Save us money	-.14	-.01	.70 *	.62
Economic motives	.10	.07	.25 *	.14

* Denotes highest loading in each row. Oblique rotation, r_{12}=.13; eigenvalues factor 1=2.3, factor 2=2.0; X^2 for two-factor model is 3.59 with 1 degree of freedom (.10>p>.05), indicating adequate fit.

A high "economic" factor score would indicate a respondent who cited economic considerations on the open-ended motives question, and who agreed that water conservation would save their household a significant amount of money. With this recoding, "idealistic" and "economic" motives have a weakly negative correlation ($r=-.13$).

On the basis of these three factor analyses, and extensive supporting work exploring their robustness, factor scores were constructed for the two water-use factors, three conservation-step factors, and two attitude/belief factors. This set of seven composite variables was used in place of the nineteen original items throughout the multivariate analysis that follows. However, to be sure that no spurious conclusions resulted from this index construction, the multivariate results were checked at various stages by using the original items instead. No significant changes resulted, so the following discussion will focus solely on the composites. Distributions of three of these composites are shown in Figure 6.

```
"IDEALISTIC MOTIVES" FACTOR SCORES

     EACH * REPRESENTS   5 OBSERVATIONS

     MIDDLE OF   NUMBER OF
     INTERVAL    OBSERVATIONS
        -2.5        1      *
        -2.0        7      **
        -1.5       20      ****
        -1.0       48      **********
        -0.5       50      **********
         0.0      104      *********************
         0.5      145      *****************************
         1.0       43      *********
         1.5       13      ***      MEAN=0.01   MEDIAN=0.15   S.D.=0.73   N=431


"ECONOMIC MOTIVES" FACTOR SCORES

     EACH * REPRESENTS   5 OBSERVATIONS

     MIDDLE OF   NUMBER OF
     INTERVAL    OBSERVATIONS
        -2.0        1      *
        -1.6        6      **
        -1.2       20      ****
        -0.8       87      ******************
        -0.4       72      ***************
         0.0       40      ********
         0.4      108      **********************
         0.8       68      **************
         1.2       21      *****
         1.6        8      **       MEAN=0.00   MEDIAN=0.12   S.D.=0.71   N=431


"CONSERVATION BEHAVIOR" SCALE

     EACH * REPRESENTS   5 OBSERVATIONS

     MIDDLE OF   NUMBER OF
     INTERVAL    OBSERVATIONS
          0.       61      *************
          1.      125      *************************
          2.      179      ************************************
          3.       66      **************
                                    MEAN=1.58   MEDIAN=2.00   S.D.=0.91   N=431
```

FIGURE 6: INDEXES FOR CONSERVATION MOTIVES AND BEHAVIOR.

V. CAUSAL MODELING

The measurement findings described in section IV provide a basis for further multivariate work, aimed at developing a model of the causes of water conservation behavior. Causal models (see Duncan 1975; Heise 1975; Kenny 1979) have been widely used in the social and behavioral sciences. They are well suited to the problems of analyzing the complex interrelationships among a large set of causally connected variables, such as those described above. Causal models can be represented graphically in the form of path diagrams, or by an isomorphic set of structural equations. Direct effects in these models can be estimated by multiple regression; indirect and total effects are obtained by applying rules of derivation to sequences of direct effects.

Pre-Shortage Use and Post-Shortage Use

The core of the causal model of water conservation is the relationship between two variables: household water use in the summer before the shortage (1980), and household water use one year later, after the conservation program had had its full effect. The difference between these two figures indicates the change in household water use over the period of the conservation program. Households responding to conservation appeals would presumably reduce their consumption, while others might make no change or even use more water. A simple model for this relationship is:

$$W_{81} = a + bW_{80} \qquad (1)$$

where W_{81} represents each household's summer 1981 water use, W_{80} represents summer 1980 use, and $\underline{a}$ and $\underline{b}$ are the intercept and slope coefficients for this linear relationship. $\underline{b}$ could then be interpreted as the effect that 1980 water use had on 1981 water use. Unfortunately, this interpretation is unavoidably ambiguous, because _b_ actually conbines two quite different kinds of effects. These effects could be termed _conservation_ and _inertia_. The _conservation_ effect of W_{80} on W_{81} refers to the extent to which 1980 water use affected the degree of conservation. For example, high-1980 users might have seen the greatest need to reduce their use, or found it easiest to do so; in that case, high 1980 use would have the effect of reducing 1981 use. The _inertia_ effect of W_{80} on W_{81}, on the other hand, refers to the extent to which use patterns are persistent; large users generally remain large users, and small users remain small. In fact, then, a more appropriate model for the W_{80} - W_{81} relationship would be:

$$W_{81} = a - cW_{80} + dW_{80} \tag{2}$$

where _c_ represents the negative conservation effect of W_{80}, which decreases W_{81} and _d_ represents the positive inertia effect of W_{80}. This equation is underidentified, however, and there is no way to estimate the values of both _c_ and _d_.

One way out of this dilemma is to set the value of _c_ or _d_ a priori, on theoretical grounds. We have no reason to do this for the unknown coefficient _c_, conservation effect, because this is precisely the quantity we would most like to know. The inertia effect _d_, on the other hand, is substantively less interesting, and a reasonable case could be made for setting its value equal to one. That is, in the absence of a conservation effect, our best guess about a household's 1981 water use is that it will be the same as their 1980 use. Substituting 1 for _d_ in equation (2) gives us:

$$W_{81} = a - cW_{80} + 1W_{80}$$

, or alternatively

$$W_{81} - W_{80} = a - cW_{80} \tag{3}$$

Since equation (3) gives us a dependent variable, 1981 use minus 1980 use, that will be highest when conservation is lowest, it is convenient to reverse the signs and produce an equation for conservation:

$$W_{80} - W_{81} = -a + cW_{80} \tag{4}$$

We thus have two alternative ways of formulating the relationship between pre-and post-shortage water use: as a simple linear regression (equation 1), or as an equation for conservation itself (equation 4). The latter will be easier to interpret, but in fact they are both algebraically equivalent. The intercept in (4) is just the negative of the intecept in (1), and the slope in (4) is equal to one minus the slope in (1). Furthermore, when additional variables are brought into the analysis their effects will be numerically identical (though opposite in sign), regardless of whether W_{81} or $(W_{80} - W_{81})$ is on the left-hand side of the equation. These equivalences will be demonstrated in the multivariate analysis below.

As noted in section IV, there are good univariate reasons for working with the square root of household water use, rather than with its raw values. The square root transformation is also preferable in bivariate and multivariate analysis, for similar reasons: (1) using raw water use as a dependent variable produces heteroskedastic residuals; (2) the regression line is influenced by a few outlying high-use cases; and (3) because of this, robust estimation methods produce results that are significantly different from those generated by classical estimation. However, when square roots of water use are employed as the X and Y in equations like (1) and (4) above, the relationship between actual pre-and post-shortage water use is being modeled as nonlinear.

The linear regression of the square root of 1981 water use on the square root of 1980 water use produces the equation $Y = 8.78 + .73X$. Given that Y and X are nonlinear transformations of water use, the actual relationship is the curve shown in Figure 7. For comparison, a "no-change"

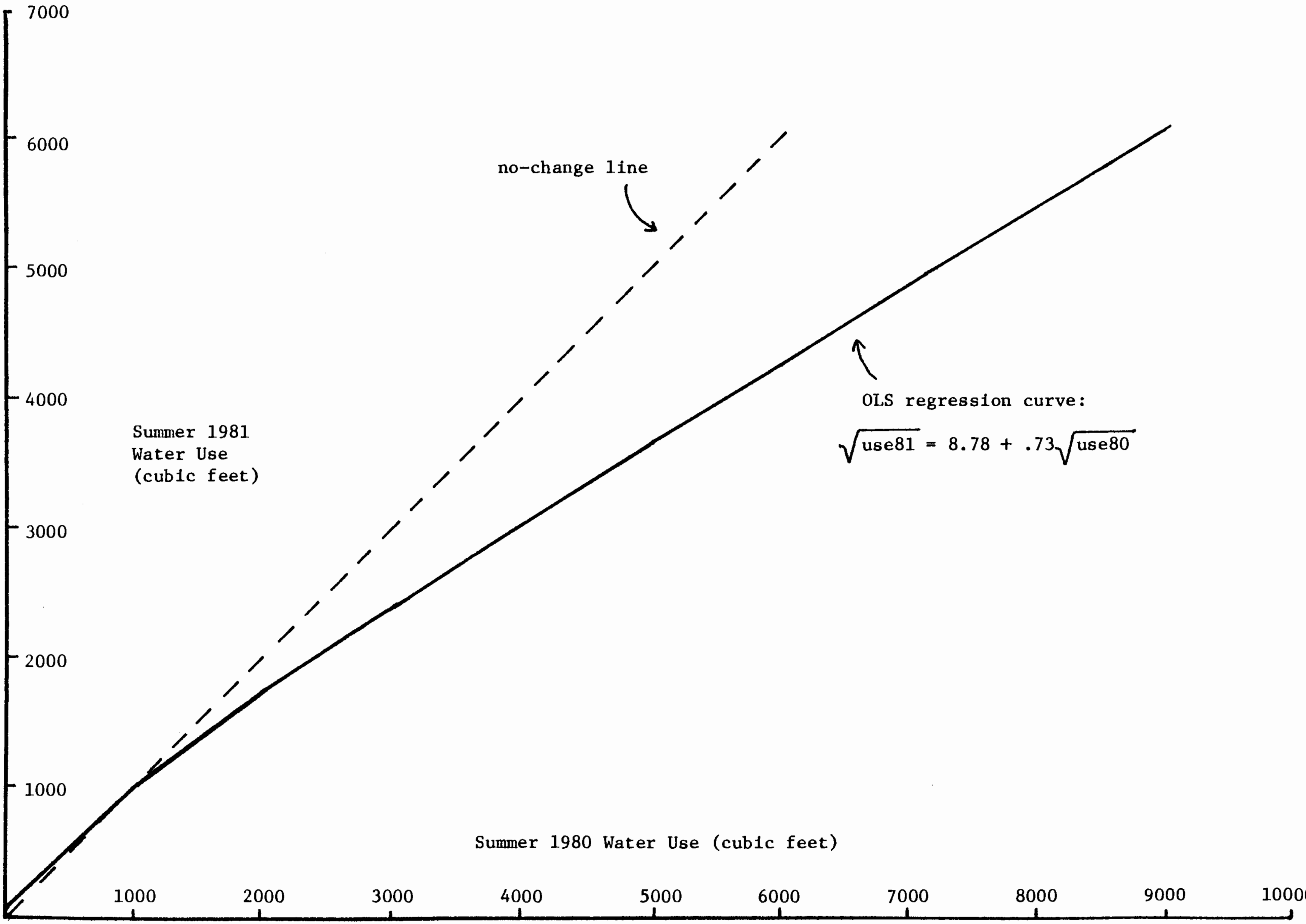

Figure 7: Bivariate Regression of Summer 1981 Use on Summer 1980 Use, 431 Concord Households (R^2 = .65).

line, Y = X, is also included in Figure 7. The divergence of the fitted regression curve from this no-change line illustrates the following important finding: The size of the use reduction increases with the magnitude of pre-shortage use. For households with small pre-shortage use, there is virtually no difference between actual post-shortage use and that predicted by the no-change line. But as pre-shortage use increases above about 1000 cubic feet, the two lines grow farther and farther apart; more and more conservation is occurring. The amount of conservation increases with 1980 use, not only in absolute terms but in percentage terms as well. The bulk of the use reductions were achieved by relatively large users, with a much smaller contribution being made by households that used less water to begin with.

The same finding is presented in another form in Table 9, in which water savings are broken down by 1980 use quartile. The lowest fourth of 1980 users achieved negligible savings (median of 0, mean of 13.5 cubic feet), as could be inferred from the position of the regression curve in Figure 7. Some conservation occurred in the second and third quartiles; this middle 50% of the households made an average use reduction on the order of a few hundred cubic feet. But more than two thirds of the total volume of water conserved by this sample, occurred among households in the top 25% of 1980 users. Clearly the strong decline in water consumption among high-consumption households was the major factor in the success of the household conservation program.

Figure 7 and Table 9 show that this conclusion can be reached by several quite different analytical approaches; it is robust across variations in method. The statistical problems of heteroskedasticity and outliers, mentioned earlier, are eliminated by the square root transformation. Robust, median-based regression methods produce curves that are statistically indistinguishable from that of Figure 7. The

TABLE 9

WATER SAVINGS, BY 1980 WATER USE QUARTILES

1980 Use Quartile (range)	Median Savings *	Mean Savings	Percent of Total Savings **
1 (200-1400 ft^3)	0	13.5	.77%
2 (1401-2200 ft^3)	200	198.2	11.26%
3 (2201-3300 ft^3)	300	266.7	15.15%
4 (3301-8700 ft^3)	1200	1281.7	72.82%
All cases	200	428.3	100.00%

* "Savings" are defined as summer 1980 water use minus summer 1981 water use (both in cubic feet), for this sample of 431 households.

** Percent of the total savings made by this sample, which were made within each quartile. These percentages have been adjusted to reflect the distribution of savings if each quartile had exactly 431/4=107.75 cases.

residuals from the least-squares regression (Figure 7) are approximately normal, as evidenced by a chi-square test against a fitted normal or Gaussian curve. These replications and tests of assumptions enhance confidence in the stability of the bivariate findings. The next problem is to insert them into a more realistic and informative multivariate context.

Constructing a Causal Model of Water Conservation

The literature on water conservation has identified many variables which are thought to affect use or conservation. Most of these have been included in this analysis. The variables do not break down into simple "independent" and "dependent" categories; they have a complex network of interconnections that make multi-equation causal modeling a necessity. These variables can be ordered into five sequential groups:

(1) Background demographic variables, exogenous to the model of conservation behavior. These variables include family income, head of household education and retirement status, number of people living at that address, number of children, number of people with full-time jobs, house value, and socioeconomic status.

(2) Pre-shortage water use, water-using appliances, number of bathrooms, etc. These variables are presumably influenced by background demographic variables in group (1), but are causally prior to the conservation-program variables that reflect the subsequent water shortage. Thus group (2) forms the first wave of intervening variables.

(3) Attitudes, beliefs, and motivations concerning the water shortage and the need for conservation. Group (3) also includes variables describing respondents' principal sources of information about the shortage. The conservation program sought to induce conservation by altering people's beliefs, on the assumption that this would in turn lead to behavioral

changes and reductions in actual water use. Group (3) variables are therefore a second wave of intervening variables, possibly influenced by both background demographic factors (group (1)), and by pre-shortage water use habits (group (2)).

(4) Specific conservation behaviors intended to reduce water use. These include the three factors identified in section IV: installing water-saving devices, curtailing outdoors water use, and changing behavior to reduce indoors use. Group (4) also includes the unrelated variable, change in number of people living in the household. This variable may be a function of background demographic variables, but there is no reason to think it has anything to do with the earlier water-use or motivational variables (groups (2) and (3)). Nonetheless, since this variable measures an important change that might have influenced changes in water use, and since it occurred during the period of the shortage, it makes sense to include the variable in group (4), the third wave of intervening variables.

(5) The output variable, post-shortage water use or, equivalently, the amount of water conserved. The main interest of this analysis is in establishing the direct and indirect effects of the variables in groups (1) to (4), upon water conservation itself.

The complete set of variables available for this model is unmanageably large; even using the scales and factor scores described in section IV, the model could involve more than two dozen variables in about fifteen separate equations. The problems of interpreting such a model would be formidable, and any meaningful findings might be obscured by a great deal of noise. The strategy of backward elimination was chosen as the best way to systematically simplify the model. In the early stages of this analysis, all possible (temporally prior) variables were entered into the equation for each possible endogenous variable in groups (2) to (5). The least significant predictor was dropped from an equation, the parameters re-estimated, and the next least significant predictor dropped again, and so on until only predictors significant at $p < .10$ remained in the equation. This process greatly reduced the clutter of non-significant relationships that were present in the original specification.

The backward elimination began by regressing the square root of 1981 water use (group (5), or the ultimate dependent variable) on all other variables in groups (1) to (4). One by one these variables were then dropped, until only the six significant predictors of 1981 use remained. Two of these predictors were from group (4); each of these two were next regressed on all possible predictors from groups (1) to (3), and again backward elimination was used to retain only their significant predictors. Some of these were variables which were not directly related to 1981 use, but they were nonetheless "brought back in" to the model by their relationship with the group (4) variables. The same procedure was repeated using the two group (3) variables, "idealistic motives" and "economic motives", which were significant predictors of any of the three endogenous variables now in the model. These two motive variables were in turn regressed on variables from groups (1) and (2). Finally, the single group (2) variable, 1980 water use, which had proven useful in predicting subsequent variables, was itself regressed on all the demographic background variables of group (1).

The reduced model contained eleven variables and twenty-four relationships significant at $p < .10$. In fact, all but one of these relationships were significant at $p < .05$ as well. The model is shown as a path diagram in Figure 8, with standardized regression coefficients attached to each path. All paths shown are significant, but three paths which were significant are left out because they are theoretically uninteresting and make the diagram too crowded: these are the effects

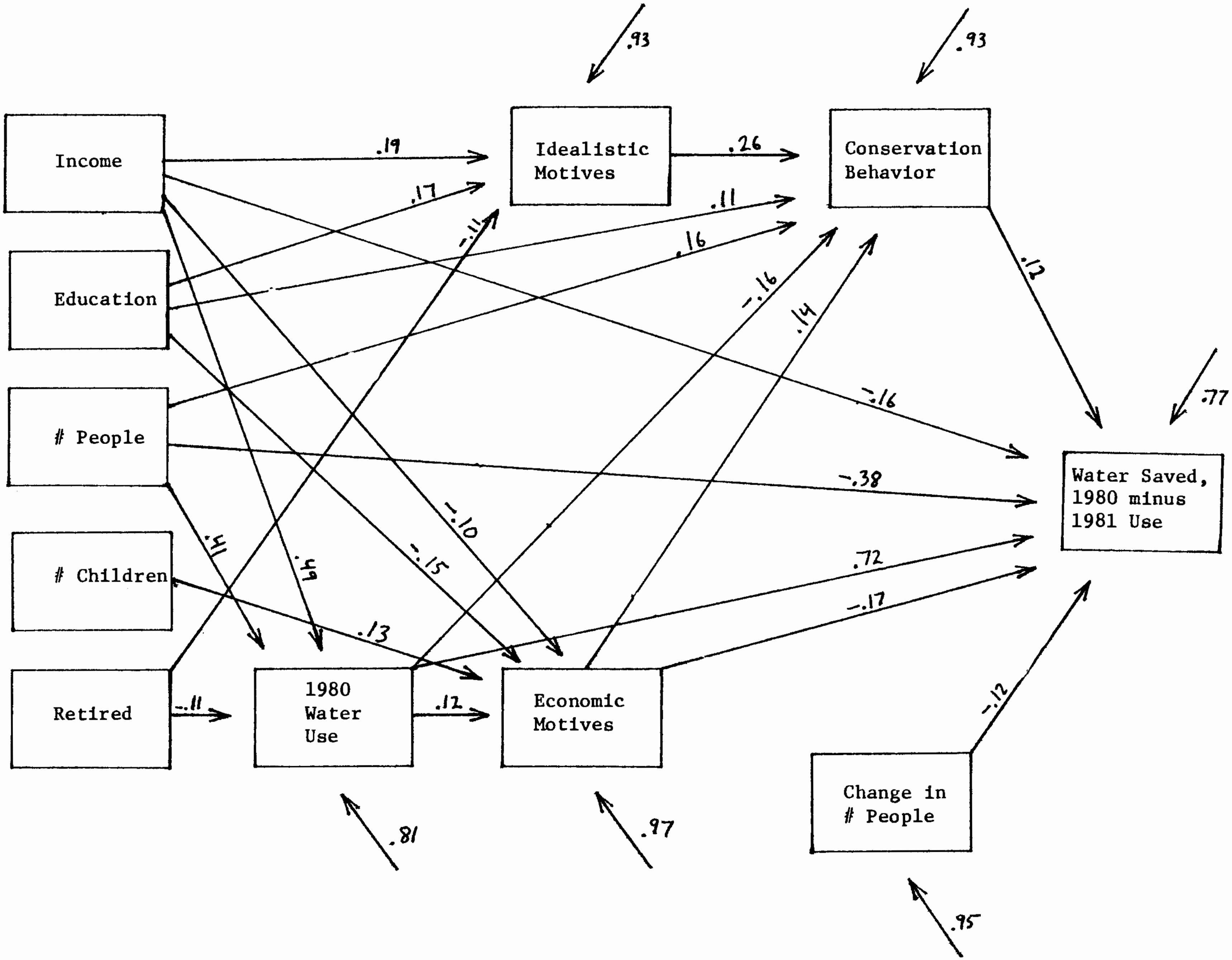

Figure 8: Causal Model of Water Conservation Behavior, with Standardized Regression Coefficients (see Table 10)

of # People, # Children, and 1980 Water Use on the Change in # People. Structural equations, with standard errors and unstandardized regression coefficients, are given for this model in Table 10. Note that Table 10 includes equations with both 1981 water use and water conservation (1980 use minus 1981 use) as the dependent variables, and that parameter estimates in the two equations follow the pattern of algebraic equivalence described above.

Findings

The central bivariate relationship described earlier remains intact in the multivariate analysis of Figure 8/Table 10: The higher the household's 1980 use, the more it reduced that use in 1981. This is by far the strongest relationship in the model. Conservation behavior, as measured by the indoors/behavioral factor of section IV, also increased conservation. Surprisingly, none of the other conservation steps (curtailing outdoors use, installing devices, repairing leaks) could be shown to have had a significant impact on conservation. Unsurprisingly, changes in the number of people living there were a significant determinant of changes in water use.

Households with higher incomes, more people living in them, and citing predominantly economic motives for conservation, were less likely to save water when other variables are controlled. This finding pertains only to their direct effects, however; assessment of indirect effects will be described below.

Indoors conservation behaviors (less flushing of toilets, shorter showers, shallower baths, etc.) are more likely in households with higher levels of education, more people living there, and both idealistic and economic motives for conservation. They are less likely, *ceteris paribus*, in households with high baseline water use levels.

TABLE 10

STRUCTURAL EQUATIONS FOR FIGURE 8*

Dependent Variable	Intercept	Conservation Behavior	Change In # People	Idealistic Motives	Economics Motives	1980 Water**	Income**	Education	# People	# Kids	1 if Retired	R_a^2
1981 Water Use**	7.21	-1.14	2.32		2.11	.57	1.06		2.19			.73
	(1.48)	(.38)	(.75)		(.49)	(.03)	(.28)		(.27)			
Conservation Behavior	1.31			.31	.18	-.01		.03	.10			.11
	(.23)			(.06)	(.06)	(.003)		(.01)	(.03)			
Change # People	-.26			-.03	.01	-.01	.03	.00	.14	-.14	.04	.09
	(.14)			(.03)	(.03)	(.002)	(.02)	(.01)	(.02)	(.03)	(.06)	
Idealistic Motives	-.91						.10	.04			-.20	.12
	(.19)						(.03)	(.01)			(.08)	
Economic Motives	.44					.006	-.05	-.04		.08		.06
	(.18)					(.003)	(.03)	(.01)		(.04)		
1980 Water Use**	28.1						2.21		3.84		-3.49	.31
	(2.8)						(.52)		(.43)		(1.54)	
Water Saved: 80-81**	-7.21	1.14	-2.32		-2.11	.43	-1.06		-2.19			.39
	(1.48)	(.38)	(.75)		(.49)	(.03)	(.28)		(.27)			

* Unstandardized regression coefficients, with adjusted R^2, and standard errors in parentheses.

** The square root of water use and household income were used in these regressions.

Idealistic and economic motives show evidence of quite different etiology. Idealistic motives are positively related to income and education, and negatively related to retirement. In other words, this motive variable has the pattern of socioeconomic correlates (income, education, and age) which are often identified with environmentalism. Economic motives are almost the reverse; they are of most concern to households with lower incomes, less education, more children, and higher baseline water use. These are exactly the people for whom the costs of water use <u>should</u> be most important, since water undoubtedly consumes a much larger fraction of their income. Pragmatism should dominate idealism or ideology in their view of the water situation.

1980 water use is strongly related to household income and the number of people. When these two variables were controlled, many other theoretically reasonable predictors such as number of bathrooms, water-using appliances or habits, etc., became statistically insignificant. 1980 water use is also lower among retirees.

Indirect effects in Figure 8 can be found by multiplying path coefficients along sequences of connecting arrows. For example, in this sample people with higher incomes were more likely to claim idealistic motives; people claiming idealistic motives were more likely to say they had adopted conservation behaviors; and people saying they adopted conservation behaviors actually did conserve more water. Thus income has an indirect effect on conservation, through idealism and conservation behavior; the magnitude of this effect is found by multiplying (.19)(.26)(.12)= .006. In other words, for every one-standard deviation increase in income, this particular indirect path produces a .006 standard-deviation increase in the average level of conservation. Most of the other indirect effects, like this one, are vanishingly small. There are two important exceptions, however, involving income and the number of people.

As shown, income has a negative direct effect on conservation: the higher the income, <u>ceteris paribus</u>, the lower the conservation. However, income also positively affects 1980 water use, which in turn <u>increases</u> conservation, with an indirect effect of (.49)(.72)=.35, a positive influence that more than cancels out income's negative direct effect of -.16. When all of income's direct and indirect effects upon conservation are added up, the total effect is near zero. From the model, though, we see that wealth in itself tends to decrease conservation, while at the same time leading to the higher water use levels that are one of the major causes of increased conservation.

Like income, the number of people in a household has a major indirect effect of opposite sign from its direct effect. The direct effect is negative (-.38), indicating that, other things being equal, larger households were less likely to reduce their use. But there is also a substantial positive indirect effect through 1980 water use, (.41)(.72)=.30. Unlike income, the total of direct and indirect effects from the number of people do not quite cancel out to zero. Household size has a negative total effect on conservation.

Summary

The findings described above can be summarized as follows:

(1) The most important single variable influencing water conservation is pre-shortage water use. The higher the pre-shortage use, the higher the the amount and percentage of post-shortage use reductions. This finding is robust across variations in analytical strategy, and remains quite strong in multivariate analysis even with more than twenty other variables in the equation. It can be concluded with some confidence that this effect is neither a methodological artifact nor a spurious consequence of income, household size, etc.

(2) The sample as a whole reduced water use, and reported near-universal adoption of some conservation steps. The only conservation steps that were useful in explaining within-sample variation in conservation were those involving indoors, behavioral changes such as not flushing toilets, and taking shorter showers or shallower baths. These indoors, behavioral changes were most strongly related to idealistic rather than economic motives.

(3) Idealistic motives for conservation were strongest among those with higher levels of income and education, and weaker among retired persons. Economic motives, on the other hand, were strongest among those with lower income and education, larger numbers of children, and higher baseline water use. People citing economic motives may actually have conserved less water than others.

(4) A set of variables including number of bathrooms, appliances, and ways water is normally used, become unimportant to the analysis when baseline water use and background demographic variables are controlled.

VI. DISCUSSION AND RECOMMENDATIONS

This study involved innovations in both methods and objectives. Results provide a basis for recommendations in two broad areas: conservation-program policy and conservation-research methodology. The more interesting policy issues will be considered first.

Policy Implications of Findings

The study was intended to suggest where conservation appeals had been most and least successful, and to provide insight into just how the successful Concord program actually achieved its water-saving goals. Findings on these topics have implications for how optimally effective conservation appeals might be structured.

Although conservation was widespread, the bulk of the savings were made by households with high baseline consumption. High-use households have more flexibility in reducing "luxury" uses such as very green lawns, long showers, running half-empty washers, etc. It may be relatively less painful to curtail such uses, and it may also be particularly obvious to high-use households that their wasteful practices should be curtailed. High-use households have the further incentive of being able to realize much larger monetary savings by making reductions in their use. These findings suggest that conservation appeals should be directed specifically at high-use neighborhoods, and at the types of consumers who are using (and presumably, wasting) higher volumes of water to begin with. Appeals to idealistic motives may be most successful with these households, despite the obvious economic incentives.

Appeals to economic motives were more important to poorer households, but these households often have less flexibility to make significant reductions in their use. Retired people, for example, use less water to begin with, and have limited scope for conservation. Families with many children may use more water, but have difficulty in reducing their use. A number of respondents reported that they, as heads of households, were all for conservation, but their teenage sons or daughters refused to cooperate in, for example, taking shorter or fewer showers. The group that may have the easiest time saving water is households with high incomes, high educations, high baseline water use, but relatively few people living there.

Some of the overall reductions in water use achieved by the people of Concord resulted from widespread decreases in outdoor water use. In this sample, reports of such outdoors conservation were so common that they had little variance (see Table 5), and consequently were unable to predict variations in conservation from one household to another. The indoors-behavioral conservation factor, which was composed of such steps as flushing toilets less often, taking shorter showers and shallower baths, running dishwashers only when full, etc., was more successful in explaining this within-sample variation. These conservation behaviors are interesting and important in several respects, and not just because they significantly affected actual water savings. Such indoors changes involve no hardware or investments, and thus can be made instantaneously. They are by and large invisible to others, so they occur in a complete absence of the peer pressure that operates against proscribed outdoors water uses. Finally, they involve changes in people's basic everyday behavior and cleanliness habits, which do not seem like easy things to change. It is interesting that the strongest single predictor of indoors-behavioral conservation is idealistic motives; economic motives were relatively less important in explaining this type of conservation behavior. From this it would appear that conservation appeals focussing on middle and upper-middle class households, describing the savings achievable by these indoors behavioral changes, and emphasizing idealistic more than economic motives, would be a valuable supplement to any more general conservation campaign.

Most of the people in the sample reported awareness of the water shortage. We know that they were bombarded with mailed flyers, presentations made to their children in school, announcements by public officials, and news items in local newspaper, radio, and occassionally television reports. The information sources that stuck in the minds of these adult respondents were primarily the newspapers, radio, and visual inspection of the reservoir. The latter was the second most common source cited, and many of those who cited newspapers referred specifically to the pictures of the reservoir which it carried. This suggests that the "realness" of the water shortage was brought home to people in two important ways: through the visual impact of seeing the low reservoir, in person or in photographs; and through the legitimacy conferred on the shortage by its appearance in the daily news. Since news releases are a relatively cheap form of publicity, they should play a major role in establishing the urgency of a water crisis. Mailed flyers may be less effective for generating this urgency, and be most useful in their ability to outline detailed steps by which a household can save water--once it has decided to do so. If there is any way to visually dramatize the water shortage (e.g., photographs or tours of low lakes, streams, etc.), this should be given high priority as a communication strategy. Unfortunately, the findings also suggest that communities relying on invisible water sources, or near plentiful but unusable water bodies, will have a harder time persuading their citizens that a real shortage exists.

Conservation education programs in the schools were seldom mentioned by the respondents. This does not necessarily indicate that such programs were ineffective; their primary targets were children, whose behavior a mailed questionnaire cannot be expected to measure accurately. Even if the education programs had no immediate impact, they may have important long-range effects, and make the children more receptive to water supply issues in the future. However, there is no evidence in this study to support the hope that educating children will have a direct impact on their parents' conservation behavior.

Implications for Future Research

This project has demonstrated the feasibility of combining water billing records and mailed survey questionnaire data, to provide an in-depth examination of which households do and do not conserve water. Some of the specific methodological findings were: (1) mailed survey questionnaires about water conservation can obtain reasonably high response rates, with no evidence of serious response bias; (2) self-reports of whether use increased, decreased, or remained the same have almost no validity, and should not be considered a useful proxy for actual changes in water use; (3) water-use distributions are positively skewed, but this skew can be readily corrected by taking the square root of household water use; the logarithm of household water use is often negatively skewed; (4) water use, conservation steps, and conservation attitudes and beliefs are all multidimensional; factor analysis can be used to identify the underlying dimensions and generate factor scores, but simple additive scales of conceptually related variables will often be misleading; (5) many of the obvious variables for a water-conservation model are redundant once previous water use and background demographic variable are controlled; (6) either post-shortage water use, or pre-shortage/post-shortage change, may be used as an ultimate dependent variable, with statistically equivalent results; and

(7) some conservation measures and pro-conservation beliefs were so widely claimed that these variables were useless for explaining within-sample variation.

Water-conservation research necessarily progresses by the accumulation of community case studies, so this Concord investigation invites replication elsewhere. Aside from replication, there are two particular areas where future studies should try to improve upon this one: in the measurement of attitudes and beliefs, and in obtaining separate measures of the "conservation" and "inertia" effects of pre-shortage water use.

Some of the attitude and belief measures included in the survey received almost universal agreement, and hence were not variables but constants. The list of opinion questions should be made longer and more sensitive in future studies, and should include more scales constructed from open-ended as well as fixed-choice questions. It is also important to note that this survey occurred well after the actual water shortage had passed. The real research question is how attitudes influence subsequent behavior. This question is only addressable in research designs where the survey is conducted during the water shortage itself. The problem is that such shortages are rarely predictable, and it is hard to obtain funding to conduct research without specifying the site selected well in advance--sometimes more than a year before doing the study. Doing a survey during a crisis would greatly strengthen the attitude-behavior component of the analysis, in particular, and provide a generally more solid foundation than a retrospective survey can.

To sufficiently untangle the "conservation" and "inertia" effects of pre-shortage use, it would be necessary to collect data going back many more years. If, in addition to 1980 and 1981 water use, we had known use for the same households for 1975-79, it would have been possible to construct an empirical model of the normal "intertia" effect in non-shortage years. The average inertia effect could then be used as an estimate of that parameter for 1981 regressed on 1980, and the difference between the actual regression of 1981 on 1980, and the regression expected from the inertia effect, could be interpreted as a conservation effect.

Both of these improvements, during-crisis surveying and longer-term water data collection, should be practical in future extensions of this work to other communities. Such replications and extensions will contribute to a sound base of empirical knowledge about public responses to water conservation campaigns. This knowledge, in turn, should be immediately useful in designing more effective campaigns.

APPENDIX A

City of Concord, New Hampshire
WATER DEPARTMENT
16 PENACOOK STREET • 03301

JOHN L. FORRESTALL
DIRECTOR
603-225-5574

May 3, 1982

Dear Water Customer,

During the two year period of 1980-1981, the City of Concord experienced a water supply emergency caused by lack of rainfall and overuse of existing supplies. At that time voluntary conservation measures were requested of its citizens and in early 1981 several water use restrictions were placed in effect.

As the situation improved and new supplies were made available, restrictions were lifted and the City returned to normalcy. Certain areas of the nation, however, are not as fortunate as we in having adequate water supply. The program which we as citizens of the City of Concord followed to conserve water was very successful, and it would be most useful to other communities to identify those factors such as attitudes, techniques and devices which contributed to our success.

Lawrence C. Hamilton, Ph.D., Assistant Professor of Sociology at the University of New Hampshire has received funding from the U.S. Department of Interior to perform research into resource conservation behavior. For the past eleven months Professor Hamilton has been investigating the statistical data available at the Concord Water Department. It is now imperative to identify the factors which led to the statistical improvements, and therefore, a random sampling of approximately four hundred households is being performed. Your household has been selected as one of these. Enclosed you will find a questionnaire which we would ask that you complete and return to Professor Hamilton in the envelope provided. The success and usefulness of this study hinges upon the willingness of citizens such as yourself to provide candid and truthful information. The confidentiality of your response is assured.

I want to thank you in advance for the time and effort which you will be expending in filling out the questionnaire. If you have any questions about this matter, please feel free to contact me at 225-5574.

Sincerely,
John L. Forrestall
John L. Forrestall
Director of Water Works

JLF/jab

______ Check here and return if this is not a residential address.

CONCORD WATER SURVEY

1. During last summer (summer 1981), how many people were there living in this house, including yourself? ______

2. How many of the people living in this house last summer were school-aged children, from first to twelfth grade? ______

3. How many of the people living in this house last summer held full-time jobs (30 hours or more a week)? ______

4. Comparing last summer (1981) with the previous summer (1980), did the number of people living in this house increase, decrease or stay the same? (Circle one answer and fill in number of people.)

   (a) increased by ______ people

   (b) stayed the same

   (c) decreased by ______ people

Below is a checklist of ways in which households use water. Check any items that are ways in which this household normally used water.

5. dishwashing machine ______
6. clothes washing machine ______
7. watering lawns ______
8. watering gardens, trees, bushes ______
9. filling swimming pools ______
10. washing cars ______
11. sink garbage disposal ______

12. How many bathrooms are there in this house? ______

13. Besides those listed in 5-11 above, and ordinary kitchen and bathroom use, can you think of any other important ways in which this household uses water?

14. In 1980 and 1981, some Concord officials reported that the City faced a serious shortage of water. Did you agree, disagree, or not know about these reports? (Circle one answer)

(5)	(4)	(3)	(2)	(1)	(0)
Agreed Strongly	Agreed	Undecided	Disagreed	Disagreed Strongly	Didn't Know

15. Can you briefly explain your opinion on the previous question 14? What were your sources of information?

Some people believe that household water-saving, or conservation, can help out in communities faced with a water shortage. Below are a few of the arguments for and against water conservation. For each argument, indicate how strongly you agree or disagree with that argument, as it applies to Concord and your current residence. If you have no opinion, or are undecided, circle (3) Not Sure.

16. Most people in Concord would not respond to requests to use less water.

(5)	(4)	(3)	(2)	(1)
Agree Strongly	Agree	Not Sure	Disagree	Disagree Strongly

17. Using less water would actually save this household a significant amount of money.

(5)	(4)	(3)	(2)	(1)
Agree Strongly	Agree	Not Sure	Disagree	Disagree Strongly

18. In recent years, water shortages have not been a serious problem for Concord residents.

(5)	(4)	(3)	(2)	(1)
Agree Strongly	Agree	Not Sure	Disagree	Disagree Strongly

19. Individuals have a moral responsibility to do their fair share in solving a community problem such as a water shortage.

(5)	(4)	(3)	(2)	(1)
Agree Strongly	Agree	Not Sure	Disagree	Disagree Strongly

20. If each household did use less water, it would go a long way in improving a shortage situation.

(5)	(4)	(3)	(2)	(1)
Agree Strongly	Agree	Not Sure	Disagree	Disagree Strongly

21. It would be too inconvenient or costly for this household to save much water.

(5)	(4)	(3)	(2)	(1)
Agree Strongly	Agree	Not Sure	Disagree	Disagree Strongly

22. Do you wish to add any explanation of your opinions on previous questions 16-21?

Below is a list of some of the things which people might do in order to use less water. Check any which were actually done by your household during 1980-1981.

23. ______ Installed water-saving device in toilet.

24. ______ Repair leaky faucet, pipe, or other.

25. ______ Water lawn less often than usual.

26. ______ Water garden or trees less often than usual.

27. ______ Not fill swimming pool (if have one).

28. ______ Wash car less often than usual.

29. ______ Take shorter showers or shallower baths.

30. ______ Installed water-saving device in shower.

31. ______ Flush toilets less often.

32. ______ Other water-saving steps (specify)____________________________

____

____

33. If you took any of the water-saving steps mentioned above, what were your most important reasons for doing so? For example, to save money, to help water shortage, other?

34. If you did not take any of these steps, can you give any reasons for not taking them? For example, too much trouble, too expensive, wouldn't do any good, didn't believe there was a real water shortage?

35. Can you think of any other reasons, besides the water-saving steps listed previously in 23-32, why your household's summer 1981 water use might have been different in any way (greater or less than) its use in the summer of 1980? For example, went on vacation, plumbing repairs, new appliances, people moved in or moved out, house guests, other?

36. Comparing last summer (1981) with the summer before that (1980), do you think your household's water use increased, decreased, or stayed about the same?

(3)	(2)	(1)	(0)
water use increased in 1981	stayed about the same	water use decreased in 1981	don't know

37. Briefly explain why you think it increased, decreased, or stayed the same.

The questions below are for statistical purposes only. We need to have some information about the background characteristics of the households filling out this survey. All answers will be kept strictly confidential.

38. What is the occupation of the head of this household? If there are two employed heads-of-household, list both occupations. If retired or not employed, answer for last full-time job.

39. Briefly describe what kind of work this occupation (or these occupations) involves.

40. Check the highest year of school completed by the head of this household. If there are two heads of household, check highest year completed by either.

______	no formal schooling (00)	______	6th grade (06)
______	1st grade (01)	______	7th grade (07)
______	2nd grade (02)	______	8th grade (08)
______	3rd grade (03)	______	9th grade (09)
______	4th grade (04)	______	10th grade (10)
______	5th grade (05)	______	11th grade (11)

______ completed high school or G. E. D. (12)

______ vocational, technical, business school, etc. (13)

______ some college (14)

______ college graduate (Bachelors degree) (16)

______ some graduate or professional school (law, medical, etc.) (18)

______ graduate or professional degree (M.A., Ph.D., M.D., etc.) (20)

41. What is the combined, before-taxes income of all members of this household?

______	below $5,000	(00)	______	$25,001 to $30,000	(25)
______	$5,000 to $10,000	(05)	______	$30,001 to $35,000	(30)
______	$10,001 to $15,000	(10)	______	$35,001 to $40,000	(35)
______	$15,001 to $20,000	(15)	______	$40,001 to $45,000	(40)
______	$20,001 to $25,000	(20)	______	$45,001 to $50,000	(45)

______ over $50,001 (specify)________________________________ ( )

42. Thank you for participating in our survey. If you have any further comments you would like to make, about any of the issues mentioned in this questionnaire, please write them below:

43. If you would like to receive a copy of the findings from this survey, give your name and address below. Otherwise this information is not needed. With or without addresses, all your responses on this survey will be kept entirely confidential.

APPENDIX B

Dear Water Customer:

This card is sent as a reminder to please fill out and return the Water Survey Questionnaire you received a few weeks ago, if you have not already done so. The results from this survey will be of interest in many other cities, so the Concord data must be as complete as possible. Your answers are extremely important to us.

Thank you for your participation.

Sincerely,

Lawrence Hamilton
Project Director

APPENDIX C

unh
UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE 03824

Water Resource Research Center
Pettee Hall — 108
603/862-2144

June 11, 1982

Dear Water Customer:

Enclosed is a replacement questionnaire and return envelope for the Concord Water Survey. If you have not already filled out and returned one of these questionnaires, we hope that you will take the time to do so now. In order to reach sound conclusions, we need to hear from as many of the households selected for this study as possible. That includes even households which were not aware of the 1981 shortage, or were unable to save any water themselves. Space is provided on the questionnaire for any additional thoughts, explanations or comments you may have.

We apologize for the necessity of these repeated mail contacts, and promise that this one will be the last.

Sincerely,

Lawrence Hamilton

Lawrence Hamilton
Project Director
Water Survey Project

LH/gd

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