APPLYING THE IWR-MAIN WATER DEMAND FORECASTING MODEL IN A GEORGIA CITY

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INTRODUCTION

Planning for reliable water supplies has been and is a major undertaking for local and regional governments. The planning process involves financing, water supply forecasting, water quality, waste treatment and water demand estimation. Although all areas of planning are important, in this paper only one input into the decision process is addressed - forecasting water demand. Many factors affect water demand for any given municipality and the ability to combine these factors into a format that provides useful inputs is an art as well as a science.

Many studies have dealt with various aspects of water demand such as residential water use and expected reactions to changes in income, price, employment, housing values, population, metering arrangements, etc.. (Ware and North, 1968; Linaweaver et al. 1964, 1966; Howe and Linaweaver, 1967; Howe, 1982; Gottlieb, 1963; Hanke, 1970; Schefter and David, 1985; Morgan, 1974; Gibbs, 1978; Kitchen, 1975; Wong, 1972; and many others). Urban nonresidential water use studies such as Wolff et al., 1966; Dziegielewski, 1988; Lynne et al., 1978; McCuen et al., 1975; Kim and McCuen, 1979; Mercer and Morgan, 1974 have attempted to provide guidance for estimating other specific uses of water. Morgan and Smolen (1976) deal with the incorporation of climatic indicators in demand analysis.

Many variations and statistical techniques have been suggested, as indicated in the above references, for associating water demand and various assumed independent variables. The forecasting techniques in the IWR-MAIN System (Davis et al., 1988) use some accepted econometric methods such as those suggested in Taylor (1975), Nordin (1976), and Howe (1982) for residential demand estimation and unit use coefficients methods for all other uses. Residential demand is considered to be a function of income, housing value, price, number of occupants per unit, total population, climatic conditions, and conservation and other water savings efforts.

Commercial/institutional and industrial water use estimates are based on coefficients developed through various studies and expressed as gallons per day per employee. These establishments are broken down by SIC code, and coefficients were estimated for each general SIC code grouping. These use coefficients were derived from studies done in various sections of the United States and averaged. The commercial coefficients are from 1984 data while the industrial coefficients are from 1982 (Davis et al., 1988). Total nonresidential water use is calculated by multiplying the various category parameters (employment per category) by the category's water use coefficient. Distribution losses are estimated as a percentage of the total municipal water use when no additional information is available. To summarize, the IWR-MAIN water use forecasting system is a computerized planning tool for estimating current and future water requirements for municipalities. The system used by IWR-MAIN follows accepted methodology for estimation (See Tables 1 and 2) and has been evaluated for reliability for several municipalities by comparing IWR-MAIN estimates to actual data (Dziegielewski and Boland, 1989).

THE FORECASTING PROCEDURE FOR THE IWR-MAIN SYSTEM

Parameter Projection Methods

For each forecast year, water use is calculated as a function of water use parameters (e.g., housing units, marginal price, employment). Some of these parameters are projected to the forecast year for which water use is to be estimated. The IWR-MAIN System provides three alternative methods for projecting future values of the determinants of water use:

1. Projection by internal growth models.
2. Projection by extrapolation of local historical data provided by users.
3. Use of projections made external to the IWR-MAIN System, as provided by the user.

In general, for each forecast year each projected method may be selected independently of other parameters and other years. When several different projection options are employed for a given year, the possibility of conflicts or

Sector	Water Use Category	Forecast Method
Residential	Metered and sewered residences	Econometric demand models
	Flat rate and sewered residences	Mult. coef. rqrmts. models
	Flat rate and unsewered residences	Mult. coef. rqrmts. models
	Master-metered apartments	Mult. coef. rqrmts. models
Commercial/ Institutional	Up to 50 user categories, including 23 categories defined as groups of four-digit SIC codes	Unit use coefficients (per employee)
Industrial	Up to 200 user categories, including 198 manufacturing categories defined by three-digit and four-digit SIC codes	Unit use coefficients (per employee)
Public/ Unaccounted	Up to 30 user categories, such as distribution system losses and and free service	Unit use coefficients or per capita requirements

Table 1. Organization of the IWR-MAIN System
Source: U.S. Army Corps of Engineers. 1988. IWR-MAIN Water Use Forecasting System Version 5.1. IWR Report 88-R-6.

inconsistent assumptions must be considered. IWR-MAIN resolves these internal conflicts by a given system of priorities. As a general rule, the external projections supersede those made by extrapolation of historical trends, which, in turn, supersede those made by the internal growth models (Davis et al., 1988).

Internal projections can be made for:

1. Total number of housing units
2. Number of housing units per category (individual metered, flat rate, master metered, etc.)
3. Number of housing units per value range
4. Employment per major industry group
5. Employment per commercial/institutional category
6. Employment per industrial category.

The projection methods for growth components were estimated from available data using ordinary least squares regression analysis. Several attempts were made at finding the best combinations of explanatory power and suitability with respect to data requirements. The projection models selected for inclusion in the IWR-MAIN System seemed

Mean Sprinkling Use for Metered and Sewered Residences in United States, East of 100th Meridan

$$Q = (385.0 + 2.876V - 285.8P_{s\,-\,4.35}I^{s} + 157.77{*}B{*}MD)N_r$$

where

Q = mean summer water use for category, gallons per day

V = median market value for residence within specified value

P_s = marginal price of water in summer, dollars per 1,000 gallons

I_s = effective summer bill difference variable, dollars per billing period

B = irrigable land per dwelling unit, acres per unit

MD = summer season moisture deficit, inches

N_r = number of residences in value range

TABLE 2: EXAMPLE OF ECONOMETRIC DEMAND
Source: U.S. Army Corps of Engineers. 1985. IWR-MAIN Water Use Forecasting System Version 5.1. IWR Report 88-R-6.

to predict and respond appropriately to changes in dependent variables.

The total projected water use requirements are affected by the anticipated conservation efforts ongoing or proposed for the users in the study area. The process of "tempering" the total estimates is discussed in the following section.

The Conservation Effectiveness Algorithm

The methodology followed in the determination of the effectiveness of conservation measures is described in Baumann et al., (1980). There are three important prameters in the determination of effectiveness of each measure: (1) the fraction reduction in water use (R), (2) the coverage or market penetration (C), and (3) the projected water use without conservation (O).

The water use dimensions for conservation are indoor, outdoor, and maximum-day sprinkling use. Active water conservation programs often involve the application of more than one water conservation measure to a given municipal sector. The effects of the interactions and the possible effects of an additional measure is adjusted by an interaction factor (see Richards et al., 1984). The conservation measures included in the model are: public education programs, metering, pressure reduction, pricing policy, rationing, sprinkling reduction, industrial reuse/recycling, commercial reuse/recycle, leak detection and repair, retrofit of showerheads and toilets, moderate plumbing code, advance plumbing code, low water-using landscaping for new construction, and low water-using landscaping for existing areas.

The conservation algorithm uses reductions coefficients that are stored in the Library of Conservation Coefficients (LCC) and can by changed to reflect any known differences is the coefficients in the LCC and those found in local research. The algorithm also takes into consideration the timing of implementation of the measures. If a measure has been in place for a long period of time, little additional reduction in water use coefficients can be expected for future projections.

Pricing variable changes are reflected first as a reduction fraction (R_{msd}) and then worked through the model using the elasticity's associated with the selected water use category. The particular elasticity coefficient selected by the IWR-MAIN model for a specific water use category is the midpoint of the range of reported price elasticities as found in Boland et al. (1984). These coefficients, as well as any others, may be adjusted based upon studies and other information that indicated that there are "better" estimates of coefficients than those in the LCC.

Summary of IWR-MAIN

The IWR-MAIN System, in general, allows for input of all commonly recognized decision variables for water use requirements and allows for changes in use coefficients contained in the libraries that are used in the forecasting procedures. Minimum data requirements can be obtained from government publications and utility records. The problems associated with gross data and data that is dated are always present. But the IWR-MAIN System can, if properly calibrated, be used to obtain useful estimates for water use requirements for municipalities. Most applications used to verify the results of the IWR-MAIN have been on relatively large systems due in part to the fact that secondary data have been readily available from census data for large metropolitan area. Larger utility companies have had better reporting systems for water use than the majority of the smaller systems.

In an attempt to demonstrate the process and usefulness of the IWR-MAIN System for Georgia cities, the forecasting procedure was applied to the Macon-Bibb County Water Authority System. After considerable effort and many attempts at calibrating the model for Macon, we were able to consistently generate forecasts that respond in the changes in variables in the direction and magnitude expected. In the following section, the various difficulties with the Macon case and adjustments in coefficients necessary for realistic estimates are discussed.

THE MACON EXAMPLE

Secondary data from federal, state and local sources were gathered to generate an economic and demographic data base. Most data was dated due to the fact that U.S. Department of Commerce data is available at ten year intervals for population, etc. and five year for employment and other considerations. Georgia Department of Labor and Revenue data were used to update inputs for more recent periods. Economic development agency data and data from the Macon-Bibb County Chamber of Commerce were used to indicate changes in possible water- requiring commercial/institutional and industrial facilities. Data on water use was supplied by the Macon-Bibb County Water Authority for the years of 1988 and 1989. This data was broken down by type of service, meter size and usage by route. The billing procedure used by the water authority simplified the classification procedure because all service in the area is metered and most have sewer connections. For residential customers there are only two classifications: (1) Meter and sewered single family units; and (2) master metered apartments. Billing rates and usages were supplied for average usages by different classifications and could be used to calculated the pricing variables for the model.

The data was placed into the model through the use of model supplied input screens. No modification to the model coefficients was done on the first run. The results of this run were not very satisfactory due to the fact that for 1980 and 1990 estimates for all classification were not within known limits.

The first adjustment to the forecasting procedure was aimed at correcting the estimating procedure for residential uses. The adjustment was to use data for residential usage to indicate the magnitude of the underestimate of the model. Then the prediction equations were adjusted by moving the intercept of the use equation upward. The general slope of the funcions seemed to be acceptable; the problem was that the estimates were consistently lower than actual metered amounts. After this relatively small adjustment, the model generated realistic estimates for all residential usages.

The same problems were encountered in the industrial and commercial sectors. What had to be done to make the model work for these sectors was to attempt to relate the water use to the number of employees for most of the major water users on a case by case basis and update the library of coefficients accordingly.

At this stage it was determined that for this model to be used, the use coefficients for major water users had to be generated external to the model for most establishments. The large tobacco manufacturer, for instance, used 1222.7 gallons per day per employee and not the 643.8 gallons suggested by the library provided internally. A zipper factor fell in a SIC classification that the model indicated that the water company should have a coefficient of 187.8 and, in fact, the coefficient for this company was 1204.8 due to the fact that this particular factory did the complete fabrication. There was also the problem of a complete residential community purchasing in bulk from the water authority. The model allows for inclusion of a water user classification not included in the standard SIC classifications. Once the bulk buyer was included in this classification and the above modifications were done, the model generated estimates that compared very favorably with known water uses and losses. At the time the study was completed we did not have the actual total data for 1980 or 1988-1989 period for comparison. Once the actual totals were known for 1980 and 1989, the 1980 backcast was within two percent error and the 1990 forecast was four percent higher than the 1989 actual.

The problems remain in forecasting future events. What we know as the adjusted model seems to be able to generate reasonable estimates and seems to fit the data very well based on backcasting. It should be clear that a lot of work must be done to adequately describe the specific characteristics for any given study area and much care must be taken to make sure the coefficients used in the model are near those that exist in the community. By using U.S.G.S. data and other data, it was able to do that for Macon. Local municipal and regional water authorities should be able to acquire enough data of reliable quality to use the IWR-MAIN System.

If there can be one simple statment made concerning the usefulness of the model it may be this: the system uses state of the art methods and can be "fine-tuned" to generate reasonable forecasts. Estimating for future periods will take time to evaluate as with any other method, but the process of working through the IWR-MAIN System should benefit local planners and decision makers.

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