Special Publication SJ96-SP11

FINAL REPORT

PHASE I
EFFECTS OF WATER USE RESTRICTIONS ON ACTUAL WATER USE

BY

A. C. ROWNEY, PH.D.
M. E. HULLEY, PH.D.
OF
PB WATER
AND
JO ANN JACKSON, P.E.
OF
POST, BUCKLEY, SCHUH & JERNIGAN, INC.

PREPARED FOR

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
1996

EXECUTIVE SUMMARY

This report documents findings of Task IV, Phase I, of St. Johns River Water Management District Investigation of Alternative Water Supply Strategies - Water Conservation and Reuse of Reclaimed Water. This task deals specifically with assessing the effects of water use restrictions on actual water use within the Wekiva River Basin. The project is established in two phases with the purpose of the first phase to develop a detailed methodology for Phase II investigations.

The work was carried out in accordance with a Scope of Work set forth by SJRWMD. Available data were assessed by interview with SJRWMD staff, telephone canvassing of utilities in the study area, and accessing suppliers of climatological data for stations in the vicinity. Based on the assumption that detailed data would be forthcoming as a part of the Phase II activity, the data were found to be adequate for the purposes of this Task. This report sets out a recommended plan of action for completion of Phase II activities, developed in the knowledge of available data sources and after consultation with SJRWMD staff. The recommended program for Phase II contained in this report will, at its completion, provide the deliverables and requirements of Task IV.

CONTENTS

TABLES

APPENDICES

INTRODUCTION

St. Johns River Water Management District (SJRWMD) is responsible for managing ground water resources in a 19 county area of northeastern Florida. Ground water aquifers are currently the primary sources of potable water supply in SJRWMD. The most dependable ground water source is the Floridan aquifer. However, the *Water Supply Needs and Sources Assessment* (Vergara 1994) projected shortfalls in available water supply in certain areas within SJRWMD by 2010. Areas with existing or 2010 projected water supply problems were designated as water resource caution areas.

As a result of the *Water Supply Needs and Sources Assessment*, SJRWMD embarked on an Investigation of Alternative Water Supply Strategies. Strategies being investigated include using lower quality ground water supplies, surface water, reclaimed water, aquifer recharge, aquifer storage and recovery, mitigation and avoidance, and various water conservation techniques.

This report documents the first of two phases of a task undertaken to assess the effects of water use restrictions, using utilities in the Wekiva River Basin as case studies.

Technical requirements of this first phase are to:

- develop methodologies for performing each Subtask in Phase II, including the identification and assessment of numerical techniques and review with SJRWMD to determine the approach that will be used,

- assess the availability of data required for implementing the proposed methodologies in Phase II, including the review of water use and climatic data and other data provided by SJRWMD for the Wekiva Basin to determine sufficiency for numerical analysis, and

- recommend sources of alternative or surrogate data, if needed

As well, estimates of staffing and budgeting required to complete Phase II are dealt with in this Phase.

Essentially, therefore, Phase I is a planning effort with specific identified deliverables. Key to this planning is the development of the approach to the Phase II activity, which will require:

- Assessment of changes in water use through identification of the associations between temporary water use restrictions and actual water use, documenting a variety of specific dates.

- Assessment of climatic impacts on water use by numerically correlating daily and weekly water use with rainfall, high temperature, number of days since last rainfall, and cumulative rainfall for the last seven days, using a multivariate analysis technique and statistical tests approved by SJRWMD.

- Assessment of net effects and overall effectiveness of restrictions for reducing water use during times of temporary shortages. This will include estimation of overall costs of restrictions, accounting for costs to SJRWMD, local governments, suppliers, and users.

Complete details on scope for Task IV, as issued by SJRWMD, are contained in Appendix A.

METHODS

For this task, data and information from utilities and water treatment facilities in the Wekiva River Basin were evaluated to assess various methodologies for determining the effects of water use restrictions. Available data were gathered by interview with SJRWMD staff, telephone canvass of utilities, and contact with sources of climatological data for stations in the vicinity of the basin. The data were examined and graphical correlations between utilities and rain gauge stations were developed as an aid to data evaluation.

The approach used in this phase was as follows:

- Available types of information and copies of available information were requested from SJRWMD.

- The information obtained from SJRWMD was sorted according to pertinenace to Task IV Phase I and II objectives. The information was reformatted into a consistent format to facilitate preliminary plotting and statistical evaluations.

- Public water supply consumptive use permit (CUP) holders from the area affected by the 1993/94 Wekiva Basin water shortage were contacted and canvassed by phone to determine the type and quality of data that might be obtained from those sources. As well, an initial appraisal of the nature of cost implications of the previous water use restriction program was conducted.

- Pertinent meteorological stations were identified and costs of data recovery from those sources estimated based on published price and availability data.

- The data on hand and available were evaluated for adequacy as a basis for stochastic modeling for determining the impact of water use restrictions. Preliminary evaluations were conducted to determine if correlations between water use and climatic factors exist. Given that this is so, it should be possible to

complete the exercise of system identification and analysis that will lead to assessment of the net effects and overall effectiveness of the water use restrictions.

- A meeting was held at SJRWMD Headquarters to review initial impressions of data adequacy and discuss preferred technical approaches in Phase II.

- A proposed method of approach for the statistical analysis of data was developed, based on the identified data sources and types.

- A proposed approach for development of cost factors as required in Phase II was developed.

- A report documenting the available data, proposed methods, and other items required in this Phase was developed.

DISCUSSION

RAINFALL AND METEOROLOGICAL DATA

Availability

Data on Hand. Rainfall data are available from a number of stations around the area. On hand at present are the data from:

- Lisbon, Orlando, and Clermont National Oceanographic and Atmospheric Administration (NOAA) gauges: Daily rainfall and temperature minimums and maximums from January 1, 1988 to December 31, 1992.

- Wekiva Park gauge: Daily rainfall from April 1993 to July 1994.

- Orlando National Weather Service (NWS) gauge: Daily rainfall and temperature minimums and maximums from January 1992 to August 1995.

Other Available Data. A number of rain gauges are located near or about the study area. Of these, data sets considered most useful for the Phase II effort include:

- Records available from National Climatic Data Center (NCDC) since approximately 1960 for gauges at Crescent City, Federal Point, Sanford, Daytona Beach, and Deland.

- Records available at selected water treatment facilities in the Wekiva Basin, including the Apopka, Orange County, Sanlando, and Southern States Utilities facilities. The quality of this information is presently uncertain, and will be established in Phase II.

- As well as daily precipitation, the Clermont and Lisbon NOAA stations and the Crescent City, Federal Point, Daytona Beach and DeLand NCDC stations have been recording minimum and

maximum temperatures since at least 1958. Lisbon (NOAA) has also been recording evaporation since 1961. Daytona Beach (NCDC) has been active since 1948, and is the only major station in the group that has been recording wind speed, cloudiness, pressure, dew point and humidity over that period.

Adequacy

The long term stations of most relevance to the Wekiva Basin are the Clermont, Lisbon and Orlando gauges. These gauges demonstrate a pronounced seasonal effect, as is typical in this area. The length of record and locations available at the major recording stations in the area suggest that ample rainfall information is available to allow regional analysis of precipitation effects with a high degree of statistical significance.

The more site specific information available at the water treatment facilities in the area will require a careful review during Phase II, as they are obtained; however, it appears that there will be a significant amount of information from these sources as well.

In general, it appears that the long term records from major stations will be appropriate for regional level analysis when weekly, monthly and perhaps daily totals of precipitation are required and where a statistical significance for observations during critical periods is sought. For more detailed analysis of critical episodes or events, at daily or sub-daily levels of analysis, the distributed records afforded by water treatment facilities within the basin area can be used as a supplement to the long term records, allowing a better estimate of event volumes, rates, and distributions.

WATER USE DATA

Availability

Data On Hand. A useful data base of production flows for each water treatment facility was provided by SJRWMD. This includes:

- Data for a total of 10 public supply utilities in the Wekiva Basin, including Apopka, Maitland, Ocoee, Orange County Public Utilities (OCPU), Sanlando, Seminole County Utilities, Southern States Utilities (SSU), Utilities Inc. of Florida, Winter Park, and the Orlando Utilities Commission (OUC, also referred to as Pine Hills). These encompass some 24 water treatment facilities. Data are:

  - weekly from June 16, 1993 to March 30 1994
  - daily from March 1, 1994 to June 30, 1994

- Monthly Data for 28 utilities across SJRWMD. This information is available from January 1988 through September 1996.

Other Available Data. Table 1 provides an indication of the extent of data which were found to be available during telephone interviews conducted as a part of Phase I. Public water supply utilities within the Wekiva Basin which were contacted all indicated during interviews that substantial records exist beyond those already obtained by the study team. For the most part, these data include monthly records routinely prepared as part of operational reporting requirements. However, in some cases, the data also include daily records for the period since the inception of the facility. For the smallest facilities, there were some variations in availability of data. Monthly operating reports submitted by water treatment facilities to the Florida Department of Environmental Protection (FDEP) include daily production flow information for each water treatment facility.

Adequacy

As part of initial screening, the data were reviewed. Several points are evident from the records. The first is that clear and significant variations in demand occurred during this period. The second is that there is a strong correlation in behavior between the various stations.

Table I- List of Utilities and Water Treatment Facilities In the Wekiva River Basin Area Designated as Water Shortage Phase I

Utility	Facility	Contact	Phone	Responded	Monthly Flows	Daily Flows	Rainfall	Service Connections and/or Population
Apopka Maitland ocoee Orange County Public Utilities (OCPU)	 Bent Oaks Mt. Plymouth Lakes Orange Village Plymouth Regional Riverside	Bob Elmquist Cheryl Peters Jim Shira Robert Dehler	407-889-1731 407-875-2115 407-656-2322 407-836-6800	Yes Yes No Yes	Yes Yes Yes	Yes Yes Yes	Yes Maybe Yes	Yes Maybe Yes
Sanlando	 Des Pinar Knollwood Wekiva	Jerry Salsano	407-788-3600	Yes	Yes	Yes	Yes	Yes
Seminole County Utilities	 Hanover/Heathrow Lynwood/Bel-Aire	Roger Smith	407-323-9615	Yes	Yes	Yes	Maybe	Yes
Southern States Utilities (SSU)	 Apple Valley Holiday Heights Lake Brantley Lake Harriet Meredith Manor	Sandy Joiner	407-880-0058	Yes	Yes	Yes	Yes	Yes
Utilities Inc. Of Florida	 Bear Lake Jansen Little Wekiva Weathersfield	Mike Dunn	407-869-1919	Yes	Yes	Yes	Maybe	Yes
Winter Park		Jim Enselmo	407-623-3232	No				
Orlando Utilities Commission (OUC)	 Pine Hills	Rick Winn	407-423-9100	Yes	Yes	Yes	No	No

A third point is interpreted from a first examination of the rainfall records in the Wekiva station as compared to the average pumping rate. This examination suggests that the available data display an inverse correlation between rainfall and demand. This reinforces the interpretation that an intervention analysis based on a statistical interpretation of the data will be a suitable means of establishing the degree to which water use restrictions have affected total consumption. As a fourth point, some insight into appropriate time scales can be gained by examining the differences between the normalized daily and weekly flows for the same period of record. It is evident that significant smoothing occurs from this shift in time scale. There appear to be significant changes in the system, therefore, at time scales less than a week in duration.

In general, the information available suggests that data can be developed or recovered from the various suppliers in the Wekiva Basin, supplemented by long and short term rainfall records, and are suitable for the purposes of the Phase II analysis.

OTHER DATA

Availability

Also in hand are a number of other data which will be useful in Phase II:

- Contact names and telephone numbers for the Wekiva Basin utilities.
- A contact name and telephone number for the Wekiva State Park (rain gauge).
- Maps and documentation of the Phase I Water Shortage Restrictions imposed from June 12, 1993 to August 10, 1994.
- Anecdotal information regarding responses to the water use restrictions, including enforcement practices and observed shifts in behavior. Close documentation will have to occur in Phase II,

but it seems clear that some of the issues raised, and which will have to be dealt with, include perceptions that a significant response to water use restrictions was a change in behavior. For example, watering during the evening as opposed to the day time, and/or watering induced by an increased consciousness as restrictions are publicized. As well, there have been comments regarding the apparent effect at the water treatment facilities when and if demands are shifted from traditional peaking patterns to distorted patterns associated with use restriction practices. The objective significance of these effects will have to be obtained during Phase II, as much as possible. Further interview and documentation will be sought.

- As an aid to this further assessment, it appears that the available records at some of the Wekiva Basin water treatment facilities include records of diurnal fluctuations in demand. This takes the form of automatic recording devices at the plant delivery point. These records, properly interpreted, can give a very good idea of the extent and reality of shifts in behavior in the form of changes in demand patterns, as opposed to demand totals.

- SJRWMD has supplied useful direction concerning appropriate approaches to system identification, in the form of a report (Brandes, 1990) which cites prior experience in similar applications in this state. This document provides insights into characteristic variables of most significance, and implies an appropriate model structure. This can be used as a basis for initial and possibly ultimate definition of stochastic models for use in Phase II.

- Substantial literature exists, which will permit the evaluation of findings in Task IV in terms of experience elsewhere. A number of technical papers and documents have been gathered during the course of the Phase I work and more will be obtained and interpreted in Phase II.

A summary of the data collected in Phase I is presented in Appendix B.

Adequacy

Phase I findings suggest that the available data are adequate for the Phase II effort.

CONCLUSIONS

The documentation of data in this study is persuasive in several regards. First, it is apparent that the information will support the study. Second, it is possible to define a study approach in light of the preliminary conclusions of the Phase I examination of the data. Key points are:

- The Wekiva Basin public water supply utility demands are highly mutually correlated, which makes excursions from global average behavior relatively easy to identify. This in turn implies that:

  - The Wekiva Basin utility pumpages can either be assessed independently or, where advantageous, can be lumped and averaged as a means of obtaining global or regional responses to rainfall and temperature. This extends the potential extent and ease of use of the data.

  - The individual utility pumpages may not prove to differ statistically in form from each other in the long term, because of their close correlations. However, they will display differences on an instance by instance basis (i.e., at particular moments in time or during particular events.). This means that it may be possible to identify and relate excursions from the norm to interventions in the form of water use restriction enforcement.

- The long term rainfall records are strongly correlated on a monthly or longer basis, but only weakly correlated on a weekly or shorter basis. This means that the gauges, necessary for generation of long term statistics, should as much as possible be associated with a nearby geographical area.

- It may be that the effects of enforcement of water use restrictions are expressed as a change in use behavior, such as a shift in water demand patterns, rather than as an absolute change in the

net amount of water used. However, the significant concern is to determine potential increases in sustained peak flows resulting from the water use restrictions. Water transmission and distribution facilities are designed for peak hour demands of water. An increase in peak hourly flows could result in the inability to provide water service to certain customers without increasing pumping capacity or pipeline diameters. This means that the analysis will have to consider effects at least at a diurnal level of detail. This will not require a stochastic approach for best effectiveness. Generally, departures from accepted demand norms can be interpreted in terms of departures from use patterns displayed during 'normal' periods. Diurnal water use fluctuations are a well understood effect. Examining patterns from periods before, during, and after the restriction period will allow an assessment of this class of effect.

- Scales of analysis are approximately known based on the Phase I interpretation of data, and based on past experience:

  - The data suggest that a period of approximately five years (five complete annual cycles) will be a suitable base for development of model parameters representative of the cyclic annual component of rainfall and demand variability. Where intervention occurs within a period of one year, this implies that at least six years of rainfall and response data should be available.

  - Where an intervention occurs over a time frame in the order of a week, past experience in public water delivery systems suggests that a period of approximately one month (30 daily cycles, encompassing four weekly cycles) prior to, during, and after the intervention is necessary if a convincing assessment of cause and effect is to be undertaken based on diurnal delivery patterns. This implies a need for gathering at least three months of data within carefully chosen time periods. Past experience shows that this data assembly will have to be done on site, with the cooperation of the utility staff, and by an experienced individual. It will probably be practical to

select three or four utilities for detailed analyses. These utilities should provide typical characteristics which can be extended across the basin.

- It also may be necessary to reconstruct elements of an annual cycle as a part of this exercise, to establish baseline shifts in monthly use. The information noted above could additionally fulfill this need.

RECOMMENDATIONS

In keeping with the Phase I scope, and with the above interpretations and conclusions, as well as feedback obtained in a meeting SJRWMD, the following tasks are proposed:

1. Data Assembly,
2. Data Reduction,
3. Development of a Regional Stochastic Model Representation,
4. Development of A Local Event interpretation,
5. Analysis of Cost Implications,
6. Reporting, and
7. Project Progress Meetings.

A brief overview of each task of the proposed work plan is presented below.

TASK 1: DATA ASSEMBLY

This stage of the work will provide basic data for all aspects of the Phase II study, including physical information and documentation of restrictions and enforcement activities. Documentation of water use restrictions and enforcement activities will be included in two tasks.

As a part of the Phase I effort, a variety of background information was collected and reviewed during the development of this work plan. Some of this was in final form (for example the Orlando and other rain gauge records), and can be used as it now exists. However, in this first Phase, some of the data assessment provided information in the form of references to data sources, locations, type, and accessibility. This level of detail was suitable for Phase I purposes, but must be improved during Phase II.

Prior to data collection, a preliminary screening will be conducted using existing data to select three to four utilities for more detailed analyses. Selection will be reviewed with SJRWMD prior to proceeding with data collection and will include consideration of such factors as availability of detailed data, level of enforcement activities,

and location within the basin. This task will obtain necessary data in final form for completion of Phase II as follows:

- Rainfall records from the period 1985 to date will be collected for the gauges identified above. This will provide a set of records useful in this and a number of other Tasks in this program.

- Monthly operating reports for the selected utilities in the Wekiva Basin for the period 1988 to date will be collected from DEP.

- Site visits will be conducted to the selected Wekiva Basin utilities or to water treatment facilities to obtain all data on:

  - meteorological records (precipitation, temperature and other data as available) , for the period from 1988 to date if possible or for the period of record if shorter.

  - formal records of water restriction compliance, public announcements, and enforcement activities.

  - anecdotal or formal interpretations of consequent events during the restriction periods, such as perceived changes in behavior and effectiveness of enforcement.

- Diurnal demand data (delivery rates) in the form of strip chart and disk recorder records for the period of water use restrictions and for a period identified on site (by inspection of records) as being representative of pre- and post- restriction behavior will be acquired. The sites will be chosen on the basis of the best available data, enforcement patterns, and the most likelihood of a useful interpretation of shifts in diurnal demand patterns.

TASK 2: Data Reduction

The data in this study will be analyzed in two separate assessments. First, there will be a significant amount of statistical manipulation of

information for time series and statistical analysis. Second, there will be a significant amount of effort involved in estimating demand periodicity for the assessment of demand pattern shifts. In both cases, a data base providing rapid access and substantial integrity will be required. It is also recognized that the data will be of continuing interest at the completion of the study, so the data should be delivered to SJRWMD in a form readily adapted for subsequent use.

The delivery format adopted for the study will be dBASE IV. To facilitate analysis during the actual course of the study, however, Borland Paradox will be used as a database engine. This environment has direct interface capability with a variety of statistical routines and is directly compatible with Delphi, which will be the language of choice if direct programming is required. It is also noted that conversion to other formats including dBASE IV can be accomplished from Paradox.

The specific steps in this item are:

- Develop a data codification scheme. Ready interpretation and access to data will be facilitated if a logical identification scheme is developed. A first step will be to confirm and apply SJRWMD data nomenclature. It is necessary that site identification be a primary data key, and that an additional key represent time, with parameters (rain_ins, temp_F, flow_mgd and others as necessary) defined as fields.

- Develop a data base structure. This study will complete a large number of lengthy computations, so an efficient data base structure is necessary. The critical step in the analysis will be rapid access and storage of time series data. To facilitate this, the data structure has been defined as follows for use during the analysis stages of this phase.

- Data will be maintained in two independent data base structures: one for long term data and one for short term data. These can be reconciled on an as needed basis, but the bulk of the analysis will treat the information separately. For each of these structures, the following will be developed:

- Site characteristics and identification/location information will be keyed in one table.

- Anecdotal/ narrative/ intervention/ episode information will be in a second table, keyed by date and site. Native data formats and sources applied in this study will be incorporated.

- Tables will be developed to maintain records of information, with parameters set as fields, and with records keyed by location.

- For actual analysis, secondary binary tables will be developed for each necessary time step and parameter, encompassing all locations in each table, one time step per record. (i.e. each case of time step and parameter will have one table maintaining time series for all stations). Time steps will be daily, weekly, and monthly for the long term stations and hourly, daily, and weekly for the short term stations.

  This will create redundancies in information, but the volumes of information are not extreme and, by eliminating the need to interpolate or extrapolate "on the fly", this step will ensure that the most rapid and error free access and analysis processes are achieved. Given the computational intensity of multiple long term stochastic process determinations, this is a priority in this analysis. These tables will be transient, existing only for the duration of a relevant series of analyses. Development of this information is discussed below.

- Import long term rain gauge records. These are available in digital format and import/check functions are routine and simple.

- Digitize hard copy records. This is more demanding. Experience shows that significant amounts of data required for this study will be in the form of printed or handwritten paper

reports. Some records are likely to be in the form of strip chart or digital files.

- Tabular numeric data will be typed into a spreadsheet formatted in a manner similar to the original material. This will be maintained as a record copy of transcription. These spreadsheets will then be transformed digitally, and incorporated into the data base.

- Analog data (strip charts, etc.) will be digitized using AutoCAD with point input capabilities and a digital tablet. As an alternative, traditional hand techniques could be used. The final information will be developed in digital form and will be incorporated into the data base.

- Routines will be developed to generate the binary tables. Two functions will be necessary.

  - Aggregation to longer time steps will be accomplished by simple averaging, so that mass is preserved.

  - Disaggregation to shorter time steps will be accomplished by linear interpolation accounting for neighboring values. If necessary, low order Markov series will be generated between time steps to preserve random elements of behavior; however, the need to use Markov series is not anticipated at this time.

TASK 3: DEVELOPMENT OF A REGIONAL STOCHASTIC REPRESENTATION

The analytical models will be developed at this stage to achieve most of the specific quantitative aspects of Phase II.

Two main factors will be assessed and compared to establish the net effect of restrictions: changes in water use and climatic impacts on water use. Essentially, changes in water use will be developed as a gross measure of the impact of restriction efforts. This interpretation

will then be refined by accounting for the probable concurrent impact of climatic factors on water use.

The steps needed to accomplish this are well precedented in the literature. The basic issue is to adopt proven techniques to the specific problem at hand. The steps in the analysis generally involve 1) identification of model form and variables, 2) estimation of parameters, and 3) application. Model verification is a desirable aspect of the second step.

There are a number of choices in this study in terms of characteristic variables and model form. Generally, the process of time series analysis for this type of problem is well understood. A forcing function(s) and a response function(s) are operated on by a transform process(s) which includes explicit recognition of a deterministic and a random component of behavior. It is the identification of model form and variables which governs the nature of the final model; it is the estimation of parameters that governs the expression of model behavior. Together, these factors determine model validity.

Precedent work suggests a strong case for adopting a limited number of reasonable alternatives for the model form and variables. The paper by Brandes, cited above, describes a systematic search that identified the most relevant variables pertinent to this class of problem, under specified conditions, as: current and lagged rainfall, temperature, and daylight. There are a number of results presented, based on a regression treatment of the data. Several groupings of these variables were found to produce good results. This work is generally consistent with the literature and is accepted as a good basis for initial selection of model parameters. Accordingly, the following approach is proposed:

- Analysis will begin with the assessment of changes in water use. The utility data will be evaluated and identifiable instances of water use restrictions and enforcement activities will be documented in temporal association with water use records. This will provide a definition of the interventions that may have had an impact on consumption.

- The water use information will be evaluated to establish if breakpoints in behavior can be associated with instances of documented interventions. Breakpoints will be detected by evaluation of second and possibly higher order terms in raw and piecewise smoothed data. Where the data support a difference in water consumption, the raw difference in consumption will be estimated and expressed in terms of quantities of water use change accompanying the observed events.

- The assessment of climatic effects will then proceed. The region will be divided into a Theissen network based on the existence of long term (5+ years of daily records) meteorological data suitable for this analysis. This will be adjusted to ensure that the various utility service areas within the basin are well represented by the gauges associated with each. Proximity of the geographic centroid of the service area to the climate station will be the basis for this adjustment.

- Utilities will be grouped by climate station association and will be tested in subsequent steps both as an aggregate and individually.

- It also may be necessary to consider the counter position to the above. An examination of mapping suggests that some of the utilities might best be tested against an aggregate of rainfall information because of the location of their service area. This will be verified during the early stages of analysis.

- Initial testing will be done by an Multiple General Linear Hypothesis (MGLH) analysis, taken to define a local optimum, that will establish the best global fit for parameters. Fit will be established over a period of 5 years, not including periods of restriction efforts. Tested parameters will be weekly rainfall, lagged 0 through 8 weeks, and assessed individually and in contiguous permutations; sunlight, expressed as a daily duration; and temperature, lagged 0 through 1 week. Temperature will be tested as a raw variable, and also as discretised by Brandes. The robustness of the fit will be verified

by re-initializing the analysis at a point of significant departure near the mid-point of the simulation, and establishing its subsequent performance. The measures of performance for fit will be parametric (mean and variance of error) and non-parametric (error distribution).

- In order to provide insights into the significance of temporal aggregation of rainfall and use information, the above analysis will be conducted again for monthly time steps. This will provide a basis for performance comparison and will determine the most appropriate level of discretization for the remainder of the analysis.

- This analysis will provide an appreciation of major variables and cause and effect. Results will be reviewed with SJRWMD at this stage. If appropriate, the advisability of proceeding to an alternative analysis, wherein the deterministic and random components of use are explicitly treated (see for example Shaw et al, 1987; Galperin, 1985) as parts of the transfer function, can be considered at this time.

- The net effects of restrictions will then be considered. The analysis will move forward to an evaluation of conditions prevailing during the period of the water use restrictions. For the chronological year surrounding that event, the model will be applied, and estimates of behavior will be generated. By the nature of the model development listed above, the model will not account for the effects of intervention in the form of water use restrictions. If restrictions have a measurable impact on use, this should be evident as a difference in values predicted and actually encountered. The amounts and percentages by which quantities changed as a result of restrictions will be estimated as possible from these results.

- Results will be interpreted and assessed in terms of experience elsewhere. The demonstrated effectiveness of restrictions will be a particular consideration in this comparison. Similarities and differences will be noted. Where differences exist,

hypotheses to explain them will be developed, and recommendations for further action, if necessary, will be stated.

TASK 4: DEVELOPMENT OF A LOCAL EVENT INTERPRETATION

This task is proposed as a useful step after the initial review of data with SJRWMD, on the expectation that some of the effects of restrictions will express themselves as changes in patterns of use rather than quantities.

This item will be accomplished in several steps

- Based on available daily data, the selected utilities in the basin will be subjected to cross-correlation (lagged zero to two weeks) analysis, and tested using established techniques (Student's t-test) to determine if a case can be made for significant differences in flow patterns between them. If these differences exist, it may be that results can be interpreted in terms of level of enforcement activity. If correlations are poor, it may be that the instances of differing response are of short duration, and lost in the noise of the data. Therefore, the following more detailed evaluation is a necessary adjunct to the strict statistical interpretation.

- The selected utilities will be evaluated in detail. Diurnal patterns will be normalized according to daily volume, and averaged for periods of like conditions. This will provide a simple base line estimate of diurnal fluctuation, useful for screening. The emphasis will be on the magnitude of observed peaks rather than general shifts in characteristics.

- Evidence of perturbations associated with intervention instances (identified enforcement sweeps, publication dates etc.) as determined in the steps described above, will be sought by superimposing observations from the intervention period on the baseline condition at the time of the intervention.

TASK 5: ANALYSIS OF COST IMPLICATIONS

This task is to assess the cost of water use restrictions to SJRWMD, water suppliers and local governments, and water users. Potential cost factors include:

- Costs to SJRWMD
  - Declaration and implementation of water shortage order
  - Public information
  - Enforcement
  - Administration

- Costs to water suppliers and local governments
  - Reduced revenue
  - Cost of meeting peak hour demands
  - Public information
  - Enforcement

- Costs to water users
  - Irrigation system modifications

Costs to SJRWMD: The estimates for these costs will be based on information supplied by SJRWMD regarding labor and non-labor costs associated with implementing the watering restrictions. Interviews will be conducted with SJRWMD staff involved in the water shortage declarations and implementation to determine approximate costs.

Costs to water suppliers and local governments: Water use changes estimated through the modeling activities will be used to assess the impact of the water restrictions on utility revenues. Meetings will be held with the financial staff of the selected utilities to obtain financial data. To the extent feasible, this activity will be coordinated with PBS&J's separate Task III assignment regarding the implementation of water conservation rate structures (this will only be practical for the large utilities that are participating in the Task III assignment that are within the Wekiva Basin).

Modeling results will be reviewed to determine if the water use restrictions resulted in a shift in the peak hour demand of the selected

utilities. If an increase is documented, the impact of the increased peak demand will be evaluated in terms of cost to the utility. The impact of the shifts will be based on the design basis of water transmission and distribution facilities. The increased peak hour flow will be compared to design peak hour estimates. If design values appear to have been exceeded, an estimated cost associated with regaining capacity will be developed (increased pumping capacity or additional transmission/distribution mains).

Utility and local government costs associated with advertising and enforcing the watering restrictions will also be estimated.

Potential costs to water users: Through utility and SJRWMD interviews, a list of potential costs to water users will be developed. These could potentially include the installation of in-ground irrigation systems and timer installation/modification to comply with the restricted watering hours. General, itemized costs will be developed per item. These will be very site specific and will not be applied across the customer base or included in the overall cost of implementing the watering restrictions.

Overall cost estimate: An overall cost estimate will be developed based on the cost to SJRWMD and cost to the utilities and local governments. If a decrease in water use is demonstrated through the modeling activities, then an approximate cost per 1,000 gallons of water saved will be developed and presented. If modeling demonstrates that enforcement and/or public information had a direct impact on decreased water use, then the results of the increased cost of these activities will be reflected in the cost of increased water savings.

TASK 6: REPORT OF FINDINGS

This task will result in the delivery of all information and findings from Phase II to SJRWMD. It will be necessary to complete this effort by ensuring that results are turned over to SJRWMD as a useful set of deliverables.

Some specific items will be generated and delivered to SJRWMD:

- The entire digital data base, in dBASE IV format, exclusive of transient binary files, will be delivered on PC format CD ROM disc.

- Plots of key correlations and optimal fit conditions will be provided.

- Documentation of anecdotal information and plant records, as received and as reduced, will be provided.

- Documentation of assumptions, methods, and conclusions, including equations, relationships and empirical bases for analysis.

- As the primary deliverable for this Task, a summary report formatted in accordance with SJRWMD guidelines will be developed which addresses the following:

  - Changes in Water Use:

    - Dates when water use restrictions are initiated or levels of restrictions are changed.

    - Dates when enforcement activities are initiated or intensified.

    - Quantities of water use change accompanying the initiation or changing of water use restrictions and enforcement activities.

  - Climatic Impacts on Water Use

    - Water use and climatic data used.

    - Multivariate analysis technique and statistical tests used.

    - Results of numerical analysis.

- Net Effects of Restrictions

  - Which information from previous analyses was used.

  - Assessment of the net amount and percentage by which water use was changed in response to restrictions during times of the various levels restrictions after adjustment for climatic influences.

  - Assessment of the costs of water use restrictions.

TASK 7 - PROJECT PROGRESS MEETINGS

Project progress meetings will be held periodically throughout the course of development of this project. This task is to cover up to two meetings in Palatka with the PBS&J and SJRWMD task team members. Periodic conference call meetings may also be held, as needed, through the course of the work and these are included in association with the development of each task.

Coordination meetings to be held with members of other consulting teams involved in other task assignments of the Investigation of Alternative Water Supply Strategies, utility presentations, and other meetings not specifically identified in this scope of services will be considered additional services and budgeted separately.

KEY STAFF

The following key staff members are proposed for completion of the Phase II work:

Project Director:	Robert A. Morrell, P.E., PBS&J
Project Manager:	Jo Ann Jackson, P.E., PBS&J
Technical Manager:	Charles A. Rowney, Ph.D., Consultant to PB Water

Technical Support:	Mike Hulley, Ph.D., PB Water Doug Pickell, PB Water Edward H. Talton, PBS&J
Financial Impacts/ Technical Review:	Robert Lockridge, Burton and Associates

REFERENCES

Brandes, D. (1990) *Selection of Climatic Variables for Modeling Weekly Municipal Water Use*, Visiting Assistant Professor, University of South Florida, Department of Geography, Tampa, Florida.

Galperin, E.A. 1985. Deterministic regression models for prediction and control. *Mathematical Modeling*. Vol. 6, pp. 157-171.

Shaw, D.T. and Maidment, D.R. 1987. Intervention analysis of water use restrictions, Austin, Texas. *Water Resources Bulletin*, American Water Resources Association.

Vergara, Barbara, editor. 1994. *Water Supply Needs and Sources Assessment*. St. Johns River Water Management District, Palatka, FL.

APPENDIX A

TASK IV. - EFFECTS OF WATER USE RESTRICTIONS ON ACTUAL WATER USE.

Purpose

The purpose of this task is to assess the effects of water use restrictions, using utilities in the Wekiva River Basin and other areas as case studies.

Objectives

- Assess the effects of temporary water use restrictions on actual water use accounting for climatic impacts on water use during times of restrictions;
- Assess the net impacts of water use restrictions on water use;
- Assess the costs of water use restrictions.

PHASE I

Task IV - Phase I Subtasks

CONSULTANT shall perform the following services in Phase I.

A. Develop methodologies for performing each Subtask in Phase II, IV.A through IV.C, including the identification and assessment of numerical techniques and review with SJRWMD to determine the approach that will be used.

B. Assess the availability of data required for implementing the proposed methodologies in Phase II, including the review of water use and climatic data and other data provided by

SJRWMD for the Wekiva Basin to determine sufficiency for numerical analysis.

C. Recommend sources of alternative or surrogate data, if needed.

D. Name the key staff who would perform the work specified in Phase II.

E. Provide the charge by CONSULTANT for performing the prescribed work in Phase II.

Task IV - Phase I Deliverables

CONSULTANT shall deliver written documentation of the following to SJRWMD at the completion of Phase I.

A. Proposed methodologies for performing each Subtask, I.A through I.D, described in sufficient detail for SJRWMD reviewers to assess the appropriateness of the methodology for providing valid results.

B. Assessments of availability of data required for performing Phase II services.

C. Recommendations for sources of alternative or surrogate data, if needed

D. Names of staff who would perform Phase II services.

E. The charge by CONSULTANT for performing Phase II.

PHASE II

Task IV - Phase II Subtasks

CONSULTANT shall perform the following services in Phase II.

A. Changes in Water Use. Assess the associations between temporary water use restrictions and actual water use for up to 10 utilities in the Wekiva River Basin and for other utility service areas. Develop a proposed methodology for each step and obtain approval from SJRWMD prior to performing services

1. Document dates when the following activities occurred.

2. Water use restrictions initiated or levels of restrictions changed.

3. Enforcement activities initiated or intensified (to the extent data are available.

A. Identify and assess temporal associations between water use and the initiation or changing of water use restrictions and between water use and the level of enforcement activities. Express the assessment of those associations in terms of quantities of water use change accompanying the various events.

B. Climatic Impacts on Water Use. Account for climatic impacts on water use. Numerically correlate daily and weekly water use with rainfall, high temperature, number of days since last rainfall, and cumulative rainfall for the last seven days, using a multivariate analysis technique and statistical tests approved by SJRWMD.

C. Net Effects of Restrictions. Assess net effects and overall effectiveness of restrictions for reducing water use during times of temporary shortages.

1. Based on A and B, above, determine the net impacts of water use restrictions and enforcement of restrictions after adjustments for climatic impacts to water use; expressed in terms of amounts and percentages by which the quantity and amount of use water use was changed in response to restrictions during times of the various levels of restrictions for the utilities.

2) Determine the economic costs of water use restrictions.

   a) Costs to SJRWMD.

      i) Declaration and implementation of water shortage order;

      ii) Public information;

      iii) Enforcement;

      iv) Water shortage administration (such as issuance of variances);

      v) Other.

   b) Costs to water suppliers and local governments.

      i) Reduced revenue;

      ii) Cost of meeting peak demands;

      iii) Public information;

      iv) Enforcement;

      v) Other.

c) Costs to water users.

i) Irrigation system installation or modification;

ii) Other.

d) Overall cost of restrictions.

i) Calculate the total cost of implementing water use restrictions, based on a) through c) above.

ii) If water use appears to be reduced as a result of restrictions, calculate the cost per 1.000 gallons of saving water through use restrictions, for SJRWMD, water suppliers and local governments, and water users, based on costs identified in a) through c) above.

Task IV - Phase II Anticipated Deliverables

CONSULTANT shall deliver written documentation of the following to SJRWMD at the completion of Phase II.

A. Documentation of:

1) Dates when water use restrictions are initiated or levels of restrictions are changed;

2) Dates when enforcement activities are initiated or intensified;

3) Quantities of water use change accompanying the initiation or changing of water use restrictions and enforcement activities.

B. Documentation of:

1) Water use and climatic data used;

2) Multivariate analysis technique and statistical tests used;

3) Results of numerical analysis.

C. Documentation of:

1) Which information from previous analyses was used;

2) Assessment of the net amount and percentage by which water use was changed in response to water use restrictions during times of the various levels restrictions after adjustment for climatic influences.

APPENDIX B

Summary of Data Collected in Phase I

Filename	Description	Source
3053493.DAT to 3053795.DAT	daily rainfall at Wekiva Springs State Park for the period 4-'93 to 7-'95	Cynthia Moore, SJRWMD
ORLPRCP.WK1, LISPRCP.WK1, CLERPREC.WK1	daily rainfall at Orlando, Lisbon and Clermont (NOAA) for the period 1-'88 to 12-'92	Cynthia Moore, SJRWMD
DASTA.XLS	daily rainfall at Orlando (NWS) for the period 1-'92 to 8-'95	Cynthia Moore, SJRWMD
CLERMIN.WK1, CLERMAX.WK1, LISBMIN.WK1, LISBMAX.WK1, ORLMIN.WK1, ORLMAX.WK1,	daily min/max temperature at Orlando, Lisbon and Clermont (NOAA) for the period 1-'88 to 12-'92	Cynthia Moore, SJRWMD
DASTA.XLS	daily min/max temperature at Orlando (NWS) for the period 1-'92 to 8-'95	Cynthia Moore, SJRWMD
SHORT.WK3	average daily flow (mgd) from monthly water use, by selected utility District-wide, for the period 1-'88 to 9-'95	Cynthia Moore, SJRWMD
WRBUSE1.WK3	weekly water use (mgd) from the utilities within the Wekiva River Basin for the period from 6-16-93 to 3-30-94	Cynthia Moore, SJRWMD
WRBUSE2.WK3	daily water use (mgd), by plant, from the utilities within the Wekiva River Basin for the period from 3-1-94 to 6-30-94	Cynthia Moore, SJRWMD
WRWTP.XLS	names and contacts list for utilities within the Wekiva River Basin	Cynthia Moore, SJRWMD
WRBPLANTS	list of water plants, with utility name, within the Wekiva River Basin	Cynthia Moore, SJRWMD