Abstract

The Department of Environmental Resources of Durham, NC, owns and operates two raw water reservoirs: Lake Michie on the Flat River and the Little River reservoir. To ensure that reservoir releases are adequate to meet target demands, Durham has relied on mathematical models developed by Research Triangle Institute and the University of North Carolina. However, most of the modeling work predates the addition of the Little River reservoir in 1988. In 1999, Durham decided to update its decision support system for drought management with a model that includes both reservoirs.

This report describes a risk-based simulation model that was developed using 72-years of historical data for reservoir inflows, precipitation, and evaporation. The model simulates reservoir performance for each year of record using any target demand and any initial storage volume in any week of the year. The risk that target demand cannot be met is determined by the model in probabilistic terms to be used as criteria for drought management decisions. If a risk is considered unacceptable, alternative conservation policies can be explored with the model to determine an appropriate solution.

An analysis of the impacts of alternative conservation policies on risk in meeting demand produced results that will be useful in drought contingency planning by Durham. These findings define the effects of rationing, its duration, and start date of conservation on the risk that future demands can be met.

Acknowledgments

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Chapter 1. Introduction

1.1 Motivation

The Environmental Resources Department of Durham, North Carolina, owns and operates two reservoirs for its service area, namely Lake Michie and Little River Reservoir. Durham has historically been well prepared for drought management, using conservation policies as the result of contingency plans developed with the assistance of Research Triangle Institute and the University of North Carolina. In seeking to reevaluate and update the existing drought management strategy in the spring of 1999, Durham sought the assistance of the Department of Environmental Sciences and Engineering at the University of North Carolina. In the midst of the discussions regarding this undertaking, the water storage system was under great strain due to severe environmental conditions, and conservation efforts in the summer of 1999 seemed likely. As a result, several questions were posed involving a modeling effort that would include issues dealing not only with risk assessment, but also the impacts that alternative conservation policies would have and an idea as to when such implementation would be required.

In August 1999, Durham was facing a 100-year drought, storage levels were becoming alarmingly low, and demands were observed through July and August to be increasing at a rate of 1.4 % per day (0.5-MGD/day). The implications if the trend continued were distressing. Fortunately, Durham had embarked on a study with help from the UNC Department of Environmental Sciences and Engineering back in April 1999 to update and develop its drought management plan.

Some form of drought management appeared to be needed in the near future, but the effects that alternative policies would have on the situation were vague. Consequently, several questions arose relating to the initiation of conservation efforts as a drought contingency plan. Should the sale of water to Cary be terminated? If so, when? Should a public rationing policy be issued as a conservation effort? If rationing were recommended, how long should the policy last? When should it start? Or perhaps more pertinent, how long could rationing be delayed?

The drought management strategy in place uses a decision support system based on estimates of the probabilities of being able to sustain a given demand over the remainder of the year. Different stages of drought management are determined to be required at specified ranges of probability in meeting future demands to ensure that the projected level of demand can be maintained. In addition, a second risk-based model, using as its criteria the probabilities that given amounts of water in storage can support demands over the remainder of the year is employed to determine the required volume at any week necessary to attain an acceptable level of risk. With knowledge of the minimum storage requirement needed to meet the risk criteria, Durham can quickly and easily evaluate the storage at any week of the year by checking to see if it falls below the desired level.

The modeling effort employed in development of the drought management strategy pre-dates construction of the Little River reservoir in 1988. A study was requested by Durham to reevaluate the methodology used for risk determination that would include both of Durham's reservoirs.

1.2 Objectives

The goal of this project is to develop a tool to aid Durham in drought contingency planning and water conservation policy selection. The objectives for meeting this goal are to: (1) develop a simulation model of Durham's reservoir system, (2) consider alternative water conservation policies and analyze their impacts, and (3) draw conclusions from the analysis about what policies seem best suited for managing drought.

The primary objective of the project is development of a model that simulates the water reservoir system of Durham, making use of historical input data to estimate the risk associated with various drought management alternatives. Durham was pleased with its model of Lake Michie developed by the Research Triangle Institute (McCrodden and Paddock, 1982), but now Little River reservoir must also be included in the risk analysis. It seemed clear that the output of the new model should be in the form of risk probabilities that Durham has been accustomed to using.

One approach to modeling the Durham reservoir system is to use simulation, which models the response of the system to various input scenarios reflecting the operational alternatives under consideration. The input for simulation includes reservoir inflows, target withdrawals, working volumes of the reservoirs, and other factors. The response to these inputs is evaluated over each interval of the simulation period and may serve as decision support for drought contingency planning.

An alternative approach employs linear programming (LP) not unlike the model applied to the Orange Water and Sewer Authority (OWASA) in North Carolina which serves Chapel Hill and Carrboro (Brandt and Lauria, 1999). This method uses a goal-programming optimization model seeking to minimize an objective function measuring economic losses resulting from conservation efforts through rationing. Such an approach holds promise for Durham, which may want to consider its implementation in the future. Because of the long record of inflows for the Durham reservoir system and the city's prior experience with simulation models, a model using the simulation method was determined to be most suitable.

The second objective of this study is to select various public water conservation policies and provide an analysis of their impacts. The policies formulated for consideration are numerous, with impacts varying widely. Drought management policy alternatives include termination of water sales to a neighboring town in July, not selling water to it during the months of June and July, terminating wholesale sales after September until the following year, enforcement by law of emergency conservation efforts by the public for two weeks in August when reservoir surface levels reach a critical point, conservation for four weeks in July, and so forth. Once any policy is selected for consideration, its effectiveness can be evaluated in probabilistic terms using simulation and compared to the case with unrestricted demands to measure its impact.

The final objective of the study is to draw conclusions and provide recommendations based upon the analysis of alternative conservation policies. With the ability to compare specific demand reductions over specified periods, the overall response of the system to such policies can be determined so that appropriate actions can be taken for any particular drought event. This ability expands the options available for the decision-maker in planning the management of a drought.

2. The Durham Reservoir System

The raw water supply for the City of Durham is from Lake Michie that is fed by the Flat River and from the Little River Reservoir fed by the Little River. The combined usable storage of the two reservoirs is about 6.35 billion gallons (BG).

2.1 Lake Michie

Lake Michie is a 3.61 billion-gallon reservoir with a170-square mile drainage area and a 70-year safe yield of approximately 23 to 24 million gallons per day (MGD) (Moreau and Little, 1989). The water surface elevation (WSE) when full is 341.0-feet above mean sea level, and minimum WSE of Lake Michie is 312-feet, corresponding to the top of the baffle board at the intake structure. The relation between lake levels and volume is depicted in Figure 2.1.

Dead storage is the volume at the bottom of the reservoir that cannot be used. The factors that define dead storage include such considerations as the physical ability to withdraw water, water quality, emergency reserve, space for sediment deposits, etc. The dead storage in Lake Michie at the minimum WSE is about 800 million gallons (MG). The working volume of the reservoir is defined as that volume of storage available for drawdown and refill, also defined as the total volume minus dead storage; the working volume of Lake Michie is about 2.81 billion gallons.

Figure 2.1 Lake Michie Drawdown-Storage Curve

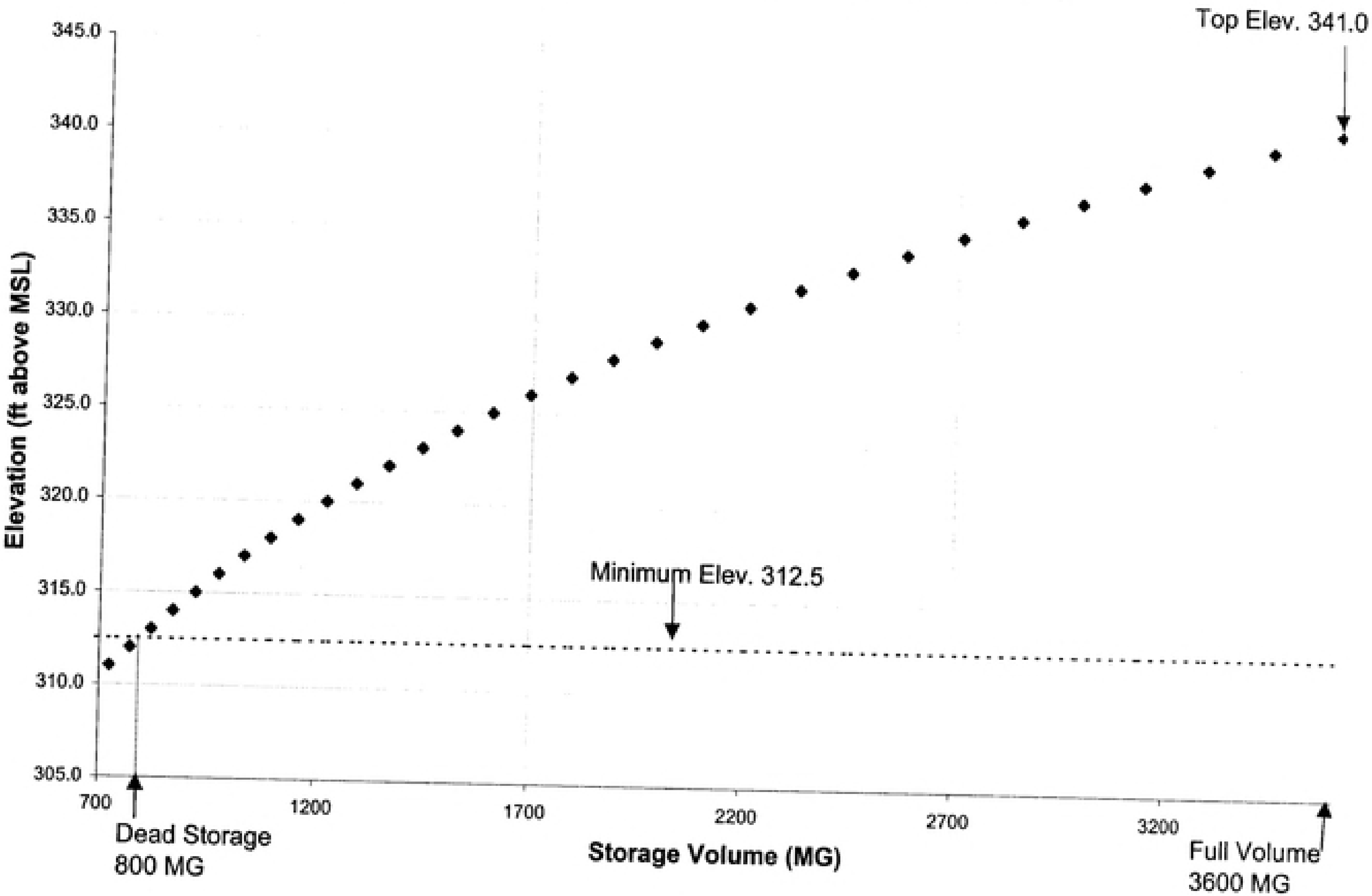
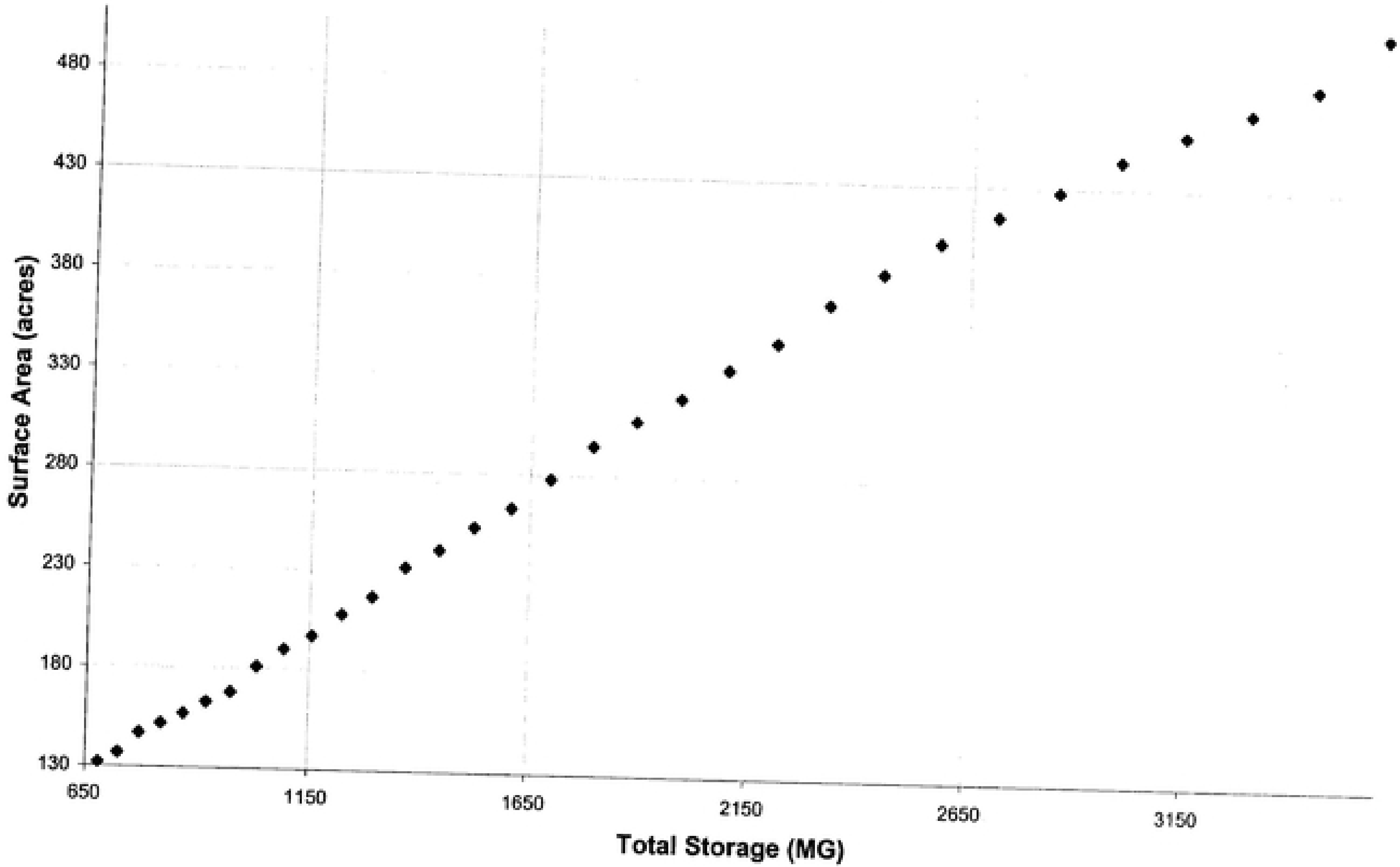


Figure 2.2 Lake Michie Surface Area Verses Total Storage



Lake Michie volume can be estimated as a function of lake levels from the equation:

$$V_{LM} = 2.081(WSE)^2 - 1262(WSE) + 191942 \quad (1)$$

where V_{LM} is the total volume of Lake Michie in millions of gallons. The data and regression analysis used to obtain this equation are in Appendix A; the model fits the data very well, with R-square of 0.9998.

The surface area of Lake Michie is required to compute the effects of rainfall and evaporation on storage. Figure 2.2 shows the relation between total storage and estimated surface areas. The surface area can be expressed as a function of storage in the equation:

$$A_{LM} = 0.132 \times (V_{LM}) + 48.3, \quad R^2 = 0.9945 \quad (2)$$

where A_{LM} is the surface area in acres. Note that the linear relationship between area and volume makes surface area a quadratic function of water elevation. The regression analysis used to develop this equation is in Appendix A; this model similarly fits the data well.

2.2 Little River Reservoir

Durham built a second reservoir in 1988 on the Little River with 120-square miles of drainage area, 4.9 billion gallons of total storage capacity, and approximate safe yield of 20-MGD (Moreau and Little, 1989). Durham determined that the minimum allowable

Figure 2.3 Little River Reservoir Drawdown-Storage Curve

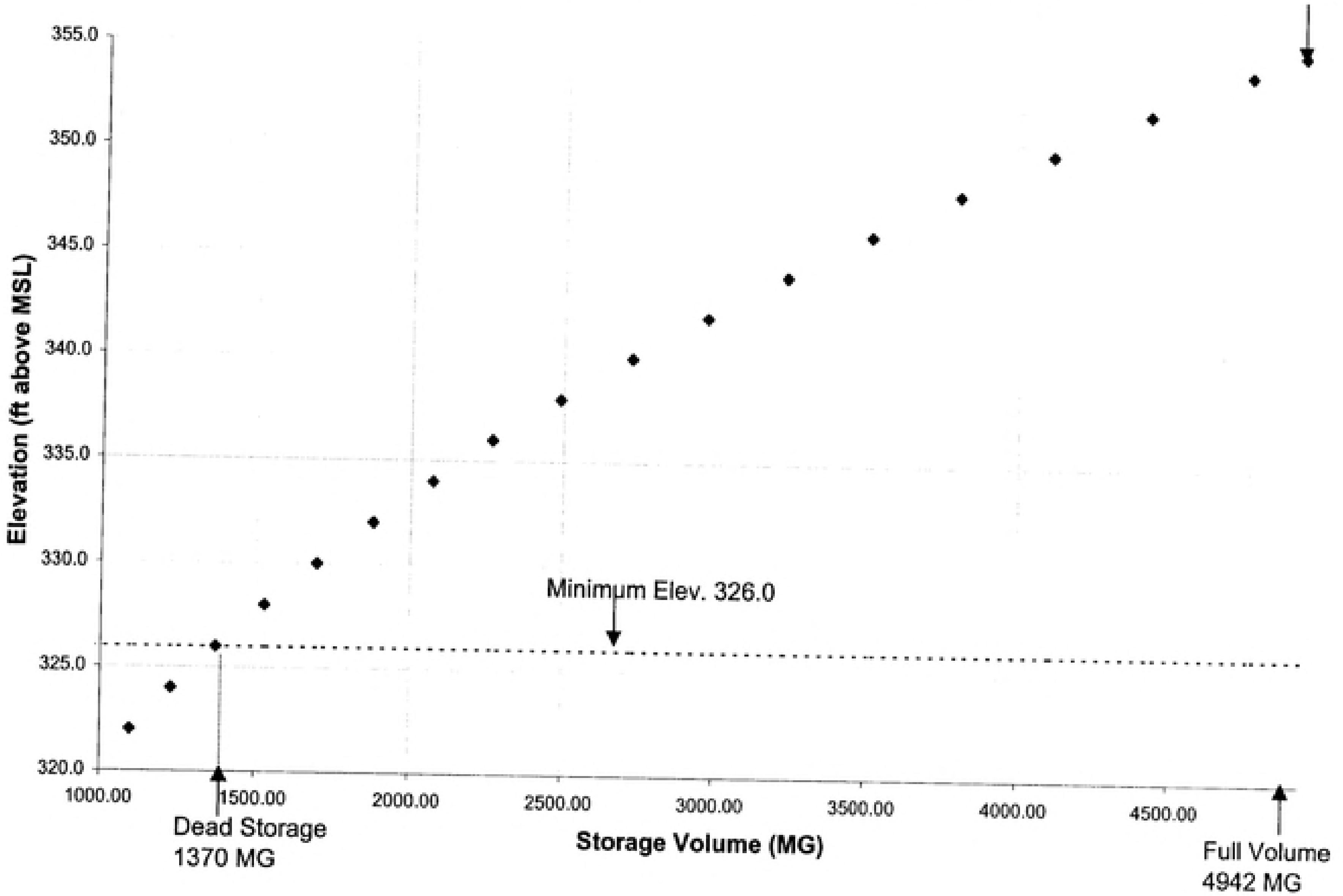
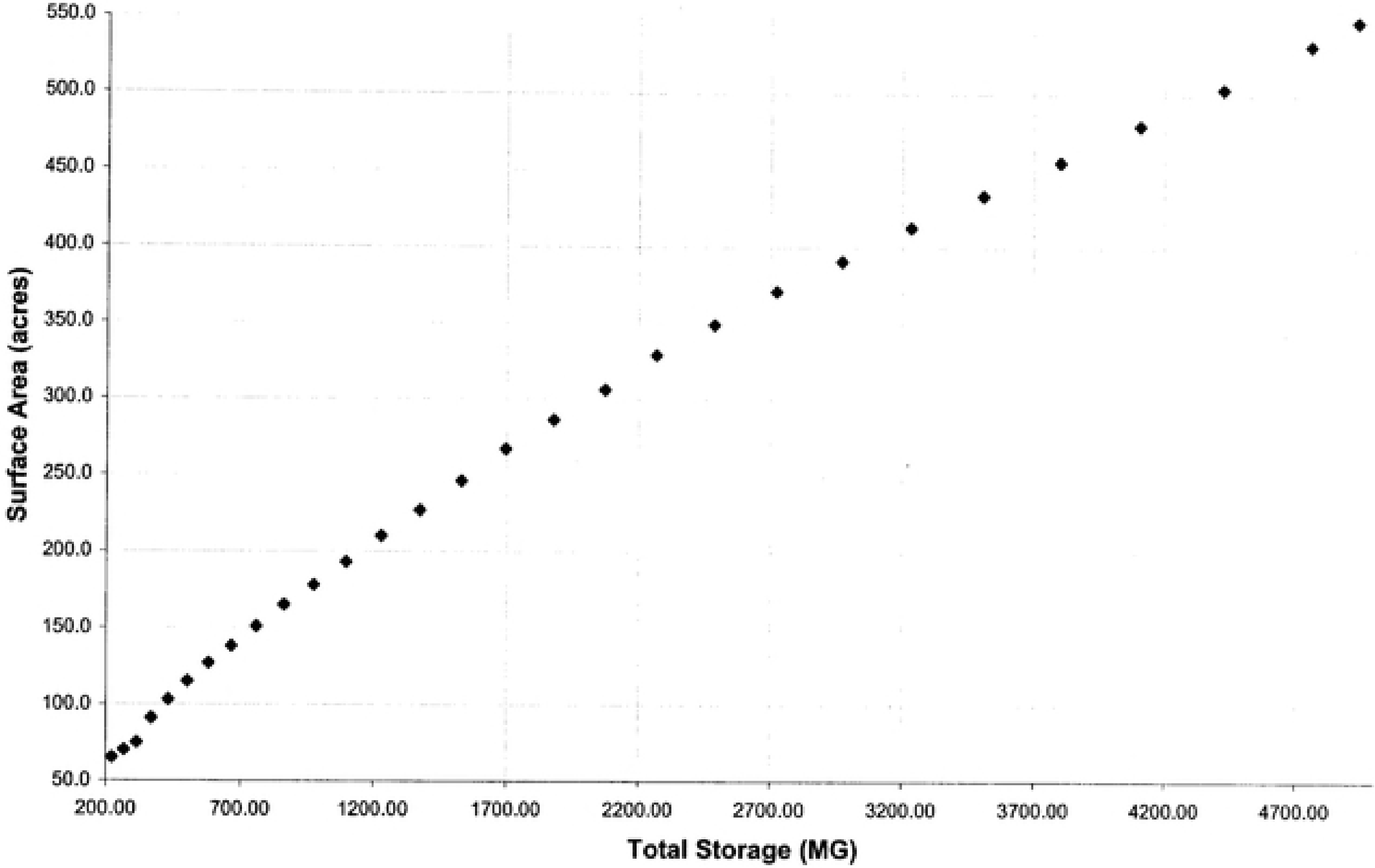


Figure 2.4 Little River Reservoir Surface Area Verses Total Storage



lake level should not fall below 326.0 feet, the invert elevation at the second intake gate. Figure 2.3 depicts the drawdown and corresponding available usable storage of the reservoir. With a maximum WSE of 355 feet and dead storage of 1370 million gallons, the working volume is 3.57 billion gallons. The total volume of the reservoir can be expressed in terms of lake levels by the equation:

$$V_{LR} = 1.645 \times (WSE)^2 - 997.84 \times (WSE) + 151787.77, \quad R^2 = 0.9999 \tag{3}$$

where V_{LR} is the volume in millions of gallons. The regression analysis and data used to derive this equation are in Appendix A.

Similar to Lake Michie, the surface area of the Little River Reservoir is proportional to the total volume (Figure 2.4). This area can be expressed as a function of volume by the equation:

$$A_{LR} = 0.1 \times V_{LR} + 72.25, \quad R^2 = 0.9856 \tag{4}$$

where A_{LR} is the surface area in acres. This linear relation implies that the surface area is a quadratic function of the surface elevation. The regression analysis and data used to formulate equation (4) are located in Appendix A.

2.3 Inflows

Inflows into the reservoirs are crucial determinants in the analysis of storage requirements and yield. System performance is governed by the ability of the reservoirs to store sufficient amounts of water from the tributaries during wet periods to compensate for low inflows associated with dry periods. Fortunately, immense collections of streamflow records exist to assist forecasting and risk estimation.

Daily inflows to the reservoirs are measured and stored by the United States Geological Survey (USGS) streamflow recording stations. The daily values were summed over weekly intervals to produce fifty-two observations per year, reported in millions of gallons per week. This simplification aids the process of simulation for reasons described in Chapter 3.

Inflow to Lake Michie is primarily from the Flat River (FR); other contributing streams are ungaged or insignificant. The Flat River flows have been monitored continuously since 1926 at USGS gaging station 0208550 in Bahama, NC, a site just upstream from the reservoir with a drainage area of 150 square miles. The total drainage area at the Lake Michie Dam is approximately 170 square miles. To account for this difference, inflows to the lake are estimated using a ratio of drainage areas, 1.13 (=170/150) times the gaged flow (Moreau and Little, 1989). For the research herein, 72 years of data were used (1926-1997).

Little River Reservoir inflows have been monitored upstream of the Little River (LR) at USGS gaging station 02085220 near Orange Factory, NC, since 1962, except for 1987 and 1988, yielding 34 years of data through year 1997. The drainage area of the reservoir is 120 square miles, compared to 80 square miles at the gaging station. To estimate Little River Reservoir inflows, a multiplier of 1.50 (= 120/80) is used.

In order to extend the record of Little River flows to match that of Flat River (i.e., for 72-years), Little River flows were predicted for years 1926-1961, 1987, and 1988 based on those of the Flat River. As can be seen from Figure 2.5, the streamflows of Little River and Flat River are highly correlated, suggesting that one of the river's flows can be estimated as a function of the other. This relationship is depicted by the straight line in Figure 2.5 based on the linear regression analysis in Appendix B. The correlation coefficient (R^2) for the model is 0.88, indicating an excellent fit to the data. The equation for the regressed line in Figure 2.5 is

$$Q_{LR} = 0.49 \times Q_{FR} \qquad (5)$$

Equation (5) is used to extend data for the missing years of Little River streamflows over the entire period of Flat River observations from 1926 to 1997. Hence, the historical inflows for the two reservoirs are estimated (using the drainage area multipliers) over a period of 72 years.

Figures 2.6 and 2.7 show the seasonal variability of the Little River and Flat River, indicating the relatively wet period in late winter and early spring, with a peak around March 1, followed by a dry period that lasts through summer and fall, with minimum

Figure 2.5
Little River Flows vs. Flat River Flows (1962-1986, 1989-1997)

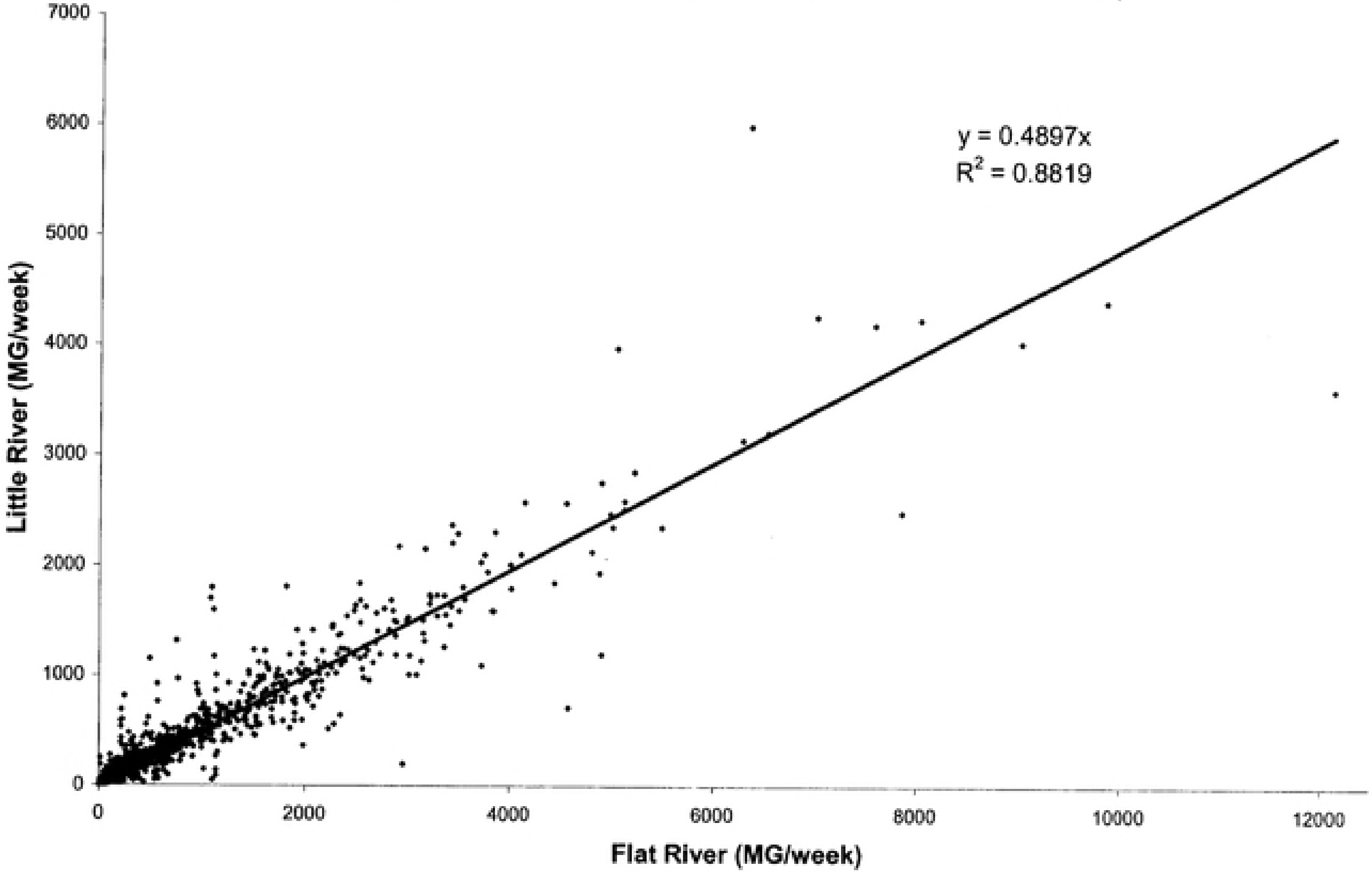


Figure 2.6
Average Monthly Flat River Flows and Standard Deviations (1926-1997)

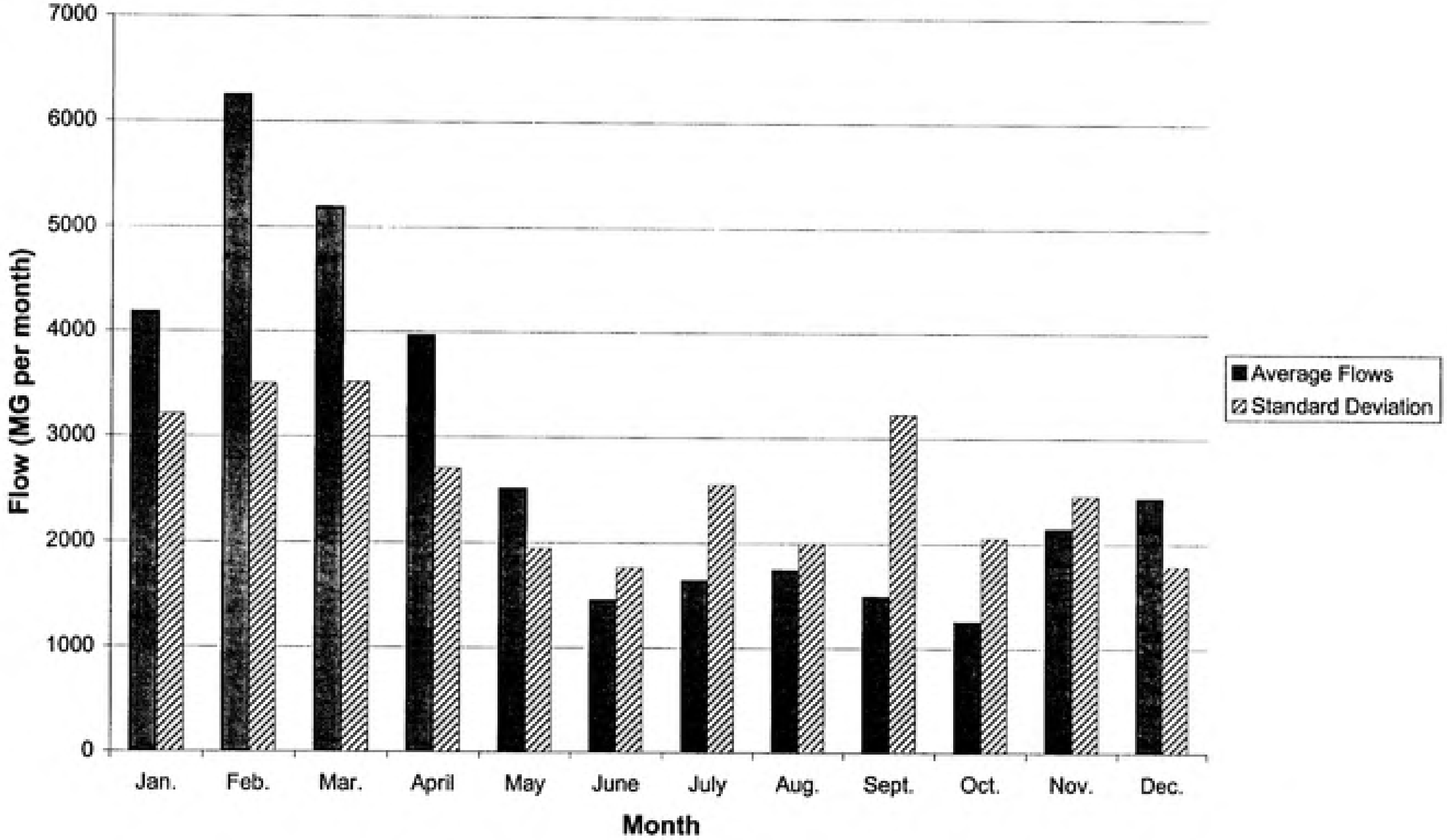
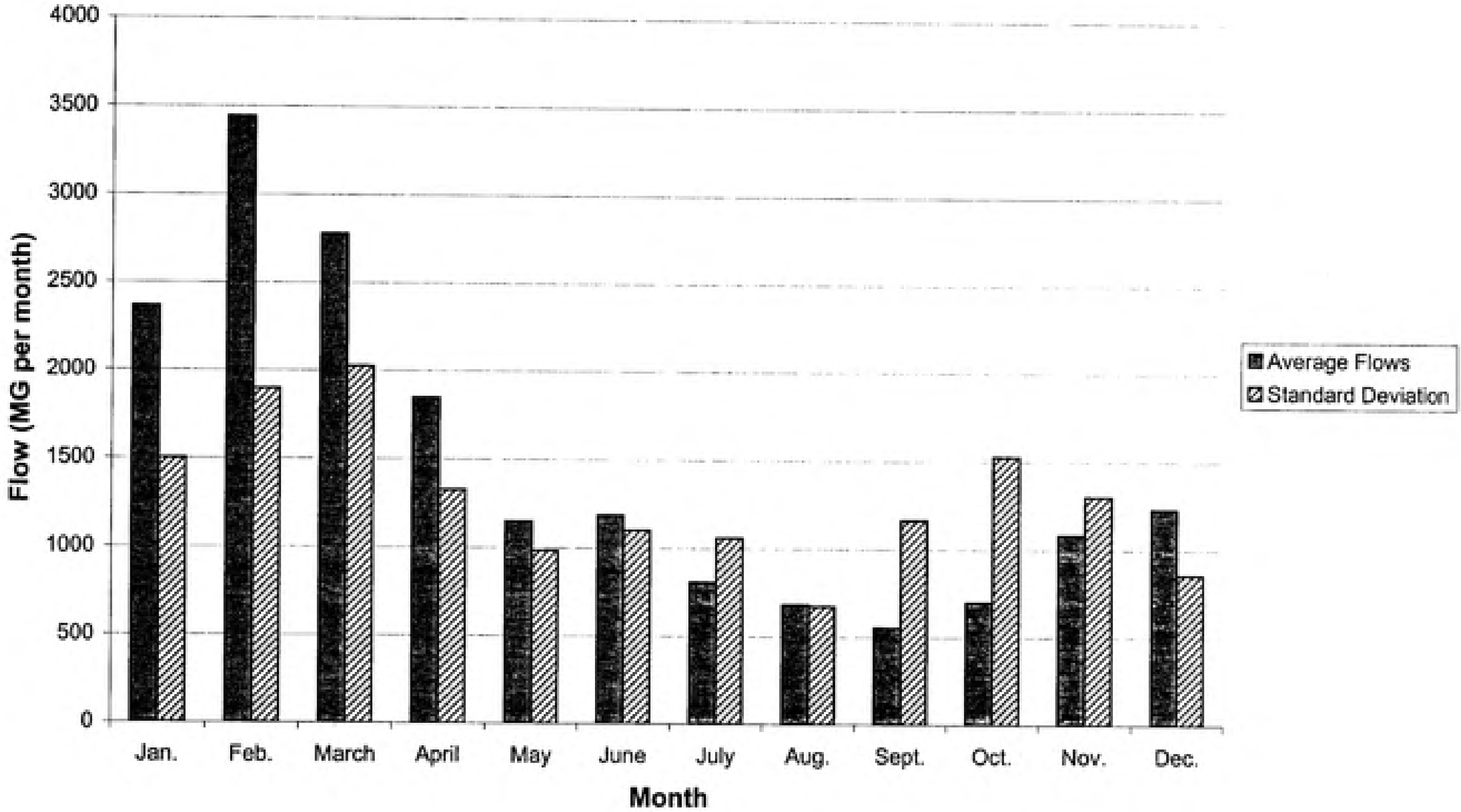


Figure 2.7
Average Monthly Little River Flows and Standard Deviations
(1962-1986, 1989-1997)



flow in September and October. The standard deviations of the flows of both Little River and Flat River are fairly large and in most cases are of the same magnitude as the mean. In July through November, the standard deviation exceeds the mean, a phenomena suggesting large variations and uncertainties in flows from year to year. This variation results from a fairly dry period that is occasionally introduced with an extreme rainfall event characteristic of hurricanes, tropical storms, or other storms that have large rainfalls in comparison to the average precipitation of that period.

Chapter 3. Simulation Model of Reservoir System

3.1 Reservoirs Modeled as Single Unit

The first step in developing the simulation model for Durham was to decide whether to treat the city's two reservoirs as separate or to combine them into a single unit. If modeled separately, then an operating rule is needed to ensure that one of the reservoirs is not being drawn down while the other is overflowing and spillage is occurring. If this were to happen, the storage capacity would not be used efficiently. One method to ensure efficient operation of multiple reservoirs is the space rule (Maass et al., 1962)

$$\frac{S_{\max,j} - S_{j,k} - Q_{j,k} + W_{j,k}}{\sum_{j}^{m}(S_{\max,j} - S_{j,k} - Q_{j,k} + W_{j,k})} = \frac{Q_{j,n-k}}{\sum_{j}^{m} Q_{j,n-k}} \qquad (6)$$

where $S_{max,j}$ is the full capacity of the jth reservoir out of a total of m reservoirs, $S_{j,k}$ is the water stored in reservoir j in the kth week, $Q_{j,k}$ is the inflow into reservoir j in the kth week, $W_{j,k}$ is the withdrawal, and $Q_{j,n-k}$ is the predicted inflow over the remainder of n total weeks in the drawdown-refill period.

The space rule is mathematically cumbersome in a simulation model and its use is less important if the inflows to the reservoirs are highly correlated. If the inflows are highly correlated, it is not likely that one reservoir will receive large inflows (requiring a large storage space to capture it) while the other reservoir gets very small inflow. Figure

2.5 shows that the flows of Flat River and Little River are, indeed, highly correlated (R^2=0.88). Hence, in operating the two reservoirs, it is not very difficult to ensure that one reservoir is not overflowing while the other is drawn down. Moreover, Durham has stated that such a situation has never occured.

To check the assumption of treating the reservoirs as a single source, a comparison of storage calculations using the space rule and the single-reservoir simplification of this report is provided in Appendix C. The results show that for any week, determination of the total available storage at that time is identical for either method. Therefore, treating the reservoir system as a single storage unit is justified.

3.2 Continuity Equation

The combined reservoir system may be simulated as a single unit using the *continuity equation* that expresses the storage at any week as a function of the inputs and outputs of the system and the ending storage of the previous week. The continuity equation is

$$S_t = S_{t-1} + Q_t - W_t + P_t - E_t \tag{7}$$

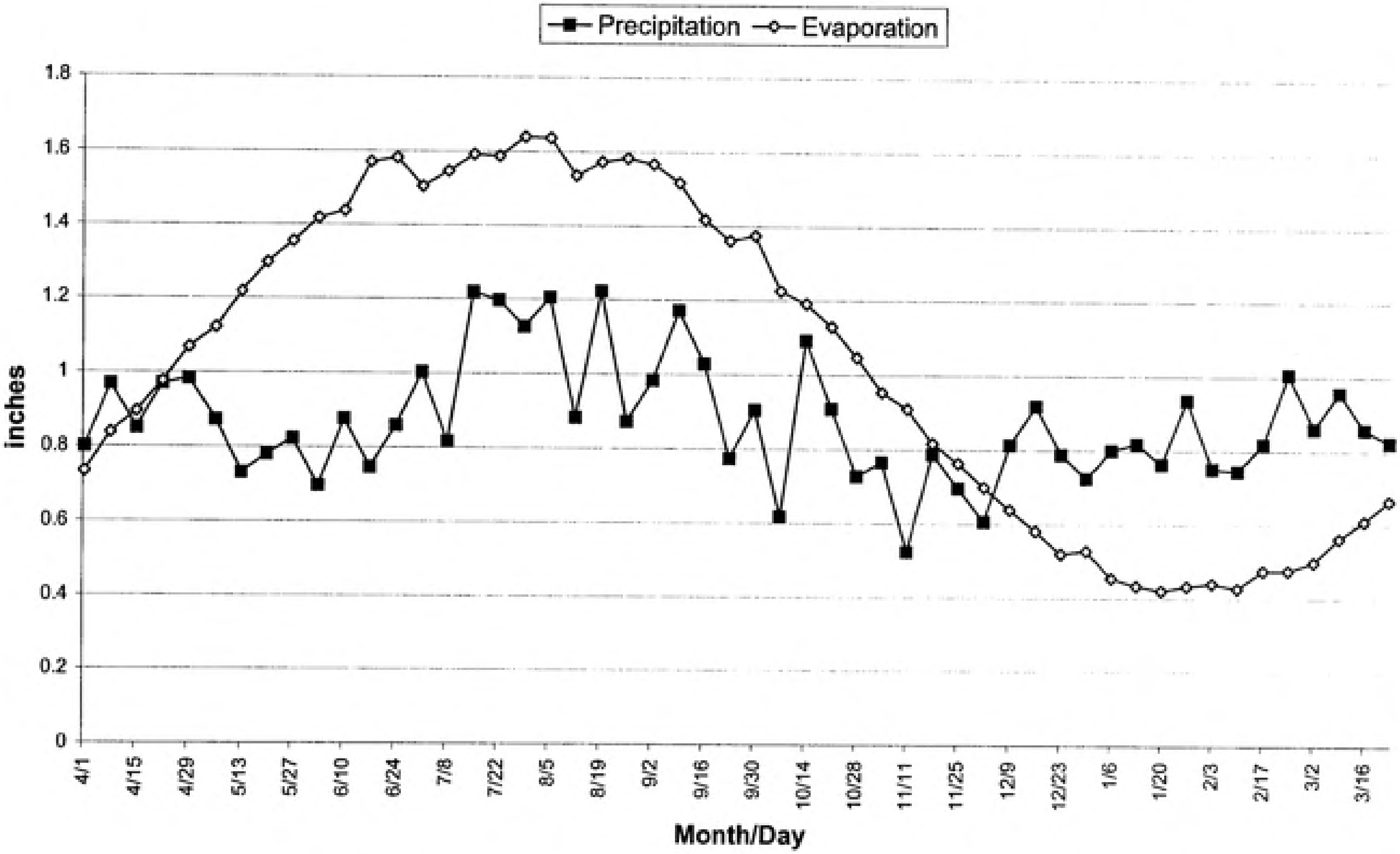
where S_t is the storage at the end of any week (t) of the year, S_{t-1} is storage at the end of the previous week, W_t is the withdrawal in week t, and P_t and E_t are the precipitation and evaporation directly on the surface, respectively, in week t. If S_t in equation (7) represents (net) working volume (i.e. the amount above dead storage) rather than the total amount of storage, then $S_t \geq 0$ for all weeks. This condition prevents negative storage and assumes that the working volume is completely empty when $S_t = 0$. Similarly, for continuity equation (7) to hold true, S_t cannot exceed the maximum working volume of the system ($S_t <= S_{max}$).

3.3 Precipitation and Evaporation

The historical record for precipitation (P_t) extends from 1930 to 1995. Daily measurements were recorded in inches and provided by the National Climatic Data Center TD-3200 file by gages at Durham, Chapel Hill, and Moncure, NC. To account for the missing years of data, the average of the weekly observations over the available period of record are used. The daily measurements are summed over weekly intervals for input into the continuity equation (Appendix F). The averages of the weekly observations over the available period of record are depicted in Figure 3.1.

The contributions of precipitation in combination with evaporation are almost negligible, so the generalization of the behavior of the missing years of data is considered justifiable. Only the *accumulated* effects of precipitation and evaporation are of concern in simulation, with impacts not noticeable until mid-September. The use of average values instead of observations that are correlated with streamflow magnitudes does not significantly alter this accumulated effect. Although the addition of direct rainfall onto the reservoir surface in conjunction with evaporation was stated as nearly negligible, the accumulated effect does periodically result in a failure (zero working volume) occurring a week earlier, but the failure nevertheless eventually occurs.

Figure 3.1
Average Weekly Evaporation/Precipitation Over Refill-Drawdown Period (1930-1995)



The historical record of evaporation (E_t) in inches is provided by the USGS WASTORE database and consists of daily observations by two gages in Chapel Hill, NC. The period of record is from 1930 to 1995. Evaporation in missing years was estimated by using weekly averages of recorded observations (Figure 3.2). The daily measurements are summed over weekly intervals for model input (Appendix G).

The flux attributed to precipitation and evaporation is dependent upon the surface area of the two reservoirs. The surface area of each reservoir as a function of storage volume can be determined using equations (2) and (4). Consider equation (2) for Lake Michie, which predicts full and empty surface areas of 524 and 156-acres based on full and dead storage volumes of 3,606 and 800-MG, respectively. Similarly, equation (4) for Little River reservoir predicts full and empty surface areas of 576 and 212-acres based on full and dead storage volumes of 4,952 and 1,370-MG, respectively. Hence, the total surface area is 1,101-acres corresponding to the total full volume of 8,550-MG, and the total area is 369-acres when the reservoirs are empty with 2,170-MG of dead storage. Combining these results yields (Appendix A):

$$A_T = 116 + 0.115 \times V_T \tag{8}$$

where

V_T = Total Storage Volume, MG
A_T = Total Surface Area, acres

Evaporation and Precipitation can be combined into a single flux term that represents the net effects. Let

$$G_t = \text{Precipitation} - \text{Evaporation} \qquad (9)$$

where G_t is in inches per week at any week t. By utilizing equation (8) and converting units[1] to MG per week, the precipitation/evaporation flux term in million gallons per week can be expressed as

$$G_t \times A_{t-1} = G_t \times 0.02715 \times (116 + 0.115 \times V_{T,t-1}) \qquad (10)$$

where A_{t-1} is the total surface area, in acres, of the previous week and $V_{T,t-1}$ is the total volume (MG) in the previous week (if S_t is expressed in working volumes, $V_{T,t-1} = S_{t-1}$ + dead storage). Substituting into the continuity equation (7) yields

$$S_{t+1} = S_t + Q_{t+1} - W_{t+1} + G_{t+1} \times 0.0271 \times (116 + 0.115 \times V_{T,t}) \qquad (11)$$

3.4 Period of Simulation

Most reservoirs in the southeast refill by April 1. Figures 2.6 and 2.7 show that by the end of March, the relatively high flows of winter and early spring enable the reservoirs to fill. The period from the end of March to the following April is termed the drawdown-

[1] 1 acre-inch = 0.02715 million gallons

refill (D-R) cycle. The assumption that the reservoirs refill is essential to estimating the probability that an amount of storage is ample to meet projected demands (Moreau,1991).

3.5 Simulation Model

Simulations calculate the working volume for each week of a given year using continuity equation (11) modified as follows, where j is the year, t is the start week of simulation, and $t+k$ is the week of simulation

$$
\begin{aligned}
S_{j,t+1} &= S_{j,t} + Q_{j,t+1} - W_{j,t+1} + G_{j,t+1} \times 0.0271 \times (116 + 0.115 \times V_{T,t}) \\
S_{j,t+2} &= S_{j,t+1} + Q_{j,t+2} - W_{j,t+2} + G_{j,t+2} \times 0.0271 \times (116 + 0.115 \times V_{T,t+1}) \\
&\quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
&\quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
S_{j,t+k} &= S_{j,t+k-1} + Q_{j,t+k} - W_{j,t+k} + G_{j,t+k} \times 0.0271 \times (116 + 0.115 \times V_{T,t+k-1})
\end{aligned}
\qquad (13)
$$

Suppose we want to assess whether a specific storage amount, say $S_{j,0}$ = 6300 MG, at say, July 15, is sufficient to meet an average daily demand of say, 60-MGD ($W_{j,t}$ = 60) for every week $t+k$ in the remainder of the drawdown-refill period. Suppose also that we choose to simulate the storage ($S_{j,t+k}$) for each week $t+k$ using only data for year j = 1933.

Recall that when the working volume is less than zero, a failure in meeting demand is recorded for that year. When the storage is calculated to be less than zero, then the available storage is set equal to zero (if $S_{j,t+k} < 0$, then $S_{j,t+k} = 0$). If $S_{j,t+k} = 0$ then a failure has occurred in the system and demand cannot be met without conservation/rationing.

When the maximum working volume (S_{max} = 6350 MG) is exceeded, spillage occurs. Therefore, if $S_{j,t+k} > S_{max}$, $S_{j,t+k} = S_{max}$ to account for spillage. Hence the maximum working volume is an important parameter in simulation: if the storage is expanded, the maximum working volume increases and spillage can be reduced. Thus, expansion can improve the ability to meet demands by enabling the system to store water that would have otherwise spilled.

Table 3.1 shows simulation of the reservoir over a period of 29 weeks until failure occurs (in mid-October). To simplify the example, the effects of precipitation and evaporation are ignored. The reservoir starts nearly full in week 1 with 6300-MG. At the end of the first week, the reservoir is still full and spillage occurs. Spillage continues until week 7. During the dry summer months the storage volume is gradually drawn down until failure occurs when the volume equals zero in week 29.

The simulation can be repeated for each year that historical data are available and the number of times that failure occurs can be counted. Even if failure occurs in several months of the same year, that year is counted as a single failure. The number of years in which failures occur out of the total number of years simulations are made are used to determine the risk associated with any given initial storage and a target demand.

Table 3.1
Simulation of 6350-MG Reservoir With 60-MGD Withdrawal Rate

Week t+k	Start Volume S(t+k-1) (MG)	+	Inflow Q(t+k) (MG)	-	Demand W (MG/wk)	=	End Volume S(t+k) (MG)
1	6300		512		420		6350
2	6350		900		420		6350
3	6350		3219		420		6350
4	6350		645		420		6350
5	6350		742		420		6350
6	6350		1795		420		6350
7	6350		399		420		6329
8	6329		396		420		6305
9	6305		476		420		6350
10	6350		148		420		6078
11	6078		406		420		6064
12	6064		193		420		5837
13	5837		125		420		5542
14	5542		62		420		5184
15	5184		95		420		4859
16	4859		52		420		4491
17	4491		67		420		4138
18	4138		165		420		3883
19	3883		112		420		3575
20	3575		63		420		3218
21	3218		152		420		2950
22	2950		66		420		2596
23	2596		204		420		2380
24	2380		62		420		2022
25	2022		30		420		1632
26	1632		13		420		1225
27	1225		8		420		813
28	813		7		420		400
29	400		12		420		0

The probability that a particular storage level in any week of the year is sufficient to meet projected demands over the remainder of the drawdown-refill period is termed the *probability of success* (PS), which is expressed as

$$PS = \left(1 - \frac{(\#\ failures\ )}{(\#\ years\ )}\right) \times 100\ \% \qquad (14)$$

The PS is a useful measure that can assist in determining whether or not the initial storage is adequate to meet future demands. If the PS falls short of a selected level of acceptable risk, then drought management measures may be considered necessary. The levels of acceptable risk are chosen based upon the risk-seeking/risk-aversion characteristics of the decision-maker (Moreau, 1991).

The simulation model developed for Durham is a Visual Basic program operating as a macro in an Excel 97 spreadsheet (Appendix D). The program accesses all input data from Excel spreadsheets and prints the output to another worksheet in the same workbook. All calculations are carried out in Visual Basic, with Excel serving only for storage of the input and output.

The input worksheet for the simulation program is depicted in Figure 3.2. There are two variations of the input page: one with reservoir surface elevations for storage volume calculations using equations (1) and (3) as in Figure 3.2, and the other with reservoir volumes entered directly. Both versions have their own advantages. This input page supplies information about the working volume, the initial volume in storage, the current week, the average demand to be met, and alternative conservation policies.

Figure 3.2 Input Worksheet for Simulation Model

Reservoir and Demand Inputs

Lake Michie Stage (ft)	341
Lake Michie Min. (ft)	312.5
Little River Stage (ft)	355
Little River Min. (ft)	326
Avg. Demand (MGD)	60
Start week	16

For the probability of success over the remainder of the year:
Ctrl-a , or click on **"RUN"**

RUN

(results stored in "output")

Status of Phases for Rationing

	Percent reduction	start week	duration (weeks)	Enacted
Phase 1 rationing	0.1	30	4	no
Phase 2 rationing	0.1	30	0	no
Phase 3 rationing	0.25	0	4	no

NOTE: Duration of phases should not overlap unless marginal increases in reduction are used (durations *include* the start week of rationing).

The historical data input for reservoir inflow, precipitation, and evaporation are provided by additional worksheets that can be viewed in Appendix E. Inflows for Lake Michie and Little River reservoir are combined and expressed in millions of gallons per week. The precipitation and evaporation data in inches are combined into a single flux term using equations (9) and (10).

Minimum flows are required downstream of the reservoirs for the Flat River and Little River. These flows can either be added to the target demand or entered directly into the Visual Basic program. For the models herein, the minimum flows are written into the program and assume 2.1 MG/week below Lake Michie and 1.4 MG/week below Little River reservoir for a combined total of 3.5 MG/week over and above target demand.

If the user wishes to model the impacts of a particular rationing policy, the policy can be entered in the table of the input page entitled *Status of Phases for Rationing.* Input requires a percent reduction in demand for a particular period. A "yes" in the *Enacted* column tells the program to include the policy in making simulations. For example, if "no" in the first row of the status table were changed to "yes", the simulation would assume that "phase 1 rationing" could reduce target demand by 10 percent, that it would start in week 30, and that it would continue for 4 weeks. Note that the model permits up to 3 different phases of rationing. The "percent reduction" value, which is specified by the user, always indicates the reduction in target demands.

It may be useful to permit variations in demands through the use of multipliers rather than holding target demand constant throughout the year. Demands generally vary for each month and are typically higher during the summer. The multipliers for each month (ratio of monthly to average annual demand) were determined from historical data collected from Durham during the years 1980 to 1994. The model includes a separate worksheet for the multipliers that are accessed during the running of the simulation program (Figure 3.3). The average 1980-1994 factors are depicted in the column of Figure 3.3 labeled *Default Multipliers.* If the user wishes to use another set of multipliers, they can be entered in the column labeled *Monthly Multipliers.* If the *Monthly Multiplier* column is left blank, then the default factor will be used. A "1.0" in the *Monthly Multiplier* column is equivalent to using the target demand. As the program runs, the monthly average daily demands are calculated and printed in the column entitled *Demand*

Figure 3.3 Monthly Multiplier Input Sheet

Monthly Multipliers of Average Yearly Demand

	Monthly Multiplier	Default Multiplier	Demand (MGD)
April		0.94	28.20
May		1	30.00
June		1.07	32.10
July		1.13	33.90
Aug		1.12	33.60
Sept		1.08	32.40
Oct		1.04	31.20
Nov		0.95	28.50
Dec		0.94	28.20
Jan		0.95	28.50
Feb		0.85	25.50
Mar		0.92	27.60

* A blank space in "Monthly Multiplier" initiates "Default Multiplier" values

(MGD). The demands in Figure 3.3 show monthly variations for a mean annual demand of 30 MGD.

The program reads the multiplier values off the input page and applies them to the respective months. With data from Figures 3.2 and 3.3, the model now has values for the week when simulation starts, initial storage ($S_{j,k}$), maximum working volume, and a target withdrawal rate for each month (W_m) of the remainder of the drawdown-refill period, plus a rationing policy if one is selected. The initial storage is calculated using surface elevations with equations (1) and (3); summing the amounts for each reservoir produces a single value for $S_{j,t}$. The volumes calculated with the user-supplied minimum elevations are subtracted from the full elevations to determine the maximum working volumes of the reservoirs (Figure 3.2).

Once the data are inputted, the program initiates simulation of the reservoir system using the 72 years of historical data for storage inflows, precipitation, and evaporation. The simulation process is carried out in the manner described in Table 3.1 for each year on record. If the working volume falls below zero, the simulation is terminated for that year and the process is restarted for the next year.

The output sheet is shown in Figure 3.4. Output from the program is reported for every year whether a failure occurs or not. If a failure does occur, the week in which the working volume is drawn to zero is also reported. Once the years with failures are identified, the PS is determined and printed onto the output sheet together with all the information that was pertinent to the simulation.

The output sheet in Figure 3.4 reports results of our example with initial storage of 6300-MG in the third week of July (week 16), a demand of 420-MG/week (60-MGD), and no rationing enacted. Unlike Table 3.1, the effects of precipitation and evaporation are included in the simulation. Again, for 1933, the simulation determines zero working volume in mid-October (week 33). With failures to meet demands in 14 out of 72 simulations, the PS is calculated to be 76.4 %. That is, if combined storage (over and above dead storage) in the third week of July is 6300 MG, the reservoirs would be able to meet a target demand of 60 MGD (adjusted with monthly multipliers) in 76.4 years out of 100.

Figure 3.4 Output of Simulation Model

Start Week	16
Probability of Success:	76.39
Initial Working Vol. (MG):	6300
Max. Working Vol. (MG):	6350
Avg. Demand (MGD):	60

	% Red.	Start Week	End Week
Phase 1			
Phase 2			
Phase 3			

Year	Failure Status	Week of Failure
1926		
1927		
1928		
1929		
1930	1	34
1931		
1932		
1933	1	33
1934		
1935		
1936		
1937		
1938		
1939		
1940		
1941	1	33
1942		
1943	1	32
1944		
1945		
1946	1	39
1947		
1948		
1949		
1950		
1951	1	34
1952		
1953	1	31
1954		
1955		
1956		
1957		
1958		
1959		
1960		
1961		
1962		
1963		
1964		
1965	1	40
1966		
1967	1	34
1968	1	31
1969		

Year	Failure Status	Week of Failure
1970		
1971		
1972		
1973		
1974		
1975		
1976	1	32
1977		
1978		
1979		
1980	1	36
1981		
1982		
1983	1	31
1984		
1985		
1986		
1987	1	33
1988		
1989		
1990		
1991	1	34
1992		
1993	1	32
1994	1	37
1995		
1996		
1997		

If the PS of 76.4% is concluded to be too low, then rationing can be used to raise the probability and reduce the risk of failure. One policy could be a voluntary public conservation effort that could restrict watering of lawns to specified days, encourage the public to reduce the frequency of car washing, etc. To include rationing in the simulation, we selected a policy that would result in a 10% reduction in demand, be started immediately (in week 16), and have a duration of six weeks, as shown in Figure 3.5.

Figure 3.5 Input Sheet With "Voluntary" Conservation

Reservoir and Demand Inputs

Initial Storage (MG)	6300
Max. Storage (MG)	6350
Min. Storage (MG)	0
Avg. Demand (MGD)	60
Start week	16

For the probability of failure over the remainder of the year:
Ctrl-e , or click on **"RUN"**

(results stored in "output")

Status of Phases for Rationing

	Percent reduction	*start week*	*duration (weeks)*	*Enacted*
Phase 1 rationing	0.1	16	6	yes
Phase 2 rationing	0.2	22	4	no
Phase 3 rationing	0.25	0	4	no

NOTE: Duration of phases should not overlap unless marginal increases in reduction are used (durations *include* the start week of rationing).

Results from the simulation are shown in the output sheet of Figure 3.6; PS has now increased to 77.8 %.

If this PS is judged to be unacceptably low, a second policy can be considered in addition to the first, for example, involuntary conservation enforced by law.

Figure 3.6 Output Sheet of Simulation With "Voluntary" Conservation

Start Week:	16
Probability of Success:	**77.78**
Initial Working Vol. (MG):	6300
Max. Working Vol. (MG):	6350
Avg. Demand (MGD):	60

	% Red.	Start Week	End Week
Phase 1	0.1	16	21
Phase 2			
Phase 3			

Year	Failure Status	Week of Failure
1926		
1927		
1928		
1929		
1930	1	35
1931		
1932		
1933	1	34
1934		
1935		
1936		
1937		
1938		
1939		
1940		
1941	1	34
1942		
1943	1	33
1944		
1945		
1946		
1947		
1948		
1949		
1950		
1951	1	35
1952		
1953	1	32
1954		
1955		
1956		
1957		
1958		
1959		
1960		
1961		
1962		
1963		
1964		
1965	1	40
1966		
1967	1	35
1968	1	32
1969		

Year	Failure Status	Week of Failure
1970		
1971		
1972		
1973		
1974		
1975		
1976	1	33
1977		
1978		
1979		
1980	1	37
1981		
1982		
1983	1	32
1984		
1985		
1986		
1987	1	34
1988		
1989		
1990		
1991	1	35
1992		
1993	1	32
1994	1	37
1995		
1996		
1997		

Assuming that this policy would reduce demand by 20 %, be started at the end of the 6-week voluntary rationing period, and have a duration of four weeks, the input sheet would be as shown in Figure 3.7.

Figure 3.7 Input Sheet of "Voluntary" Conservation Followed By "Involuntary" Conservation

Reservoir and Demand Inputs

Initial Storage (MG)	6300
Max. Storage (MG)	6350
Min. Storage (MG)	0
Avg. Demand (MGD)	60
Start week	16

For the probability of failure over the remainder of the year: **Ctrl-e** , or click on **"RUN"**

RUN

(results stored in "output")

Status of Phases for Rationing

	Percent reduction	*start week*	*duration (weeks)*	*Enacted*
Phase 1 rationing	0.1	16	6	yes
Phase 2 rationing	0.2	22	4	yes
Phase 3 rationing	0.25	0	4	no

NOTE: Duration of phases should not overlap unless marginal increases in reduction are used (durations *include* the start week of rationing).

Output of the simulation incorporating the two policies is in Figure 3.8. The addition of the second conservation policy increases the PS to 80.7 %. Hence, the marginal payoff from the second policy increases the PS by 4.3 %.

In summary, the simulation model developed for Durham enables the user to determine the risk associated with any storage available at a specified week of the year in meeting projected demands over the remainder of the drawdown-refill period. If the risk is concluded to be too high, the user has the ability to select up to three different

Figure 3.8 Output Sheet of Simulation with "Voluntary" and "Involuntary" Conservation Policies Enacted

Start Week	16
Probability of Success:	**80.56**
Initial Working Vol. (MG):	6300
Max. Working Vol. (MG):	6350
Avg. Demand (MGD):	60

	% Red.	Start Week	End Week
Phase 1	0.1	16	21
Phase 2	0.2	22	25
Phase 3			

Year	Failure Status	Week of Failure
1926		
1927		
1928		
1929		
1930	1	36
1931		
1932		
1933	1	34
1934		
1935		
1936		
1937		
1938		
1939		
1940		
1941	1	35
1942		
1943	1	34
1944		
1945		
1946		
1947		
1948		
1949		
1950		
1951	1	36
1952		
1953	1	33
1954		
1955		
1956		
1957		
1958		
1959		
1960		
1961		
1962		
1963		
1964		
1965	1	41
1966		
1967		
1968	1	32
1969		

Year	Failure Status	Week of Failure
1970		
1971		
1972		
1973		
1974		
1975		
1976	1	34
1977		
1978		
1979		
1980	1	39
1981		
1982		
1983	1	33
1984		
1985		
1986		
1987		
1988		
1989		
1990		
1991	1	36
1992		
1993	1	33
1994	1	38
1995		
1996		
1997		

conservation policies and include them in the simulation. The impacts of the selected policies can be analyzed and compared with other policies under consideration. This enables the decision-maker to select the policy that best suits the situation given influences that may not be foreseen by a deterministic model that selects policies that meet criteria predetermined for that model. Such influential factors may have a bearing on the start date, duration, or percent reduction in demand that a conservation effort is associated with. An analysis of the impacts of various conservation policies and the reaction of the system to such efforts is provided in Chapter 4.

Chapter 4. Impacts of Alternate Conservation Policies

4.1 Levels of Acceptable Risk

The acceptable risk level that is selected as the criterion for decision support of drought contingency planning varies from one utility to another and from one person to another. Moreau and Little (1989) reviewed several utilities where risk levels were the criteria for drought managerial decisions and discovered that the stringency of the acceptable levels were related to the sufficiency of the supply to meet the utility's respective demands. The utilities with supplies observed to have problems meeting stringent criteria are consequently managed with higher levels of risk (Moreau and Little, 1989).

Since the expansion of Durham's water supply in 1986 with addition of the Little River reservoir, the city has not experienced difficulty in supplying water for the growing community. With a safe yield of about 45-MGD and an average annual demand in 1998 of 30-MGD, the utility assesses the acceptable risk of system failure at relatively stringent levels. The PS associated with that level of risk is set at 95%. Any PS calculated below the 95% criterion is determined unacceptable, and conservation is considered necessary to increase the PS.

Triggers can be identified using the model of this report to designate the required volume in any week to maintain a certain PS level. Those volumes are referred to as *trigger volumes*, and they are convenient for analysis of a supply's storage requirements over a period of interest. Triggers may be set at varying PS levels and serve as criteria for implementation of different degrees of water conservation (Moreau and Little, 1989).

Figure 4.1 shows the trigger volumes associated with PS levels of 95%, 90%, 80%, and 75% at a constant demand of 30-MGD throughout the length of the drawdown-refill period. The largest difference in trigger volumes of the PS's depicted in Figure 4.1 occurs from mid-May through August, which is designated as the driest period of drawdown-refill cycle and requires the most attention for drought management. The positive slope in the early weeks of the drawdown-refill period is related to the gradual decrease in magnitude of the inflows to the reservoirs and the subsequent increase in the storage required to meet demands. The negative slope in the latter weeks of the drawdown-refill cycle results from the decrease in the storage requirements as the remainder of the drawdown period shortens and the inflows gradually increase.

Trigger volumes are often used for decision support due to their relatively easy-to-visualize characteristics. Decision-makers can readily check to see if the present storage at any week is above that associated with the selected PS criterion. If the PS falls below the trigger level, then implementation of a public conservation program is considered necessary. Durham's methodology for policy selection was developed in 1982 with the assistance of the Research Triangle Institute and is outlined in Table 4.1 (McCrodden and Paddock, 1982).

Figure 4.1
Trigger Volumes (30-MGD Demand)

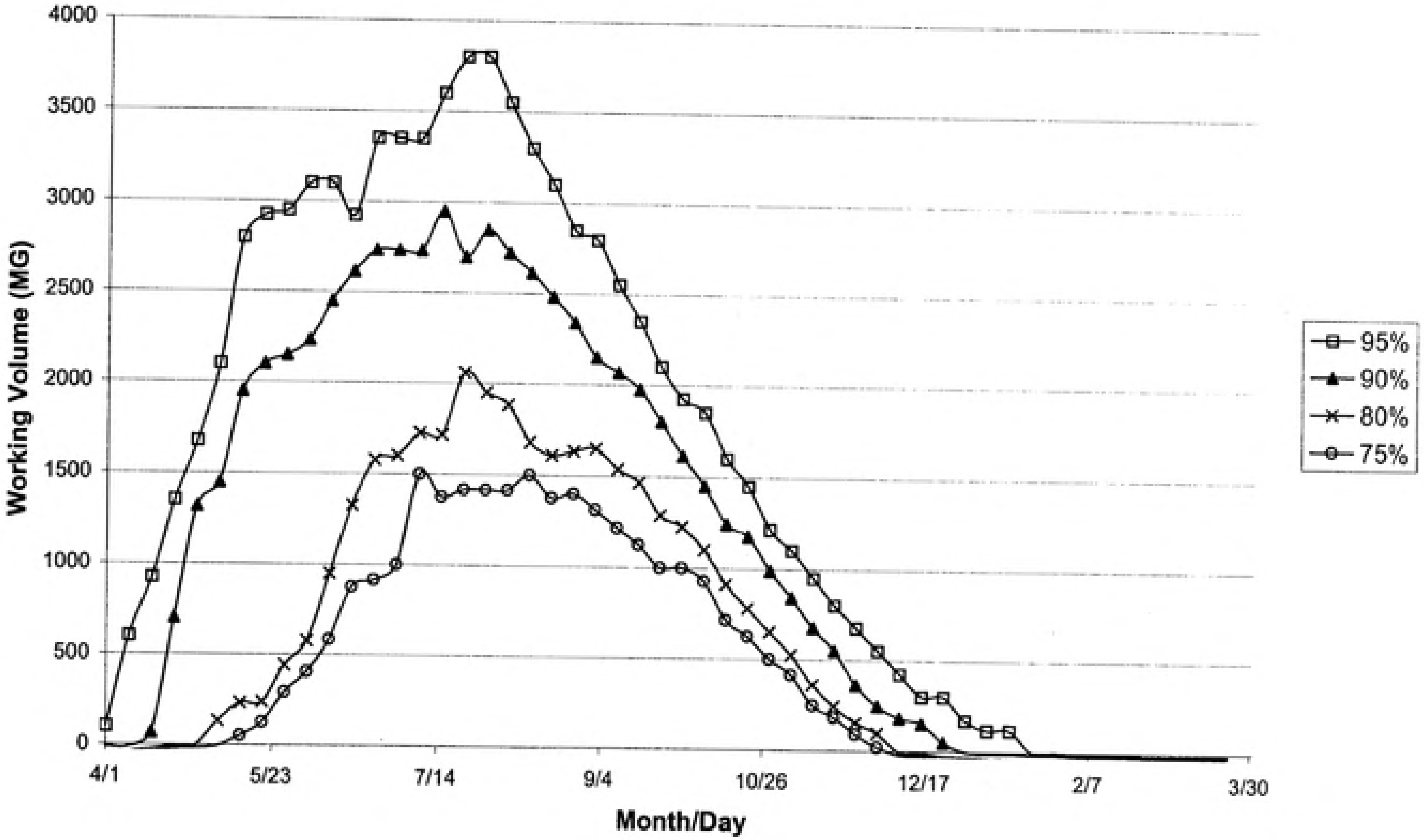


Table 4.1

PS	Action
Above 95%	Stage I: Continuing of Voluntary Practices
Below 90%	Stage II: Voluntary Conservation
Below 80%	Stage III: Moderate Mandatory Conservation
Below 75%	Stage IV: Severe Mandatory Conservation

Conservation efforts are always required below the trigger level of 95 %. This methodology requires repeated evaluations of the risk of failure as time passes, with the lifting of conservation when the 95 % PS is reached.

The model developed in this study enables the user to select specific policies for evaluation to aid in the planning of future events. Using the 95 % PS for decision, alternative policies can be simulated and compared to determine an appropriate plan of action in dealing with droughts.

4.2 Impact of Alternate Conservation Policies

It was shown in Chapter 3 that specific conservation policies with selected start dates, duration, and reductions in demand have varied impacts on the risk associated with a given storage at any week of the year. The number of policies that may be selected are endless. However, an idea as to how the system reacts to different conservation strategies can be analyzed to provide an overall understanding of their impacts.

Assuming a constant demand of 30-MGD, the impacts on the 95 % PS trigger volumes of three policies are compared (Table 4.2). The alternative policies are: (1) rationing that reduces demand by 10 % that is invoked for four weeks, (2) rationing that reduces demand by 10 % for two weeks followed by a 20 % reduction for an additional two weeks, (3) rationing that reduces demand by 10 % that is invoked for eight weeks, and (4) rationing that reduces demand by 20 % that is invoked for four weeks. The conservation policies are assumed to start in the initial week of the simulation.

Figures 4.2, 4.3, 4.4 and 4.5 depict the impacts of the alternative policies on the trigger volumes for each week. Consider week 4 in Table 4.2 and Figure 4.2. Without rationing, 1350 MG needs to be in storage to have a 95 % chance of meeting a 30-MGD demand. However, rationing for four weeks that reduces demand by 10 % would reduce the initial storage requirement in week 4 to 1200 MG. In most weeks, conservation reduced the volume required to ensure a 95 % PS. In practical terms, this suggests that if a volume at a particular week is below that of the 95 % PS trigger volume but above the trigger volume accounting for a specific conservation policy, then that policy can provide a useful remedy to ensure the system will not fail. It is obvious from the figures and table that the response of the risk assessment to the varying degrees of conservation is dynamic, with no uniform reduction in the trigger volume for all weeks, but rather a reduction that is dependent upon the weeks when conservation is imposed.

Table 4.2
Required Volumes for Meeting a 30-MGD Demand With 95 % Probability of Success

		Policy			
Week	No Ration	1	2	3	4
1	100	100	100	100	100
2	600	600	350	350	350
3	925	925	925	850	850
4	1350	1200	1175	1175	1175
5	1675	1600	1600	1600	1600
6	2100	2100	2100	1950	1950
7	2800	2600	2600	2600	2600
8	2925	2800	2800	2675	2675
9	2950	2950	2925	2850	2850
10	3100	3100	3100	2925	2925
11	3100	3100	2925	2925	2925
12	2925	2925	2850	2850	2850
13	3350	3300	3300	3100	3100
14	3350	3350	3100	3100	3100
15	3350	3350	3350	3350	3350
16	3600	3550	3550	3550	3550
17	3800	3800	3600	3550	3550
18	3800	3550	3550	3550	3550
19	3550	3550	3350	3300	3300
20	3300	3300	3300	3100	3100
21	3100	3050	3050	3050	3050
22	2850	2800	2800	2800	2800
23	2800	2600	2600	2550	2550
24	2550	2425	2350	2350	2350
25	2350	2350	2175	2100	2100
26	2100	2100	2100	1950	1950
27	1925	1850	1850	1850	1850
28	1850	1600	1600	1600	1600
29	1600	1463	1425	1425	1425
30	1450	1425	1350	1350	1220
31	1213	1175	1175	1175	1175
32	1100	1050	950	950	950
33	950	800	800	800	800
34	800	800	800	600	550
35	675	550	550	550	550
36	550	425	425	425	425
37	425	300	300	300	300
38	300	300	300	300	225
39	300	213	213	213	117
40	170	170	170	170	117
41	117	117	117	117	117
42	117	50	50	50	50
43	0	0	0	0	0
44	0	0	0	0	0
45	0	0	0	0	0
46	0	0	0	0	0
47	0	0	0	0	0
48	0	0	0	0	0
49	0	0	0	0	0
50	0	0	0	0	0
51	0	0	0	0	0
52	0	0	0	0	0

Figure 4.2 Impact of a 10% Demand Reduction for 4 Weeks on Trigger Volumes for a 95 % Probability of Success at 30-MGD Demand (week 1 = April 1)

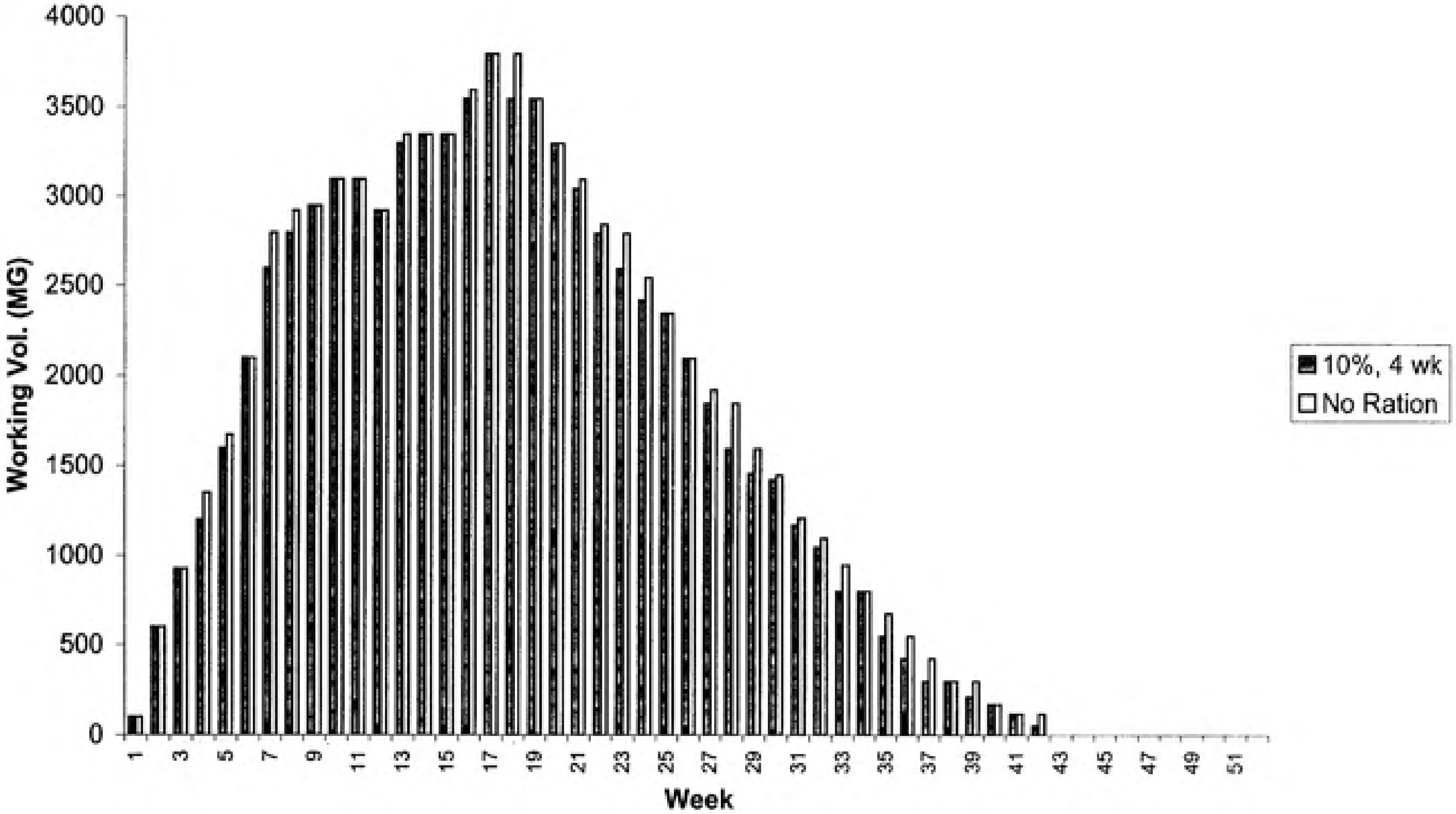


Figure 4.3 Impact of a 10% Demand Reduction for 2 Weeks Followed by a 20 % Demand Reduction for 2 Weeks on Trigger Volumes for a 95 % Probability of Success at 30-MGD Demand (Week 1 = April 1)

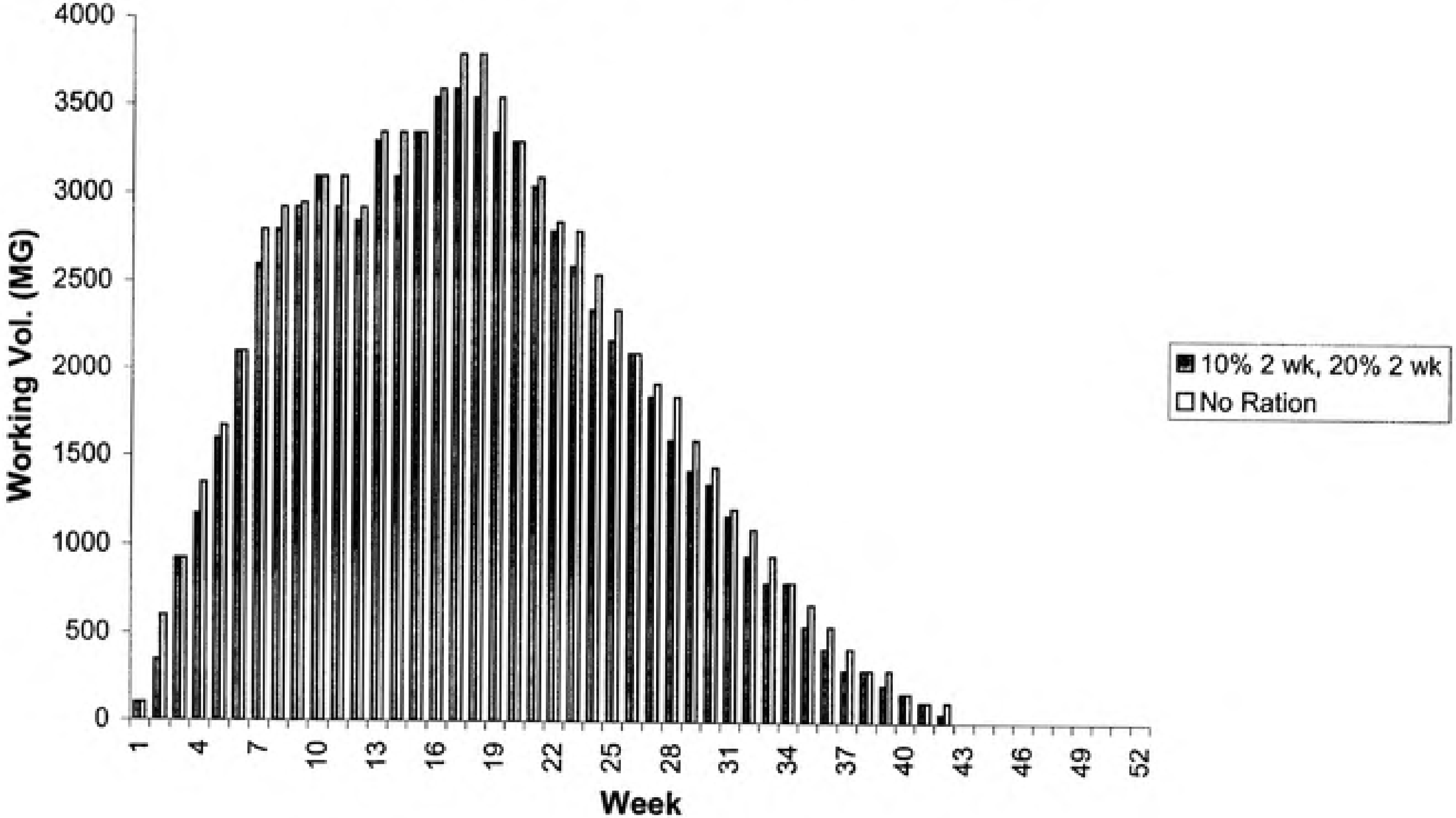


Figure 4.4 Impact of a 20% Demand Reduction for 4 Weeks on Trigger Volumes for a 95 % Probability of Success at 30-MGD Demand (Week 1 = April 1)

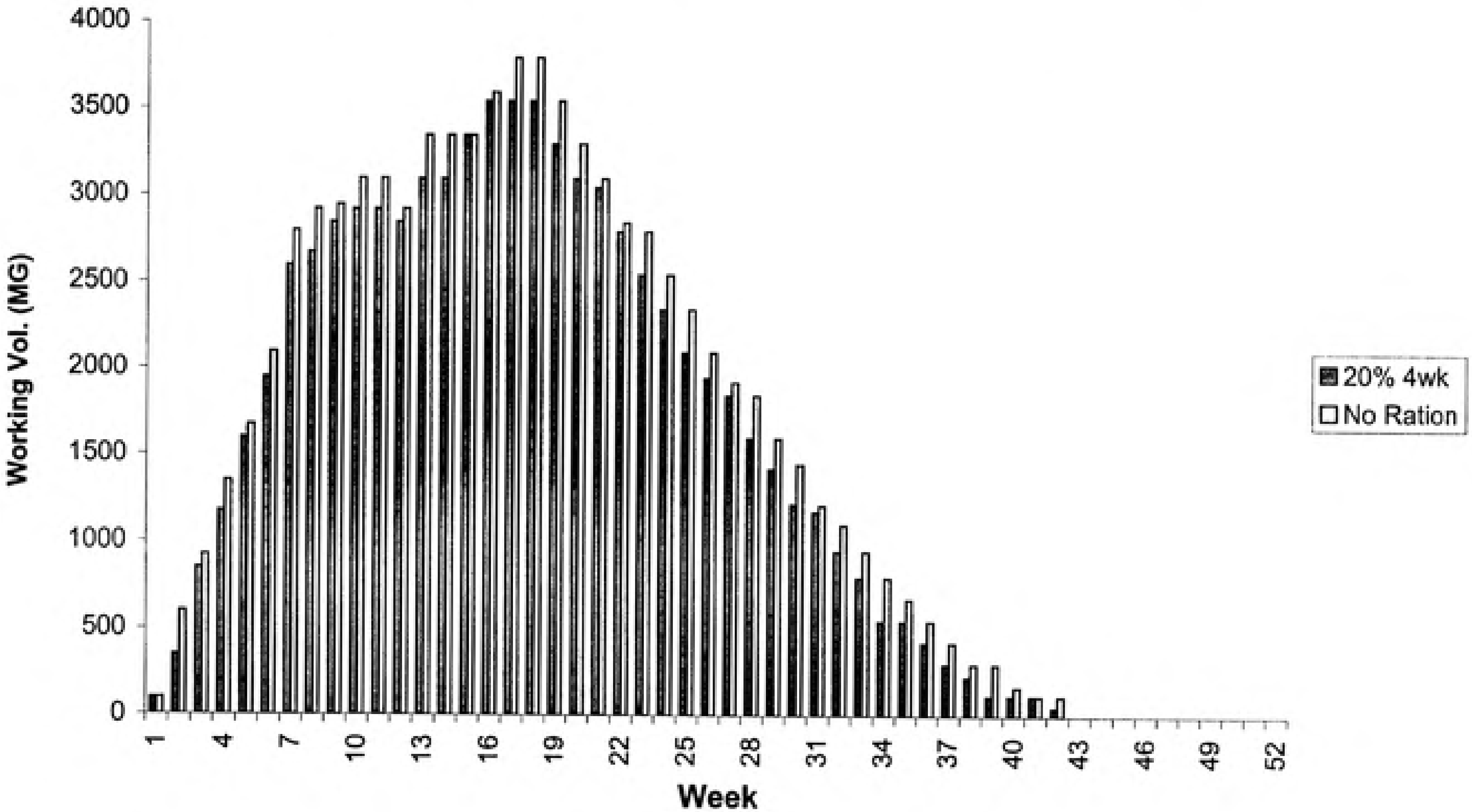
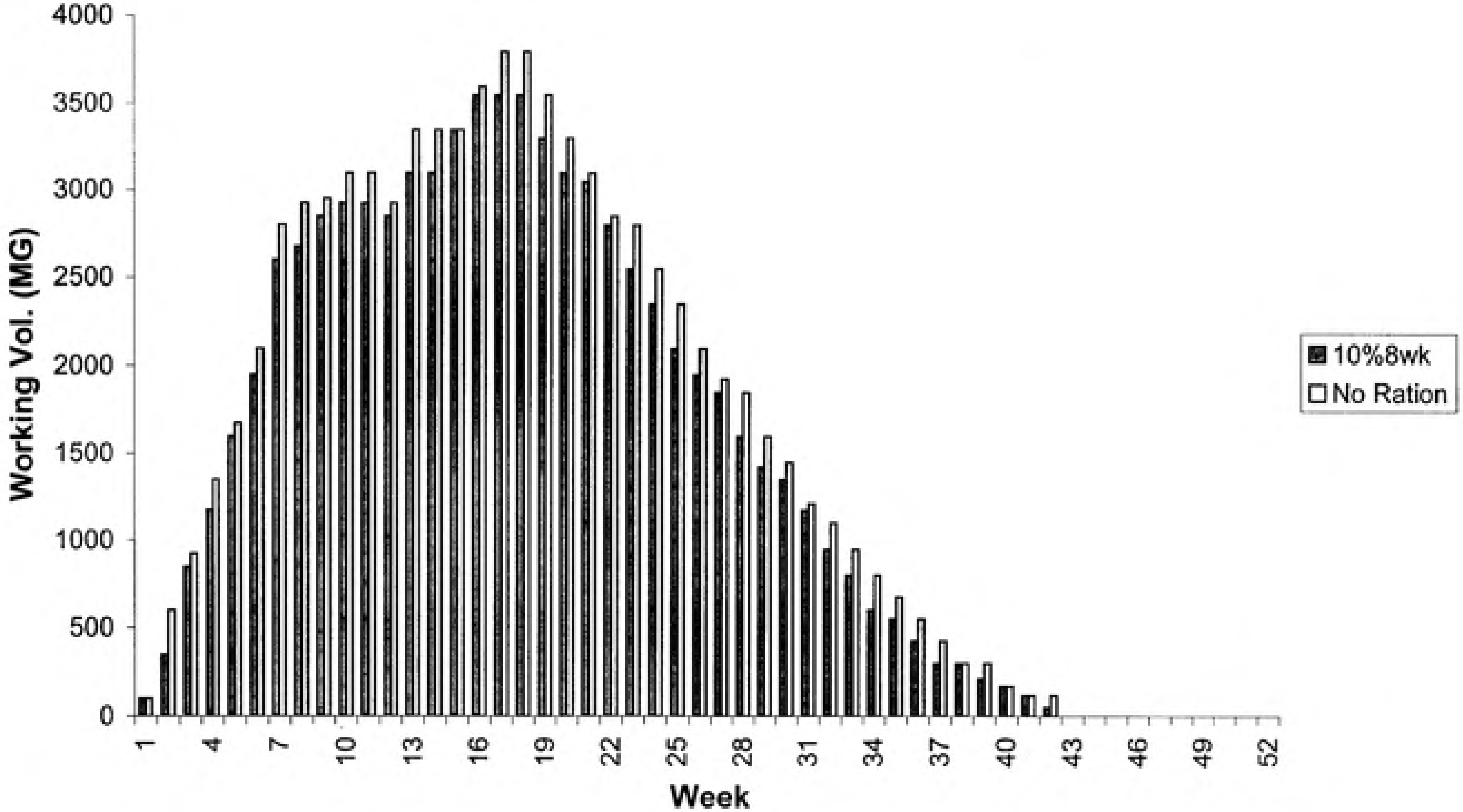


Figure 4.5 Impact of a 10% Demand Reduction for 8 Weeks on Trigger Volumes for a 95 % Probability of Success at 30-MGD Demand (Week 1 = April 1)



The stringency of the policy is shown to have a noticeable effect on trigger volumes. If voluntary conservation is assumed to reduce demand by 10 % and an involuntary policy results in a reduction of 20 %, information about how each policy will impact the risk is helpful in planning for a possible drought. Comparing Figures 4.2 and 4.3 (policies 1 and 2 in Table 4.2), it can be seen that an additional 10 % demand reduction in the last two weeks of the four-week rationing period has only minor impacts on some weeks. However minor, this effect can be a determining factor when choosing what policy to enact.

The length of the rationing period also plays an important role in the impact analysis. It is assumed that a 10 % demand reduction for eight weeks will have the same result as a 20% reduction for 4 weeks. A comparison of Figures 4.4 and 4.5 (policies 3 and 4 of Table 4.2) show that both policies indeed have almost identical results. The differences in impacts do not occur until week 30 (mid-October), but even then the difference is slight. Therefore, the duration of conservation is an important consideration when selecting a policy.

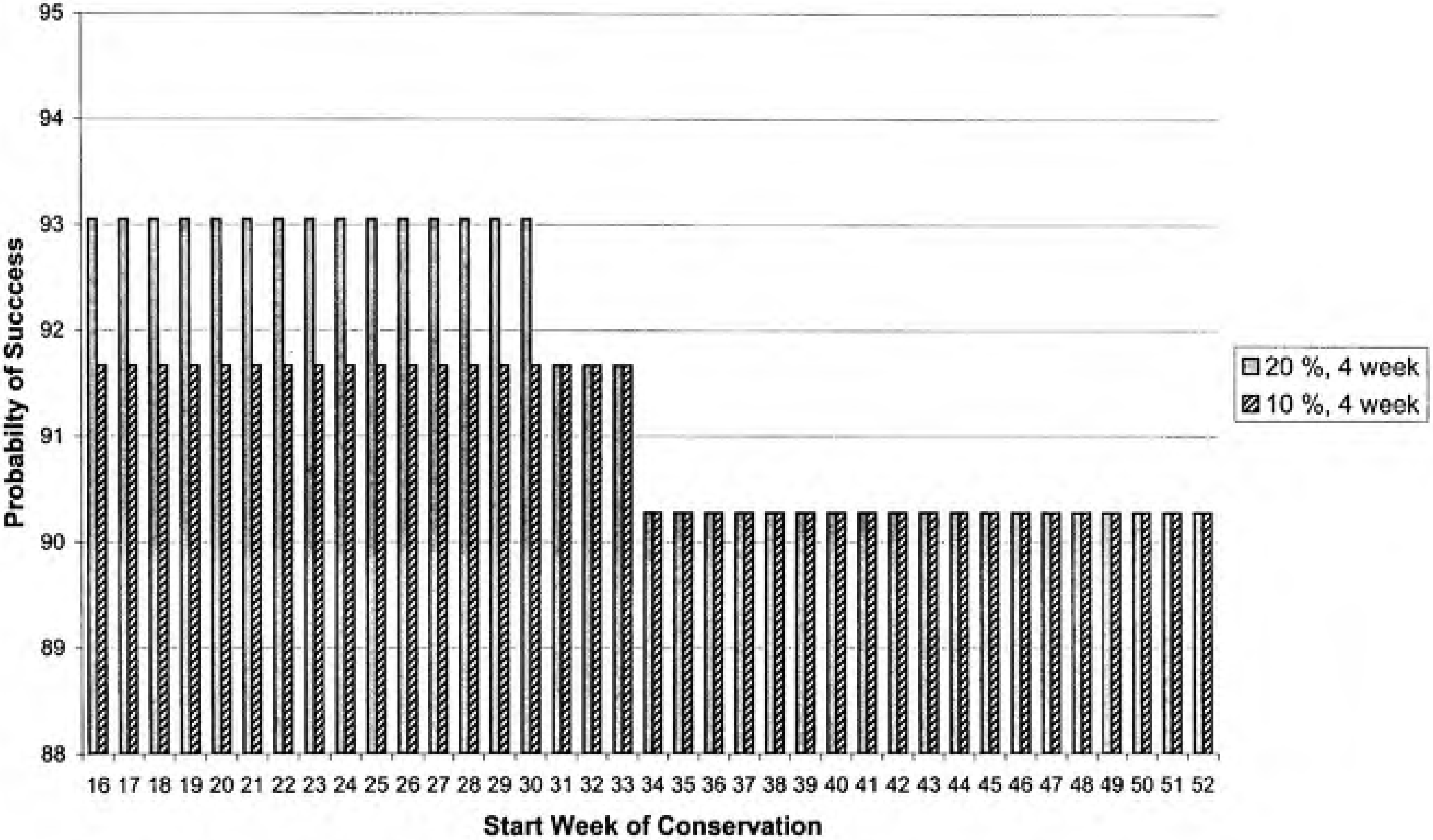
Another important consideration for drought contingency planning is *when* a conservation policy should be implemented. Figures 4.2, 4.3, 4.4, and 4.5 and Table 4.2 show that the impact on the risk of meeting projected demands depends on when the policy is enacted, assuming the start date is immediate, but how will the risk change if rationing is delayed?

To answer this question, another example is used assuming an initial working volume of 4.78 billion gallons in the second week of July (week 16) and a 45-MGD constant demand over the remainder of the drawdown-refill period. The conservation strategies are (1) a 10 % and (2) a 20 % demand reduction, each for a four-week duration. If simulation is carried out beginning week 16 and the start weeks of the conservation policies are successively delayed, insight into the ideal time to implement the policies can be obtained.

Figure 4.6 depicts the results of the simulations, tracking the change in the PS with different start dates of conservation. The PS resulting from the 10 % and 20 % reductions are 91.6 % and 93.0 %, respectively, with initiation in the first week (week 16) of simulation. As the start dates are delayed, the PS of the 20 % reduction policy does not change until week 31 (third week of October) when it declines to 91.6 %. If the start date is delayed further, both policies have a decline in PS to 90.3 % in week 34 (third week of November). Similar results are observed for several storage, modeled week, and projected demand scenarios, with reductions in the PS not caused by a delay in conservation until October or November. Hence, if an amount in storage is below a trigger volume, indicating the need for rationing, it may be possible to delay the start of rationing until fall.

The impact of alternative conservation strategies are subject to departures from a specific outcome as a result of variations in the projected demands, the working volume at any week of interest, magnitude of the demand reduction, duration of the policy, and

Figure 4.6 Probability of Success of Two Different Rationing Policies vs. Week of Initiation
(Week Beginning July 15, 45 MGD Withdrwal Rate ,4780 MG Initial Storage)



start week of the conservation effort. The variables that play a role in the analysis of impacts are numerous. However, it has been shown that different policies can be selected that have similar results depending on the amount the demand is reduced through conservation and its duration. Also, the start date of conservation is flexible with delay being another decision that is possible without risk of system failure affected.

Chapter 5. Conclusions and Recommendation

5.1 Conclusions Drawn From Analysis

The selection of a conservation strategy is contingent upon the conditions that govern the rate at which the storage will be drawn down and possibly fail with zero working volume. The factors that influence this phenomenon are the initial storage, the rate of withdrawal, the week of the year, the maximum working volume, and the degree to which a proposed strategy can reduce the amount that the storage will be degraded. A reduction in withdrawal can be produced by various forms of public conservation or the termination of sales to neighboring towns.

The first strategy for Durham to implement would likely be the termination or reduction in sales to other municipalities. The citizens of Durham would presumably not be pleased to ration their water use if a neighboring community buying from the city had no such restriction.

In general, a delay in demand reduction through rationing or reduced sales does not adversely affect the risk of meeting demand until October or November. Given that sales produce social benefits (and revenues), a delay would be beneficial, especially if by fall sales to neighboring towns would normally be reduced due to lower demand. A delay in the stopping of sales can therefore benefit both parties: Durham would maximize revenues without putting its neighbor at risk of not meeting their demands.

In addition to sales, a delay in implementation of conservation provides a chance for rainfall events to remedy the situation so that no further cause for alarm is needed. However, if a voluntary or involuntary public conservation policy is delayed until October or November, it could be difficult to explain to the public *why* such measures are necessary since the hot summer period is over. This could be especially true if rainfall had been observed just before the enactment of a policy.

The first public conservation policy historically selected by Durham is generally on a voluntary basis. The philosophy is that if extreme measures such as an involuntary, law-enforced ordinance are implemented without first attempting a less stringent effort, the public may lose trust in the ability of the decision-makers. That being the case, when selecting the policy to deal with drought, the strategies considered could be either a voluntary-based demand reduction with a specified duration, or a strategy with a shorter duration that starts with a voluntary policy and changes to a more stringent program in the latter part of the planning period. However, it has been shown that an initial stringent policy (involuntary) will have essentially the same results as a less stringent (voluntary) policy with a much longer period. Therefore, a reevaluation of the methodology for policy selection may be considered. Different strategies can be simulated using the model and an ideal policy can be selected. Repeated simulations on a week by week basis will ensure that the proper strategy is maintained.

The simulation model provides a useful tool for decision support in drought planning. Its flexibility enables the user to model a variety of scenarios and policies, enabling the decision-maker to be both tactical and innovative. The model's capacity to compare alternative strategies provides Durham the capability of selecting appropriate measures to alleviate the risk of not meeting demands. In addition to drought planning, the model can analyze the effect of increased storage on meeting demands in the distant future. Such forecasting is valuable in long-term capacity planning.

5.2 Recommended Future Work

It is recommended that a comparison be made of the results from the model herein with those based on synthetic streamflows. The methodology for developing the synthetic flows involves the production of a sequence of values using a random process based on the statistical properties of the actual record. Fiering and Jackson (1971) provide several methods for the production of synthetic hydrology using a function that accounts for a deterministic part, generally a function of the mean flow for a specific week and flows of the previous week, and a random component corresponding to the underlying probability distribution of the historical record. A model that utilizes synthetic hydrology may have advantages in increasing the sensitivity of risk evaluations, thereby providing more insight into the response of the system to different conservation policies.

Another means of validating the results of the simulation model herein is with the use of a deterministic, goal- programming optimization model that seeks to minimize an objective function measuring economic losses resulting in conservation (Brandt and Lauria, 1999). Such a model could assist in choosing an initial policy that could later be varied and tested with the simulation model. OWASA of North Carolina uses just such a model as decision support for drought management (Nelson, 1996).

Finally, a study of the effect of conservation on demand during droughts is essential to devising the policies that are required to produce the reductions in demand necessary. Little and Moreau (1991) developed a model that backcasts demands during periods when conservation efforts were implemented. This model predicts, using such variables as temperature, rainfall, and seasonal variations, the demand that would have been observed if no conservation policy had been enacted. After a drought in 1986 when voluntary conservation strategies were implemented, the model was used to assess the significance of the demand reduction that resulted. Results showed that the conservation program had little effect on reducing demand. Similar studies would be helpful, but since the addition of the Little River Reservoir in 1988, no conservation policy has been necessary to reduce the risk of supply failure. When such an event presents itself, a reevaluation of the effects of conservation would be vital since an overestimation of expected reductions in demand through conservation could lead to serious consequences.

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Appendix A

Regression Analysis of Lake Michie and Little River Surface Elevations, Volumes, and Surface Areas

Appendix A

Regression Anaysis of Reservoir Volumes As Function of Lake Levels

Durham Stage-Volume Relationship

Basic data for L. Michie are total vols in million gallons (MG) from City of Durham dated Sept 1993

Intake Elev from L. Michie is at elev 310 (+/-), which implies absolute dead storage is about 680 MG

City's preference for maximum drawdown in L. Michie is about elev 312.5 (+/-), which implies dead storage of about 800 MG

Predicted Volumes

The model assumes max working vol for L. Michie is 2570 MG, which implies dead storage at elev about 319 or 320

Dead storage in L. Michie is about 800 MG at elev 312.5, & in L. River, dead storage is 1370 MG at elev 326 ft

Predicted vols of LM and LR based on following 2nd order eqs

Total LM Vol (MG)=191942-1262*(Elev, ft)+2.081*(Elev, ft)^2

Total LR Vol (MG)=151787-997.84*Elev(ft)+1.6454*Elev^2

Selected for Model

Lake Michie Elevation	Lake Michie (Elev)^2	Total Lake Michie Volume in MG	predicted (LM1) Total Lake Michie Volume in MG	predicted (LM2) Total Lake Michie Volume in MG
341.0	116281.0	3606	3310	3581
340.0	115600.0	3443	3215	3426
339.0	114921.0	3288	3120	3275
338.0	114244.0	3137	3025	3128
337.0	113569.0	2990	2930	2985
336.0	112896.0	2848	2836	2847
335.0	112225.0	2710	2741	2712
334.0	111556.0	2578	2646	2582
333.0	110889.0	2449	2551	2456
332.0	110224.0	2327	2456	2334
331.0	109561.0	2208	2361	2216
330.0	108900.0	2097	2267	2103
329.0	108241.0	1990	2172	1994
328.0	107584.0	1888	2077	1888
327.0	106929.0	1790	1982	1787
326.0	106276.0	1695	1887	1690
325.0	105625.0	1607	1793	1598
324.0	104976.0	1523	1698	1509
323.0	104329.0	1443	1603	1425
322.0	103684.0	1366	1508	1344
321.0	103041.0	1292	1413	1268
320.0	102400.0	1223	1318	1196
319.0	101761.0	1156	1224	1129
318.0	101124.0	1093	1129	1065
317.0	100489.0	1033	1034	1006
316.0	99856.0	975	939	950
315.0	99225.0	921	844	899
314.0	98596.0	869	749	852
313.0	97969.0	819	655	809
312.0	97344.0	770	560	771
311.0	96721.0	723	465	736
310.0	96100.0	679	370	706

Appendix A
Regression Anaysis of Reservoir Volumes As Function of Lake Levels

Total Little River Volume in MG	Little River Elevation	Little River (Elev)^2	predicted (LR2) Total Little River Volume in MG
4,942	355.0	126025	4915
4,765	354.0	125316	4747
4,596	353.0	124609	4581
4,427	352.0	123904	4419
4,266	351.0	123201	4260
4,106	350.0	122500	4105
3,953	349.0	121801	3952
3,801	348.0	121104	3803
3,655	347.0	120409	3657
3,510	346.0	119716	3515
3,372	345.0	119025	3376
3,234	344.0	118336	3240
3,103	343.0	117649	3108
2,972	342.0	116964	2978
2,848	341.0	116281	2852
2,724	340.0	115600	2730
2,606	339.0	114921	2610
2,489	338.0	114244	2494
2,379	337.0	113569	2381
2,269	336.0	112896	2272
2,165	335.0	112225	2166
2,073	334.0	111556	2063
1,974	333.0	110889	1963
1,879	332.0	110224	1867
1,786	331.0	109561	1774
1,697	330.0	108900	1684
1,611	329.0	108241	1597
1,528	328.0	107584	1514
1,449	327.0	106929	1434
1,373	326.0	106276	1358
1,300	325.0	105625	1284
1,230	324.0	104976	1214
1,162	323.0	104329	1148
1,097	322.0	103684	1084
1,035	321.0	103041	1024
976	320.0	102400	967
919	319.0	101761	914
863	318.0	101124	863
810	317.0	100489	816
760	316.0	99856	773
711	315.0	99225	732

Appendix A

Regression Analysis of Reservoir Volumes as a Function of Lake Levels

LM1

L. Michie Total Vol (MG)=-29024 + 94.82*(Elev, ft)

Regression Statistics	
Multiple R	0.982901569
R Square	0.966095495
Adjusted R Square	0.965001801
Standard Error	174.5151796
Observations	33

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	26902383.53	26902383.53	883.3327709	2.39208E-24
Residual	31	944121.9854	30455.54792		
Total	32	27846505.52			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-29024.14951	1040.531396	-27.89358363	1.59658E-23	-31146.32847	-26901.97055	-31146.32847	-26901.97055
X Variable 1	94.82319519	3.190453461	29.7209147	2.39208E-24	88.31621882	101.3301716	88.31621882	101.3301716

LM2

L. Michie Total Vol (MG)=191942-1262*(Elev, ft)+2.081*(Elev, ft)^2

Regression Statistics	
Multiple R	0.999875385
R Square	0.999750786 ← ***Best Correlation***
Adjusted R Square	0.999734172
Standard Error	15.20936035
Observations	33

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	27839565.78	13919782.89	60174.23285	8.88355E-55
Residual	30	6939.739268	231.3246423		
Total	32	27846505.52			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	191942.3963	3472.750421	55.27100225	9.54963E-32	184850.1011	199034.6916	184850.1011	199034.6916
X Variable 1	-1261.957288	21.31795085	-59.19693207	1.2411E-32	-1305.494307	-1218.420269	-1305.494307	-1218.420269
X Variable 2	2.080951662	0.032693462	63.65039113	1.43215E-33	2.014182773	2.14772055	2.014182773	2.14772055

LR2

Total Little R. Vol (MG)=151787-997.84*Elev(ft)+1.6454*Elev^2

Regression Statistics	
Multiple R	0.999967913
R Square	0.999935828
Adjusted R Square	0.99993245
Standard Error	10.44035503
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	64541534.09	32270767.04	296059.3309	2.18571E-80
Residual	38	4142.038503	109.0010132		
Total	40	64545676.12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	151786.7677	1461.513877	103.8558512	2.96762E-48	148828.0874	154745.4479	148828.0874	154745.4479
X Variable 1	-997.8355848	8.733077146	-114.2593347	7.97649E-50	-1015.514776	-980.1563938	-1015.514776	-980.1563938
X Variable 2	1.645428518	0.013032821	126.2526785	1.8146E-51	1.619044951	1.671812085	1.619044951	1.671812085

Predicted Areas of LM and LR Reservoirs

At mtg w/ Durham on August 13, 1999, the absolute minimum dead storages for the two reservoirs were decided to be:
LM: Elev 312.5 (which is the top? of a baffle board at the intake), which implies dead storage of about 800 MG
LR: Elev 326.0 (which is the invert elevation of the 2nd intake gate), which implies dead storage of about 1370 MG
Combined Dead Storage=1370+800=2170
Combined Full Storage=3606+4942=8548; i.e. about 8550 MG
Max Working Vol=8550-2170=6380 MG; i.e. about 6400 MG

Lake Michie Elevation	Lake Michie Min. Elev.	Total Lake Michie Volume in MG	Lake Michie Surface Area	Predicted Lake Michie Surface Area Acres
341.0	312.5	3606	509	524
340.0	312.5	3443	482	503
339.0	312.5	3288	469	482
338.0	312.5	3137	457	462
337.0	312.5	2990	444	443
336.0	312.5	2848	428	424
335.0	312.5	2710	415	406
334.0	312.5	2578	401	389
333.0	312.5	2449	385	372
332.0	312.5	2327	369	355
331.0	312.5	2208	349	340
330.0	312.5	2097	335	325
329.0	312.5	1990	320	311
328.0	312.5	1888	308	298
327.0	312.5	1790	295	285
326.0	312.5	1695	278	272
325.0	312.5	1607	263	260
324.0	312.5	1523	253	249
323.0	312.5	1443	241	239
322.0	312.5	1366	232	229
321.0	312.5	1292	217	219
320.0	312.5	1223	208	210
319.0	312.5	1156	197	201
318.0	312.5	1093	190	193
317.0	312.5	1033	181	185
316.0	312.5	975	168	177
315.0	312.5	921	163	170
314.0	312.5	869	157	163
313.0	312.5	819	152	156
312.0	312.5	770	147	150
311.0	312.5	723	137	144
310.0	312.5	679	132	138

Little River Elevation	Little River Min. Elev.	Total Little River Volume in MG	Little River Surface Area Acres	Predicted Little River Surface Area Acres
355.0	326.0	4942.35	549.0	576
354.0	326.0	4764.95	533.0	558
352.0	326.0	4426.63	504.0	524
350.0	326.0	4105.69	480.0	491
348.0	326.0	3800.57	456.0	460
346.0	326.0	3510.39	434.0	430
344.0	326.0	3234.13	413.0	402
342.0	326.0	2971.88	391.0	375
340.0	326.0	2723.59	371.0	350
338.0	326.0	2489.19	349.0	326
336.0	326.0	2268.51	329.0	304
334.0	326.0	2073.06	306.0	284
332.0	326.0	1878.70	286.0	264
330.0	326.0	1697.21	267.0	245
328.0	326.0	1528.49	246.0	228
326.0	326.0	1373.16	227.0	212
324.0	326.0	1229.70	210.0	198
322.0	326.0	1097.40	193.0	184
320.0	326.0	975.84	178.0	172
318.0	326.0	863.42	165.0	160
316.0	326.0	759.66	151.0	150
314.0	326.0	666.00	138.0	140
312.0	326.0	580.00	127.0	131
310.0	326.0	501.00	115.0	123
308.0	326.0	430.00	103.0	116
306.0	326.0	367.00	91.0	
304.0	326.0	313.00	75.0	
302.0	326.0	266.00	70.0	
300.0	326.0	222.00	65.0	

Appendix A
Regression Analysis of Reservoir Surface Areas as a Function of Total Volume

Appendix A
Regression of Reservoir Surface Areas as a Function of Total Volume

L. Michie Area(acres)=49.3+0.132*LMVolume(MG)

Regression Statistics	
Multiple R	0.997227596
R Square	0.994462882
Adjusted R Square	0.994278311
Standard Error	8.853024213
Observations	32

ANOVA

	df	*SS*	*F*	*MS*	*Significance F*
Regression	1	422288.5939	5387.980895	422288.5939	2.04243E-35
Residual	30	2351.281132		78.37603772	
Total	31	424639.875			

	Coefficients	*Standard Error*	*P-value*	*t Stat*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	48.29834494	3.646567354	4.55733E-14	13.24487943	40.85106854	55.74562134	40.85106854	55.74562134
X Variable 1	0.132165726	0.001800553	2.04243E-35	73.40286707	0.128488511	0.135842942	0.128488511	0.135842942

Little R. Area(acres)=72.25+0.1*LRVolume(MG)

Regression Statistics	
Multiple R	0.99276257
R Square	0.985577521
Adjusted R Square	0.985043355
Standard Error	18.65373828
Observations	29

ANOVA

	df	*SS*	*MS*	*Significance F*	*F*
Regression	1	642016.8204	642016.8204	2.14888E-26	1845.07765
Residual	27	9394.972699	347.9619518		
Total	28	651411.7931			

	Coefficients	*Standard Error*	*t Stat*	*Lower 95%*	*P-value*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	72.25322395	5.756142006	12.55236995	60.44260404	8.80119E-13	84.06384387	60.44260404	84.06384387
X Variable 1	0.1021532	0.00237818	42.95436707	0.097273582	2.14888E-26	0.107032818	0.097273582	0.107032818

Appendix A

Regression Analysis of Total Surface Area as a Function of Total Volume

Lake Michie area (LM Area) and Little Little reservoir are (LR Area) are determined using equations (2) and (4)

Full to Dead Storage in 20 Steps Using Predicted Areas

LM Vol	LM Area	LR Vol	LR Area	Tot Vol	Tot Area
3606	524	4,942	576	8,548	1,101
3467	506	4,764	558	8,231	1,064
3327	488	4,585	540	7,913	1,027
3188	469	4,407	522	7,595	991
3049	451	4,229	504	7,277	954
2909	432	4,050	485	6,959	918
2770	414	3,872	467	6,641	881
2631	396	3,693	449	6,324	844
2491	377	3,515	431	6,006	808
2352	359	3,336	413	5,688	771
2213	340	3,158	394	5,370	735
2073	322	2,979	376	5,052	698
1934	304	2,801	358	4,735	661
1794	285	2,622	340	4,417	625
1655	267	2,444	322	4,099	588
1516	248	2,265	303	3,781	552
1376	230	2,087	285	3,463	515
1237	212	1,909	267	3,146	479
1098	193	1,730	249	2,828	442
958	175	1,552	231	2,510	405
819	156	1,373	212	2,192	369

Total Area(acres)=116+0.115*Total Volume (MG)

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	1
Standard Error	5.53273E-13
Observations	21

ANOVA

	df	*SS*	*MS*	*Significance F*	*F*
Regression	1	1031296.866	1031296.866	2.4758E-279	3.36903E+30
Residual	19	5.81611E-24	3.06111E-25		
Total	20	1031296.866			

	Coefficients	*Standard Error*	*t Stat*	*Lower 95%*	*P-value*	*Upper 95%*	*Lower 95.0%*
Intercept	116.284147	3.57896E-13	3.24911E+14	116.284147	4.8028E-265	116.284147	116.284147
X Variable 1	0.1151541	6.27375E-17	1.83549E+15	0.1151541	2.4758E-279	0.1151541	0.1151541

Appendix B

Regression of Little River Flows on Flat River Flows

Appendix B
Regression of Little River Streamflows as a Function of Flat River Streamflows

LRQ = B1*(FRQ) (without intercept) ← Selected Model

Regression Statistics	
Multiple R	0.939081242
R Square	0.88187358
Adjusted R Square	0.881272257
Standard Error	179.414591
Observations	1664

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	399638258.2	399638258.2	12415.13763	0
Residual	1663	53531297.27	32189.59547		
Total	1664	453169555.4			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.489690849	0.003637918	134.6074468	0	0.482555477	0.496826221

LRQ = Bo + B1*(FRQ) (with intercept)

Regression Statistics	
Multiple R	0.940205996
R Square	0.883987315
Adjusted R Square	0.883917512
Standard Error	177.8556197
Observations	1664

← Intercept doesn't provide significant improvement

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	400596138.6	400596138.6	12664.01961	0
Residual	1662	52573416.87	31632.62146		
Total	1663	453169555.4			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	28.22345991	5.128876004	5.502854795	4.32082E-08	18.16371567	38.28320416
X Variable 1	0.477397115	0.004242228	112.5345263	0	0.469076436	0.485717793

Ln(LRQ) = B1*Ln(FRQ)

Regression Statistics	
Multiple R	0.944985868
R Square	0.89299829
Adjusted R Square	0.892396967
Standard Error	0.497634264
Observations	1664

← Correlation not improved enough to justify using complex equation

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3436.94601	3436.94601	13878.8077	0
Residual	1663	411.8250889	0.247639861		
Total	1664	3848.771098			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
Ln(FR)	0.891830319	0.002138083	417.1167837	0	0.887636706	0.896023931

Appendix B
Regression of Little River Streamflows as a Function of Flat River Streamflows

Ln(LRQ) = Bo+B1*Ln(FRQ)

Regression Statistics	
Multiple R	0.947856975
R Square	0.898432846
Adjusted R Square	0.898371734
Standard Error	0.484978151
Observations	1664

← Correlation not improved enough to justify using complex equation (pointing to R Square)

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3457.862371	3457.862371	14701.55782	0
Residual	1662	390.9087275	0.235203807		
Total	1663	3848.771098			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.42787381	0.04537272	-9.430199825	1.325E-20	-0.516867573	-0.33888005
Ln(FR)	0.964200703	0.007952172	121.2499807	0	0.948603364	0.979798041

Appendix C

Comparison of Space Rule to Single Storage Assumption

Appendix C
Comparison of Space Rule to Single Storage Assumption

1. Lake Michie
Smax(1) = 2800 MG

2. Little River Res.
Smax(2) = 3600 MG

(A) Total storage calculated using Space Rule

$$[S(1)_{k-1}+Q(1)_k-W(1)_k]+[S(2)_{k-1}+Q(2)_k-W(2)_k]$$

(B) Total storage calculated assuming reservoirs are combined into single storage

$$(S1+S2)_{k-1}+Q(1)_k+Q(2)_k-W(T)$$

Q1 and Q2 obtained from 1991 data

						Space Rule Calculations				(A)	(B)
k	Q(1) (MG/week)	Q(1,n-k) (MG)	Q(2) (MG/week)	Q(2,n-k) (MG)	W(T) (MGD)	W(1) (MGD)	W(2) (MGD)	S1 (MG)	S2 (MG)	S1+S2 (MG)	S1+S2 (MG)
1	711	19598	487	14253	30	20	10	2800	3600	6400	6400
2	387	19211	296	13957	30	16	14	2800	3600	6400	6400
3	813	18398	663	13294	30	11	19	2800	3600	6400	6400
4	413	17985	350	12944	30	13	17	2800	3600	6400	6400
5	426	17559	405	12539	30	9	21	2800	3600	6400	6400
6	244	17315	205	12334	30	15	15	2800	3600	6400	6400
7	202	17112	182	12152	30	14	16	2800	3600	6400	6400
8	284	16828	288	11864	30	10	20	2800	3600	6400	6400
9	157	16671	271	11593	30	4	26	2800	3600	6400	6400
10	83	16588	107	11486	30	14	16	2788	3592	6379	6379
11	55	16533	59	11427	30	16	14	2731	3552	6283	6283
12	55	16478	65	11363	30	15	15	2677	3515	6193	6193
13	35	16443	34	11328	30	17	13	2594	3458	6052	6052
14	37	16406	24	11304	30	18	12	2506	3397	5903	5903
15	25	16381	20	11285	30	18	12	2408	3330	5738	5738
16	13	16368	12	11272	30	18	12	2298	3255	5553	5553
17	18	16350	31	11241	30	16	14	2203	3189	5392	5392
18	34	16316	16	11225	30	18	12	2108	3124	5232	5232
19	25	16291	28	11197	30	17	13	2015	3060	5075	5075
20	44	16248	30	11167	30	18	12	1934	3005	4939	4939
21	26	16222	13	11154	30	18	12	1833	2935	4768	4768
22	33	16189	10	11144	30	19	11	1734	2866	4601	4601
23	17	16172	6	11138	30	18	12	1624	2789	4413	4413
24	13	16159	2	11136	30	18	12	1509	2709	4218	4218
25	17	16142	2	11135	30	21	9	1376	2652	4027	4027
26	386	15755	645	10490	30	0	30	1762	3087	4848	4848
27	177	15579	73	10416	30	6	24	1894	2994	4888	4888
28	69	15510	33	10383	30	19	11	1832	2949	4781	4781
29	150	15359	48	10335	30	22	8	1826	2943	4769	4769
30	44	15316	15	10320	30	19	11	1735	2882	4617	4617
31	28	15288	12	10308	30	19	11	1633	2814	4447	4447
32	36	15251	32	10276	30	17	13	1548	2758	4306	4306
33	38	15214	49	10227	30	16	14	1474	2708	4182	4182
34	28	15186	20	10208	30	18	12	1377	2643	4020	4020
35	36	15150	24	10183	30	18	12	1286	2585	3870	3870
36	101	15049	91	10092	30	16	14	1275	2577	3852	3852
37	62	14986	43	10049	30	18	12	1213	2535	3748	3748
38	61	14926	36	10013	30	19	11	1141	2493	3634	3634
39	430	14496	340	9674	30	18	12	1444	2750	4194	4194
40	5917	8578	4294	5380	30	0	30	2800	3600	6400	6400
41	398	8180	294	5086	30	14	16	2800	3600	6400	6400
42	199	7981	135	4952	30	18	12	2800	3600	6400	6400
43	316	7665	213	4738	30	17	13	2800	3600	6400	6400
44	216	7449	155	4583	30	17	13	2800	3600	6400	6400
45	152	7297	110	4474	30	17	13	2800	3600	6400	6400
46	230	7067	152	4322	30	18	12	2800	3600	6400	6400
47	278	6789	183	4138	30	18	12	2800	3600	6400	6400
48	2292	4497	1240	2899	30	30	0	2800	3600	6400	6400
49	2268	2229	1575	1323	30	0	30	2800	3600	6400	6400
50	642	1587	440	883	30	19	11	2800	3600	6400	6400
51	813	774	322	561	30	*****	*****	*****	*****	*****	6400
52	774	0	561	0	30	*****	*****	*****	*****	*****	6400

***** Indicates when future flows could not be determined due to ending of period

Appendix D

Simulation Model: Visual Basic Program

```
Sub probability_analysis()
' probability_analysis Macro
' Macro recorded 7/26/99 by Stephen Carter
'
' Keyboard Shortcut: Ctrl+p

' Clears contents of output sheet
With ActiveWorkbook.sheets("output")
.Range("A8:C52").Value = Null
.Range("E8:G52").Value = Null
.Range("F2:H5").Value = Null
sheets("storage").Range("A2:BS53").Value = Null
sheets("mon. demands").Range("E5:E16").Value = Null
End With


' Reads input variables
With ActiveWorkbook
   Dim LMmin As Variant
   Dim LRmin As Variant
   Dim LMmax As Variant
   Dim LRmax As Variant
   Dim f As Variant
   Dim w As Variant
   Dim m As Variant
   Dim b As Variant
   Dim r As Variant
   f = 72                              '#years data
   w = sheets("input").Cells(11, 3).Value      'start week
   Dim s(81, 53)
   Dim q(52)
```

```
    Dim t(52)
    q(0) = .sheets("input").Cells(10, 3).Value      'avg demand
    LMmin = sheets("input").Cells(7, 3).Value       'LM min ELEV
    LMmax = 341                                      'LM max ELEV
    LRmin = sheets("input").Cells(9, 3).Value       'LR min ELEV
    LRmax = 355                                      'LR max ELEV

' Introduces monthly demand multipliers
b = 4.33
For r = w To 52
      If r <= b Then                              '1
         t(r) = sheets("mon. demands").Cells(5, 3).Value
         If t(r) = 0 Then
            t(r) = sheets("mon. demands").Cells(5, 4).Value
         End If
         q(r) = q(0) * t(r)
         sheets("mon. demands").Cells(5, 5).Value = q(r)
      ElseIf r > b And r <= 2 * b Then                  '2
         t(r) = sheets("mon. demands").Cells(6, 3).Value
         If t(r) = 0 Then
            t(r) = sheets("mon. demands").Cells(6, 4).Value
         End If
         q(r) = q(0) * t(r)
         sheets("mon. demands").Cells(6, 5).Value = q(r)
      ElseIf r > 2 * b And r <= 3 * b Then              '3
         t(r) = sheets("mon. demands").Cells(7, 3).Value
         If t(r) = 0 Then
            t(r) = sheets("mon. demands").Cells(7, 4).Value
         End If
         q(r) = q(0) * t(r)
         sheets("mon. demands").Cells(7, 5) = q(r)
```

```
ElseIf r > 3 * b And r <= 4 * b Then            '4
    t(r) = sheets("mon. demands").Cells(8, 3).Value
    If t(r) = 0 Then
        t(r) = sheets("mon. demands").Cells(8, 4).Value
    End If
    q(r) = q(0) * t(r)
    sheets("mon. demands").Cells(8, 5) = q(r)
ElseIf r > 4 * b And r <= 5 * b Then            '5
    t(r) = sheets("mon. demands").Cells(9, 3).Value
    If t(r) = 0 Then
        t(r) = sheets("mon. demands").Cells(9, 4).Value
    End If
    q(r) = q(0) * t(r)
    sheets("mon. demands").Cells(9, 5).Value = q(r)
ElseIf r > 5 * b And r <= 6 * b Then            '6
    t(r) = sheets("mon. demands").Cells(10, 3).Value
    If t(r) = 0 Then
        t(r) = sheets("mon. demands").Cells(10, 4).Value
    End If
    q(r) = q(0) * t(r)
    sheets("mon. demands").Cells(10, 5).Value = q(r)
ElseIf r > 6 * b And r <= 7 * b Then            '7
    t(r) = sheets("mon. demands").Cells(11, 3).Value
    If t(r) = 0 Then
        t(r) = sheets("mon. demands").Cells(11, 4).Value
    End If
    q(r) = q(0) * t(r)
    sheets("mon. demands").Cells(11, 5).Value = q(r)
ElseIf r > 7 * b And r <= 8 * b Then            '8
    t(r) = sheets("mon. demands").Cells(12, 3).Value
    If t(r) = 0 Then
```

```
        t(r) = sheets("mon. demands").Cells(12, 4).Value
    End If
    q(r) = q(0) * t(r)
    sheets("mon. demands").Cells(12, 5).Value = q(r)
ElseIf r > 8 * b And r <= 9 * b Then                '9
    t(r) = sheets("mon. demands").Cells(13, 3).Value
    If t(r) = 0 Then
        t(r) = sheets("mon. demands").Cells(13, 4).Value
    End If
    q(r) = q(0) * t(r)
    sheets("mon. demands").Cells(13, 5).Value = q(r)
ElseIf r > 9 * b And r <= 10 * b Then               '10
    t(r) = sheets("mon. demands").Cells(14, 3).Value
    If t(r) = 0 Then
        t(r) = sheets("mon. demands").Cells(14, 4).Value
    End If
    q(r) = q(0) * t(r)
    sheets("mon. demands").Cells(14, 5).Value = q(r)
ElseIf r > 10 * b And r <= 11 * b Then              '11
    t(r) = sheets("mon. demands").Cells(15, 3).Value
    If t(r) = 0 Then
        t(r) = sheets("mon. demands").Cells(15, 4).Value
    End If
    q(r) = q(0) * t(r)
    sheets("mon. demands").Cells(15, 5).Value = q(r)
ElseIf r > 11 * b And r <= 52 Then                  '12
    t(r) = sheets("mon. demands").Cells(16, 3).Value
    If t(r) = 0 Then
        t(r) = sheets("mon. demands").Cells(16, 4).Value
    End If
    q(r) = q(0) * t(r)
```

```
        sheets("mon. demands").Cells(16, 5).Value = q(r)
    End If
Next r

' Reads inputs for phases and durations of rationing
With sheets("input")
Dim u(3)
Dim p(3)
Dim d(3)
Dim n As Variant
For n = 1 To 3
    u(n) = .Cells(16 + n, 3).Value
    p(n) = .Cells(16 + n, 4).Value
    d(n) = .Cells(16 + n, 5).Value
Next n


' Calculates failure status
Dim c As Variant
c = 0
Dim j As Variant
Dim i As Variant
Dim y As Variant
Dim z As Variant
z = 0
Dim LMelev As Variant
Dim LMdead As Variant
Dim LMvol As Variant
Dim LMwork As Variant
Dim LRelev As Variant
Dim LRdead As Variant
```

```
Dim LRvol As Variant
Dim LRwork As Variant
Dim LMmaxvol As Variant
Dim LRmaxvol As Variant
  For n = 1 To f
  For j = w To 52
    LMelev = sheets("input").Cells(6, 3).Value
    LMdead = 191942 - 1262 * LMmin + 2.081 * LMmin ^ 2
    LMmaxvol = 191942 - 1262 * LMmax + 2.081 * LMmax ^ 2
    LMvol = 191942 - 1262 * LMelev + 2.081 * LMelev ^ 2
    LMwork = LMvol - LMdead
    LRelev = sheets("input").Cells(8, 3).Value
    LRdead = 151787 - 997.84 * LRmin + 1.6454 * LRmin ^ 2
    LRmaxvol = 151787 - 997.84 * LRmax + 1.6454 * LRmax ^ 2
    LRvol = 151787 - 997.84 * LRelev + 1.6454 * LRelev ^ 2
    LRwork = LRvol - LRdead
    s(n, 53) = LMmaxvol + LRmaxvol - LMdead - LRdead  'max working vol.
    s(n, w - 1) = LMwork + LRwork          'initial working vol.
    i = sheets("inflows").Cells(j + 1, n).Value
    Dim precip As Variant
    Dim evap As Variant
    Dim Gt As Variant
    precip = sheets("precip").Cells(j + 1, n).Value
    evap = sheets("evap").Cells(j + 1, n).Value
    Gt = precip - evap
    For y = 1 To 3
      If sheets("input").Cells(16 + y, 6) = "yes" _
        And j >= p(y) And j <= p(y) + d(y) - 1 Then
        sheets("output").Cells(1 + y, 6).Value = u(y)
        sheets("output").Cells(1 + y, 7).Value = p(y)
        sheets("output").Cells(1 + y, 8).Value = p(y) + d(y) - 1
```

```
        c = u(y)
    End If
Next y
s(n, j) = s(n, j - 1) + ((s(n, j - 1) + 2170) * Gt * 0.115 * 0.0272) + _
            Gt * 116 * 0.0272 + i - (1 - c) * q(j) * 7
If s(n, j) > s(n, 53) Then
    s(n, j) = s(n, 53)
End If

If s(n, j) < 0 Then
    If n < 45 Then
        sheets("output").Cells(n + 7, 2).Value = 1
        sheets("output").Cells(n + 7, 3).Value = j
    Else
        sheets("output").Cells(n - 37, 6).Value = 1
        sheets("output").Cells(n - 37, 7).Value = j
    End If
    j = 52
    s(n, j) = 0
    z = z + 1
End If

'Prints out draw down
sheets("storage").Cells(j + 1, n).Value = s(n, j)

    y = sheets("inflows").Cells(1, n).Value
    If n < 45 Then
        sheets("output").Cells(n + 7, 1).Value = y
    Else
        sheets("output").Cells(n - 37, 5).Value = y
    End If
```

```
        c = 0
    Next j
    Next n


' Calculates probability of failure for a given demand
With ActiveWorkbook.sheets("output")
    i = 100 * (1 - z / f)
    .Cells(2, 3).Value = i
    .Cells(5, 3).Value = q(0)
    .Cells(3, 3).Value = s(1, w - 1)
    .Cells(4, 3).Value = s(1, 53)
    .Cells(1, 3).Value = w
End With

End With
End With
End Sub
```

Appendix E

Historical Input Data for Inflows, Precipitation, and Evaporation

week	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943
1	537	534	504	790	1415	6928	1085	844	1149	5516	14561	5204	1083	3263	723	2310	330	762
2	2427	1114	3626	868	623	1232	1366	1484	10452	2758	4905	1378	2546	1217	1536	976	354	950
3	922	714	1358	5664	576	868	627	5307	3130	6310	1312	932	496	1229	1581	524	203	4102
4	462	906	10365	1791	395	1159	622	1063	624	1729	1028	9416	343	1312	1043	717	144	679
5	372	362	1640	1381	310	1630	491	1223	396	875	714	1576	256	5619	543	362	1641	556
6	251	206	890	985	266	2807	341	2959	270	744	541	773	192	897	452	305	343	493
7	227	135	545	584	2629	504	267	658	1931	659	449	802	334	563	349	215	4400	406
8	120	107	1572	846	468	7045	210	652	1287	1508	290	423	417	555	5746	164	1512	359
9	121	134	560	826	315	506	237	785	3182	398	190	406	301	549	2735	175	251	357
10	124	389	2132	1230	336	380	132	244	3609	319	523	1630	1421	717	560	200	449	554
11	78	359	385	688	249	385	270	669	667	223	912	772	1699	519	900	433	631	356
12	182	186	234	400	636	497	190	319	1985	184	354	599	13613	1019	3240	182	205	234
13	153	86	257	1640	168	156	831	206	524	115	269	388	3260	334	382	143	141	164
14	219	348	156	1038	191	211	170	102	680	116	182	1276	1675	2466	277	258	392	393
15	303	1820	203	3463	128	149	68	157	231	350	120	312	2297	565	417	297	574	1164
16	243	1314	229	402	4960	171	39	85	204	642	2381	293	1581	979	227	341	278	223
17	797	206	121	328	409	991	20	111	1523	397	402	251	20783	1965	284	205	491	92
18	177	318	66	213	301	1587	36	272	878	170	896	2264	2318	636	267	129	226	62
19	80	367	404	1169	164	4434	95	185	473	321	298	1238	994	394	146	82	1917	43
20	91	519	2458	673	85	3784	44	104	135	123	135	2096	566	8464	7751	61	2736	30
21	1077	1311	251	2601	71	1987	22	250	988	129	130	1517	322	1608	2106	68	1015	18
22	1134	1969	141	1019	50	424	14	109	479	71	1333	1157	284	5789	827	88	350	90
23	403	441	4114	291	40	208	8	336	11338	2026	107	1903	433	807	298	351	689	75
24	77	229	403	365	179	139	6	103	3866	675	384	413	193	379	385	99	245	88
25	87	200	8608	397	88	99	4	49	1526	122	83	208	611	278	180	37	128	49
26	47	86	645	307	52	195	5	21	692	236	175	139	239	234	118	20	1153	62
27	24	515	568	17213	34	71	80	14	483	134	603	1667	204	494	112	15	227	37
28	28	1261	304	668	23	66	161	11	338	83	225	982	158	251	100	11	1198	22
29	25	325	273	420	21	187	3272	19	227	69	386	683	146	209	93	9	7087	14
30	20	187	274	467	14	64	261	6	185	54	140	418	254	161	65	8	1735	11
31	17	132	233	1188	25	65	843	5	190	512	92	322	167	263	352	9	686	11
32	17	151	214	1002	61	60	2117	7	226	929	99	268	220	378	136	9	443	17
33	26	1002	188	1503	53	97	386	6	205	1809	256	1253	170	209	7209	8	394	54
34	61	499	216	1121	68	47	1448	6	250	384	151	406	3561	476	603	8	4401	41
35	108	945	188	1682	54	33	2898	6	13265	414	185	382	586	245	507	9	1548	31
36	58	7842	193	2365	330	143	412	9	1397	264	653	318	2210	225	359	21	2586	32
37	465	3166	196	731	141	347	2967	10	618	2495	2287	287	1077	211	452	36	1496	36
38	289	1666	213	861	175	281	1998	18	2057	604	1642	284	453	233	624	40	1329	34
39	5548	617	175	1092	1234	426	6831	23	830	361	488	863	2549	1152	2454	49	3867	315
40	558	670	186	600	1224	874	1232	41	3165	12535	9480	3288	914	367	1391	49	1352	1647
41	344	583	274	612	671	6411	3046	34	1102	4378	2051	1692	1223	720	646	45	936	258
42	639	458	228	3272	1047	654	1438	32	1117	9858	10167	693	1921	1195	2212	50	2542	2137
43	378	1018	197	1711	450	558	1699	38	3170	1329	2565	1542	1547	418	1085	77	3499	321
44	389	1279	174	3336	286	2787	879	131	837	2233	4672	793	2996	481	653	72	3136	215
45	308	3135	519	2922	269	1241	1675	117	820	3278	2496	536	5036	6812	547	240	6797	819
46	2138	1675	1003	1335	454	1317	3688	65	2770	9829	1524	496	4133	1740	1083	1529	1597	4714
47	3446	1265	1916	820	495	1137	2251	96	1176	1678	2347	861	1416	4183	526	344	900	1963
48	1038	680	11602	616	578	568	1059	4789	1061	982	1548	778	5838	1127	465	924	651	990
49	5112	1200	8300	931	823	8394	810	1560	1333	1541	1217	2222	2252	1221	2589	2781	4169	2736
50	1323	3890	2387	560	377	921	660	507	3488	6963	1348	1137	4616	2359	819	482	1521	3776
51	636	1731	3334	791	1373	955	1323	1713	1991	3335	1296	604	1338	919	722	551	2166	4262
52	441	836	1506	571	2569	3651	542	4247	8038	3878	904	437	4123	922	2286	980	1675	3269

Appendix E
Inflow Data (Combined inflows of Lake Michie and Little Rive in MG/week)

week	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
1	1063	414	539	819	2853	1774	545	3843	1490	1420	1380	427	1363	1043	4156	1915	6805	3912
2	6619	372	817	1479	2271	1646	415	3874	667	2738	856	3778	5117	1870	5520	3605	1426	2148
3	1927	1798	547	1233	1270	1029	426	787	488	1066	1512	1444	1403	895	1397	2531	970	1299
4	1717	988	599	590	610	1239	384	843	4352	654	397	1389	598	4289	1433	1980	1088	768
5	642	519	795	495	539	2624	945	581	925	768	338	409	5704	561	4772	850	726	636
6	1391	373	488	355	548	2293	488	444	711	493	241	291	1193	347	4255	438	2817	4228
7	353	868	851	245	386	710	1034	298	553	442	1040	500	436	309	846	508	590	1175
8	1341	553	1112	507	608	510	330	252	1717	417	1017	1541	392	507	588	478	832	560
9	313	577	421	314	6390	369	1991	161	446	238	248	273	1079	369	501	421	2322	394
10	213	205	288	180	622	279	1258	778	315	240	158	249	384	926	421	5437	513	467
11	281	495	173	139	523	263	285	826	227	5955	1536	243	211	205	313	378	287	1329
12	277	1030	511	200	331	215	554	743	589	948	357	130	197	124	279	245	199	1218
13	114	193	217	227	365	163	3736	1822	229	566	121	93	134	162	699	147	192	1314
14	60	332	1037	110	219	161	706	403	1303	291	64	82	64	92	227	92	133	524
15	1006	744	2783	280	654	225	2324	237	1391	146	220	7324	221	57	559	414	318	372
16	418	4945	301	85	791	1376	1354	385	214	377	891	376	501	141	1590	464	122	717
17	144	4006	215	89	369	200	654	838	158	128	132	225	171	63	571	900	529	1610
18	817	720	156	87	1009	540	926	213	2530	66	160	473	577	59	831	1096	425	1048
19	555	1112	115	769	413	221	401	141	2720	49	87	142	148	95	239	324	297	596
20	91	961	86	102	284	443	182	88	316	37	45	14246	203	44	780	139	428	223
21	122	2123	116	224	193	408	140	63	437	32	60	843	265	1504	536	209	2268	4458
22	93	384	109	85	124	1983	116	42	6548	24	26	501	71	197	292	167	1162	1146
23	38	431	52	102	80	320	106	40	559	22	14	709	284	84	115	601	1233	360
24	75	2480	198	133	75	213	452	44	313	24	6	298	94	66	67	147	1775	256
25	8288	19701	91	84	70	647	511	50	518	14	7	291	45	202	55	76	374	235
26	6658	758	147	2608	1176	174	255	44	296	47	6	268	586	321	68	343	336	170
27	1719	698	78	146	3215	140	227	29	214	42	7	7747	163	681	150	615	336	122
28	473	511	450	513	530	429	227	26	297	21	5	557	135	124	79	4606	432	98
29	2524	376	133	900	301	157	118	22	187	18	1198	384	246	76	53	1428	566	83
30	860	403	79	291	251	138	443	23	165	11	45	254	1298	61	71	1507	366	202
31	415	330	128	2398	345	6234	190	63	163	14	22	243	1294	164	153	488	322	94
32	353	319	114	3307	2129	695	174	141	184	12	53	437	588	188	117	1415	261	107
33	337	354	496	4835	843	441	150	63	507	15	48	369	337	197	82	530	266	121
34	353	440	543	3306	3928	350	180	67	11534	22	758	461	326	3910	64	3975	270	220
35	4777	347	254	926	9382	414	258	56	782	28	302	441	255	2400	102	1182	274	162
36	2484	2656	168	596	5431	307	2440	454	797	44	504	344	204	2836	110	844	233	128
37	1550	750	153	1052	1166	1078	727	133	1591	605	2059	293	652	1349	94	809	852	1832
38	732	758	471	872	1587	587	369	5772	944	179	392	256	1258	950	146	5974	392	2775
39	641	7905	318	528	4088	724	324	650	651	93	213	237	1457	1131	8328	1293	333	1146
40	2239	1898	826	461	3935	458	349	404	2259	65	168	234	403	588	1709	2293	892	12111
41	1858	2908	2677	3180	1632	466	738	3153	4975	112	408	228	337	3810	575	1774	348	2246
42	1090	1886	5277	1352	1057	1581	595	529	1105	3427	254	219	264	2030	974	819	2204	1695
43	726	2569	1308	1049	1722	821	450	3521	4576	5533	698	284	1192	5512	1462	609	512	4790
44	516	4028	617	906	2968	1118	700	4995	1558	677	334	1152	10582	1351	854	5625	482	4093
45	607	6387	453	4151	3638	1048	1506	2239	1694	383	3334	4833	2466	1887	2498	7258	5176	1298
46	7946	1884	392	11571	2474	980	817	1271	5314	287	1424	1156	1042	805	3045	5564	1473	1271
47	4379	1509	643	2022	2259	884	1061	976	3845	1054	930	1812	1238	1063	868	5874	5612	8178
48	1919	912	878	1973	1389	580	580	4534	2688	2606	1652	1329	5758	5471	892	2357	2397	4707
49	1735	935	1198	6332	965	514	660	3841	2334	756	4459	801	1457	1127	2660	1198	1542	3483
50	856	811	3212	1711	614	529	2656	1858	3392	4993	2367	5310	902	926	694	5178	1500	4438
51	762	1199	948	1418	2233	2772	2365	4971	6527	1065	2293	1232	1978	1950	507	5670	4274	2260
52	568	744	718	3180	1694	809	867	1683	1928	3211	612	625	1009	2813	1123	3427	3912	4227

Appendix E
Inflow Data (Combined inflows of Lake Michie and Little Rive in MG/week)

week	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	4735	836	2790	892	399	347	1034	768	3135	3333	1414	4713	1684	1459	752	1174	819	2959
2	5766	710	2813	795	384	286	644	572	2574	1256	2475	2476	1775	1114	429	490	626	1724
3	1463	528	985	670	388	271	437	4939	960	794	1124	1179	888	1144	343	341	579	1000
4	935	415	632	4302	542	732	382	771	764	828	1079	4900	741	695	261	295	15502	965
5	967	551	521	984	1130	328	328	426	1814	568	2190	1644	1496	761	380	259	7830	663
6	552	805	370	580	465	405	281	309	643	639	959	1118	3463	580	221	298	8455	1715
7	456	299	307	471	361	304	389	387	472	3549	3210	656	1051	1909	344	158	3630	2861
8	342	279	229	303	1439	372	3889	684	353	469	959	580	671	778	171	319	685	791
9	1097	282	225	295	1188	263	2360	492	256	5110	551	1519	912	689	227	209	532	1201
10	759	243	203	186	277	178	410	485	229	540	353	464	493	361	234	150	524	3939
11	692	147	121	3774	215	104	495	1360	216	500	313	420	397	413	148	105	347	923
12	910	210	473	843	154	3035	251	789	117	318	6580	760	313	259	414	155	292	1281
13	955	131	254	1500	106	157	135	245	848	298	780	4776	329	208	125	99	625	585
14	557	256	92	374	82	1057	114	196	132	238	547	1640	222	397	167	31	201	435
15	430	193	677	2317	59	355	889	724	6264	270	772	589	163	19212	80	207	450	239
16	254	91	226	2282	64	284	170	218	283	184	421	313	100	5022	39	28	2794	359
17	247	447	254	3023	38	157	82	283	244	170	256	401	128	608	24	11	462	218
18	910	1119	894	1224	226	122	69	1043	153	513	837	1416	253	526	73	10	548	693
19	1951	131	191	520	459	125	63	330	732	266	393	373	987	715	27	20	2645	159
20	336	62	154	315	453	75	86	203	264	309	201	3657	1420	295	25	10	576	150
21	512	534	102	354	236	270	31	122	168	327	155	854	531	266	22	21	183	76
22	270	99	940	225	34	223	13	68	98	2810	97	312	552	167	12	15	804	118
23	151	62	176	153	17	72	6	174	83	194	357	217	12666	225	8	533	245	2032
24	120	124	1335	200	8	70	5	87	53	6259	93	205	838	240	12	84	129	194
25	487	77	206	152	1052	71	3	147	45	695	162	163	429	1011	39	34	110	1495
26	215	198	124	148	124	110	2	237	40	423	1039	109	314	4529	20	10	107	782
27	220	115	3258	151	108	71	3	644	36	3550	7380	106	266	463	46	11	158	1219
28	116	35	431	237	49	51	8	141	21	5011	968	89	233	463	265	22	73	456
29	89	35	729	110	340	123	46	98	29	716	497	73	273	485	449	172	44	292
30	88	32	295	98	346	71	39	83	80	16222	623	65	246	354	150	557	45	286
31	183	51	254	83	188	55	15	93	239	1753	825	106	225	303	61	112	60	779
32	6837	3142	279	105	153	49	39	97	526	845	2250	123	213	273	64	1361	97	3440
33	785	236	241	136	162	51	767	102	2902	637	3745	94	273	1305	113	204	142	3454
34	2983	185	369	117	114	65	449	113	374	2693	4704	113	308	546	103	202	152	558
35	833	1552	695	113	137	131	113	99	244	2399	3670	116	623	514	671	577	297	2769
36	622	457	1050	93	111	716	444	120	201	1530	1352	350	1652	563	1039	1242	1099	648
37	433	1071	668	93	280	1197	457	612	202	1053	6730	454	786	558	1426	1226	883	654
38	459	477	697	96	180	1306	453	495	767	1173	4313	5263	851	393	741	1422	373	522
39	3474	940	2224	98	1556	3472	740	1503	700	788	2080	803	1121	1303	575	733	1248	589
40	952	2005	570	136	776	1020	659	364	1522	698	2414	2816	1076	2502	317	620	1740	634
41	953	3500	548	144	1052	3371	254	379	1101	1431	1324	1965	12237	1468	2589	5525	2893	1906
42	3386	1580	511	150	966	2959	2428	476	542	898	1650	1977	2935	719	1255	7213	6334	3752
43	1495	3152	2069	1003	603	1290	1253	347	864	839	2259	3433	4593	2925	360	9591	5638	2311
44	1403	980	753	589	347	908	3433	1620	1028	5414	11856	2601	1841	3071	402	1451	1096	846
45	1010	4732	7414	1978	710	639	2278	836	6234	1736	1951	2537	5066	1077	281	886	857	934
46	2073	3300	1835	7213	2546	457	766	4048	2442	3638	1182	2462	1432	690	395	806	1838	1707
47	2372	2871	1397	1891	3307	394	552	1334	1560	1940	878	2589	1803	685	567	730	14918	877
48	2404	2242	1833	8581	830	474	880	629	3767	1265	5337	1009	1192	546	1506	847	6365	943
49	9376	1200	4417	2228	459	394	6341	578	1610	811	4494	800	889	1099	3307	6145	1971	3267
50	5047	1803	3198	740	458	5518	984	717	942	808	3150	1565	17832	793	1401	2406	1576	2058
51	1970	1403	2147	582	981	1466	3628	2072	904	984	3284	1530	9768	568	1674	954	6161	4690
52	1011	866	2132	496	465	780	846	2098	1960	965	6074	3031	3801	715	785	1941	1841	2331

Appendix E
Inflow Data (Combined inflows of Lake Michie and Little Rive in MG/week)

week	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	1155	695	737	3726	4814	349	620	1594	481	4597	4776	1198	514	6585	1212	340	1837	732
2	3878	581	647	4813	4419	315	485	1589	897	2436	2019	682	576	6732	835	346	1724	801
3	1351	465	811	7253	2393	369	436	5511	1401	1493	1695	1476	3037	3275	2436	256	1232	634
4	707	341	1069	4564	3134	228	400	1869	494	1684	673	763	1195	960	443	216	808	9644
5	622	228	685	1109	1132	350	244	657	441	8657	4477	831	386	757	498	225	2048	3186
6	419	300	423	740	1379	182	189	452	493	1765	2652	448	401	606	344	240	1197	947
7	799	184	399	2168	538	251	253	947	345	802	876	384	322	730	250	138	1288	566
8	2246	276	720	3491	514	793	349	601	307	484	743	572	205	493	216	104	489	412
9	388	252	656	1028	2061	177	161	1065	185	348	2823	429	276	543	189	1524	2183	774
10	619	177	4173	794	456	132	95	373	173	1344	921	189	258	310	111	572	448	1111
11	270	176	5635	603	305	128	78	330	132	1110	669	113	242	167	90	902	369	642
12	224	490	3424	698	271	95	49	274	92	922	424	120	172	157	60	3297	551	311
13	2330	57	749	391	1021	161	33	228	97	545	250	69	1153	82	745	9038	168	224
14	295	4167	1338	416	262	192	29	1715	37	1385	149	61	1281	341	320	2292	119	196
15	281	275	760	194	331	60	58	241	32	1321	219	45	130	61	92	410	136	116
16	171	127	348	123	2450	40	17	118	37	4303	339	25	61	229	65	692	90	136
17	209	542	532	135	5660	409	329	67	69	726	86	49	435	84	1655	1764	1338	152
18	135	105	384	72	1639	227	115	45	41	3656	49	50	129	49	1761	266	862	69
19	60	763	5706	87	736	66	96	68	18	421	72	53	97	71	272	118	1058	53
20	42	467	1292	42	474	2369	270	38	8	1045	224	74	644	94	197	77	697	55
21	69	555	328	29	270	1512	3126	47	8	677	181	39	122	59	417	75	215	225
22	30	98	245	25	231	2820	596	23	463	393	100	43	220	71	291	2026	195	39
23	496	1457	177	19	186	299	135	445	217	217	30	23	107	89	93	154	28619	23
24	36	242	137	24	137	122	75	215	206	190	24	15	46	57	29	81	1235	448
25	46	184	144	22	92	86	296	42	46	266	13	19	45	36	20	71	733	64
26	56	84	168	12	63	99	380	26	30	632	9	1031	143	19	56	64	560	69
27	212	67	115	10	361	443	18	29	1012	3182	10	250	462	7	20	695	623	55
28	53	75	296	13	78	99	13	32	86	332	729	103	122	14	36	153	1736	35
29	173	175	272	18	74	122	36	28	34	976	193	198	50	22	90	3168	673	197
30	69	2131	3620	189	119	169	67	305	132	400	5203	58	55	8	45	2646	462	154
31	221	424	606	22	118	2883	72	115	2118	589	320	40	669	75	66	1194	565	267
32	262	177	531	26	110	1754	129	45	450	580	675	68	643	12	58	3234	1035	237
33	94	143	541	307	118	337	211	153	429	498	444	86	954	11	73	3108	503	617
34	330	143	408	1118	152	11707	164	92	380	1057	282	48	1517	9	116	634	616	1971
35	318	177	681	548	232	4046	315	1016	1758	600	1024	60	1997	2477	133	841	3998	550
36	149	160	625	3660	1637	1157	559	219	404	727	2152	192	448	888	103	1344	4014	443
37	302	1142	5323	3760	328	1976	1329	990	383	5292	688	105	3159	662	89	1263	1339	399
38	166	777	2085	2311	251	855	281	499	272	1372	1262	97	704	1324	99	1163	908	387
39	208	2653	824	2011	227	610	4410	1907	246	889	944	770	1116	513	112	619	1232	1840
40	207	6750	2608	804	5574	518	2056	1734	1057	2062	2258	10211	2143	1494	638	734	856	732
41	162	1219	1089	5391	755	437	511	711	611	3217	9704	692	5844	1661	517	823	2844	3033
42	136	1581	731	3457	509	417	5662	2534	548	950	3226	334	1426	1431	3338	7568	2219	5260
43	237	3177	1661	1922	484	970	2070	1514	338	3737	1329	529	4357	1042	543	4150	1494	10929
44	332	3817	2879	1240	7456	610	3481	1211	286	1708	741	371	827	1439	971	2599	1742	6843
45	1542	2039	2417	1655	2195	701	1324	1550	833	3625	652	261	593	995	507	2762	1566	5254
46	1119	3559	7269	7408	2817	833	853	1194	485	3881	601	382	2397	3873	5189	1280	6260	11841
47	1063	1815	1913	5716	707	730	5207	685	9588	3626	902	462	2109	2237	1648	2252	1400	3231
48	309	4146	2547	3705	1964	1041	16317	493	8065	1582	3416	3532	14378	9223	2750	906	2432	1630
49	660	3149	4616	9710	655	525	2398	949	6875	1170	1588	3844	3764	1761	4036	2537	2065	5012
50	320	1256	5573	2749	531	3939	1271	711	4029	962	1348	1082	8409	957	940	2115	1419	3390
51	1215	1828	7836	3022	640	1618	1583	660	8715	905	1723	1135	4387	681	622	4102	2699	24432
52	794	844	2904	6058	565	776	1010	502	2985	3111	5425	1335	7814	5864	415	2209	1122	1727

Appendix E

Inflow Data (Combined inflows of Lake Michie and Little Rive in MG/week)

week	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943
1	0.73	0.73	0.73	0.73	1.26	1.21	1.16	1.11	1.06	1.01	0.96	0.91	0.91	0.91	0.91	0.91	0.91	0.91
2	0.84	0.84	0.84	0.84	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.21	1.16	1.11	1.06	1.01	0.96
3	0.89	0.89	0.89	0.89	1.33	1.32	1.31	1.3	1.29	1.28	1.27	1.26	1.26	1.26	1.26	1.26	1.26	1.26
4	0.98	0.98	0.98	0.98	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.32	1.31	1.3	1.29	1.28	1.27
5	1.07	1.07	1.07	1.07	1.38	1.37	1.36	1.35	1.34	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
6	1.12	1.12	1.12	1.12	1.42	1.41	1.4	1.4	1.4	1.4	1.39	1.38	1.37	1.36	1.35	1.34	1.33	1.33
7	1.22	1.22	1.22	1.22	1.47	1.47	1.47	1.46	1.45	1.44	1.43	1.42	1.41	1.4	1.4	1.4	1.4	1.39
8	1.30	1.30	1.30	1.30	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.46	1.45	1.44	1.43
9	1.35	1.35	1.35	1.35	1.49	1.48	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
10	1.42	1.42	1.42	1.42	1.54	1.54	1.54	1.53	1.52	1.51	1.5	1.49	1.48	1.47	1.47	1.47	1.47	1.47
11	1.44	1.44	1.44	1.44	1.59	1.58	1.57	1.56	1.55	1.54	1.54	1.54	1.54	1.54	1.53	1.52	1.51	1.5
12	1.57	1.57	1.57	1.57	1.61	1.61	1.61	1.61	1.61	1.61	1.6	1.59	1.58	1.57	1.56	1.55	1.54	1.54
13	1.58	1.58	1.58	1.58	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.6
14	1.50	1.50	1.50	1.50	1.63	1.63	1.63	1.63	1.63	1.63	1.62	1.61	1.61	1.61	1.61	1.61	1.61	1.61
15	1.56	1.56	1.55	1.55	1.61	1.61	1.61	1.61	1.61	1.61	1.62	1.63	1.63	1.63	1.63	1.63	1.63	1.62
16	1.59	1.59	1.59	1.59	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.62
17	1.59	1.59	1.59	1.59	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
18	1.64	1.64	1.64	1.64	1.57	1.58	1.59	1.6	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
19	1.64	1.64	1.64	1.64	1.49	1.5	1.51	1.52	1.53	1.55	1.56	1.57	1.58	1.59	1.6	1.61	1.61	1.61
20	1.54	1.54	1.54	1.54	1.47	1.47	1.47	1.47	1.47	1.47	1.48	1.49	1.5	1.51	1.52	1.53	1.55	1.56
21	1.57	1.57	1.57	1.57	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.48
22	1.58	1.58	1.58	1.58	1.44	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
23	1.57	1.57	1.57	1.57	1.21	1.22	1.26	1.3	1.34	1.38	1.41	1.44	1.47	1.47	1.47	1.47	1.47	1.47
24	1.52	1.52	1.52	1.52	1.19	1.19	1.19	1.19	1.19	1.19	1.2	1.21	1.22	1.26	1.3	1.34	1.38	1.41
25	1.42	1.42	1.42	1.42	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.2
26	1.36	1.36	1.36	1.36	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
27	1.38	1.38	1.38	1.38	0.9	0.95	1	1.05	1.1	1.15	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
28	1.23	1.23	1.23	1.23	0.84	0.84	0.84	0.84	0.84	0.84	0.85	0.9	0.95	1	1.05	1.1	1.15	1.19
29	1.19	1.19	1.19	1.19	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.85
30	1.13	1.13	1.13	1.13	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.64	0.84	0.84	0.84	0.84	0.84
31	1.05	1.05	1.05	1.05	0.74	0.78	0.81	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
32	0.95	0.95	0.95	0.95	0.56	0.56	0.57	0.58	0.62	0.66	0.7	0.74	0.78	0.81	0.84	0.84	0.84	0.84
33	0.91	0.91	0.91	0.91	0.56	0.56	0.56	0.58	0.58	0.56	0.56	0.56	0.56	0.57	0.58	0.62	0.66	0.7
34	0.82	0.82	0.82	0.82	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
35	0.76	0.76	0.76	0.76	0.54	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
36	0.70	0.70	0.70	0.70	0.42	0.42	0.44	0.46	0.48	0.5	0.52	0.54	0.56	0.56	0.56	0.56	0.56	0.56
37	0.64	0.64	0.64	0.64	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.44	0.46	0.48	0.5	0.52
38	0.58	0.58	0.58	0.58	0.37	0.38	0.39	0.4	0.41	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
39	0.52	0.52	0.52	0.52	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.37	0.38	0.39	0.4	0.41	0.42	0.42
40	0.53	0.53	0.53	0.53	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.36
41	0.45	0.45	0.45	0.45	0.39	0.38	0.37	0.36	0.35	0.7	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
42	0.43	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.42	0.41	0.4	0.39	0.38	0.37	0.36	0.35	0.7	0.35
43	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.41	0.4
44	0.44	0.44	0.44	0.44	0.46	0.44	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
45	0.45	0.45	0.45	0.45	0.56	0.56	0.56	0.54	0.52	0.5	0.48	0.46	0.44	0.42	0.42	0.42	0.42	0.42
46	0.43	0.43	0.43	0.43	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.54	0.52	0.5	0.48
47	0.48	0.48	0.48	0.48	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
48	0.48	0.48	0.48	0.48	0.64	0.6	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
49	0.50	0.50	0.50	0.50	0.84	0.84	0.84	0.8	0.76	0.72	0.68	0.64	0.6	0.56	0.56	0.56	0.56	0.56
50	0.57	0.57	0.57	0.57	0.87	0.86	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.8	0.76	0.72	0.68
51	0.61	0.61	0.61	0.61	0.91	0.91	0.91	0.91	0.9	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.84	0.84
52	0.67	0.67	0.67	0.67	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.9	0.89	0.88

Appendix E
Evaporation (inches/week)

week	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
1	0.91	0.91	0.91	0.91	0.91	0.9	0.89	0.55	0.68	0.92	0.92	1.16	1.3	0.5	0.71	0.59	0.68	0.85
2	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.97	0.82	1.17	0.68	0.55	0.67	1.01	0.66	0.83	0.7	1.02
3	1.26	1.21	1.16	1.11	1.06	1.01	0.96	0.9	0.87	0.76	1.24	1.27	1.03	0.62	0.65	0.95	0.73	1
4	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.39	0.99	1.69	1.17	1.04	0.94	1	0.42	1.12	1.06	0.67
5	1.33	1.32	1.31	1.3	1.29	1.28	1.27	1.25	0.98	1.29	1.25	1.44	1.07	1.15	1.03	1.19	1.5	1.16
6	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.22	1.09	1.47	1.17	1.19	1.08	1.19	1.15	1.56	1.57	1.2
7	1.38	1.37	1.36	1.35	1.34	1.33	1.33	1.12	1.18	1.74	1.48	1.98	1.47	1.33	1.46	1.2	1.66	1.32
8	1.42	1.41	1.4	1.4	1.4	1.4	1.39	1.32	1.13	1.24	1.44	1.23	1.43	1.92	1.49	1.56	1.78	1.16
9	1.47	1.47	1.47	1.46	1.45	1.44	1.43	1.45	1.17	1.11	1.51	1.61	1.07	1.27	1.01	1.66	1.39	1.4
10	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.13	1.6	1.62	1.08	1.39	1.8	1.39	0.97	1.56	1.52	1.11
11	1.49	1.48	1.47	1.47	1.47	1.47	1.47	1.3	0.93	1.45	1.3	1.55	2.1	1.64	1.63	1.4	1.26	1.38
12	1.54	1.54	1.54	1.53	1.52	1.51	1.5	1.7	1.09	1.62	1.61	1.94	1.75	1.38	1.37	1.44	1.74	1.02
13	1.59	1.58	1.57	1.56	1.55	1.54	1.54	1.15	1.7	2.13	2.23	1.95	1.46	1.35	1.63	1.64	1.79	1.02
14	1.61	1.61	1.61	1.61	1.61	1.61	1.6	1.58	1.38	1.31	1.88	1.7	1.88	1.26	1.5	1.28	1.45	1.58
15	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.04	1.82	1.23	1.56	1.62	2.13	1.56	1.99	1.83	1.64	1.91
16	1.63	1.63	1.63	1.63	1.63	1.63	1.62	1.86	1.91	1.66	2.11	1.83	1.61	1.75	1.56	1.78	1.68	1.61
17	1.61	1.61	1.61	1.61	1.61	1.61	1.62	1.5	1.77	1.79	2.14	1.84	2.3	1.69	1.5	1.76	1.3	1.26
18	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.43	1.3	1.67	2.13	1.38	2.35	2	1.8	2.12	1.8	1.23
19	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.67	1.9	1.88	2.39	1.56	2.01	2.35	1.54	1.52	1.02	1.35
20	1.57	1.58	1.59	1.6	1.61	1.61	1.61	1.56	1.81	1.85	1.43	1.73	1.39	1.7	1.57	1.2	1.45	1.64
21	1.49	1.5	1.51	1.52	1.53	1.55	1.56	1.35	1.46	1.8	2.06	1.6	2.07	1.72	1.84	1.57	1.82	1.62
22	1.47	1.47	1.47	1.47	1.47	1.47	1.48	1.31	1.47	1.37	2.06	1.65	1.62	1.88	1.52	1.49	1.11	1.7
23	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.34	1.56	1.79	1.6	1.64	2.14	1.91	1.69	1.33	2.02	1.42
24	1.44	1.47	1.47	1.47	1.47	1.47	1.47	1.5	1.22	1.22	1.7	1.91	1.81	1.58	1.67	1.55	1.36	1.75
25	1.21	1.22	1.26	1.3	1.34	1.38	1.41	1.63	1.21	1.67	1.64	1.38	1.11	1.35	1.49	1.73	1.44	1.23
26	1.19	1.19	1.19	1.19	1.19	1.19	1.2	1.2	1.3	1.57	1.59	1.2	1.47	1.39	1	1.44	0.93	1.03
27	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.57	1.06	1.58	1.93	1.08	1.21	0.98	1.63	1.25	1.49	1.46
28	1.19	1.19	1.19	1.19	1.19	1.19	1.19	0.91	0.9	1.76	1.58	1.25	1.67	1.27	1.24	1.27	1.33	1.35
29	0.9	0.95	1	1.05	1.1	1.15	1.19	1.05	0.93	0.88	1.41	0.74	1.41	0.65	1.23	0.94	1.07	1.3
30	0.84	0.84	0.84	0.84	0.84	0.84	0.73	1.25	1.02	0.96	1.52	0.9	0.54	0.67	1.26	1.1	1.16	1.13
31	0.84	0.84	0.84	0.84	0.84	0.84	0.63	0.92	0.51	0.89	1.62	0.78	0.92	0.54	0.52	0.91	0.73	1.08
32	0.84	0.84	0.84	0.84	0.84	0.84	0.53	0.71	0.68	0.84	1.35	0.76	0.99	0.83	1.17	0.86	0.6	0.95
33	0.74	0.78	0.81	0.84	0.84	0.84	0.56	0.56	0.79	0.94	0.8	0.77	0.7	0.73	0.96	0.65	0.84	1.14
34	0.56	0.56	0.57	0.58	0.62	0.66	0.68	0.38	0.75	0.69	0.91	0.92	0.53	0.56	0.67	0.76	1.02	0.79
35	0.56	0.56	0.56	0.56	0.56	0.56	0.54	0.43	0.63	0.63	0.5	0.63	0.46	0.45	0.75	0.54	0.66	0.94
36	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.51	0.47	0.46	0.56	0.38	0.64	0.62	0.64	0.6	0.9	0.79
37	0.54	0.56	0.56	0.56	0.56	0.56	0.25	0.5	0.39	0.61	0.32	0.93	0.67	0.38	0.75	0.54	0.5	0.56
38	0.42	0.42	0.44	0.46	0.48	0.5	0.38	0.39	0.47	0.7	0.3	0.54	0.5	0.55	0.57	0.48	0.61	0.34
39	0.42	0.42	0.42	0.42	0.42	0.42	0.37	0.37	0.19	0.41	0.45	0.36	0.38	0.17	0.5	0.64	0.42	0.57
40	0.37	0.38	0.39	0.4	0.41	0.42	0.31	0.32	0.55	0.91	0.24	0.38	0.73	0.94	0.41	0.46	0.47	0.47
41	0.35	0.35	0.35	0.35	0.35	0.29	0.29	0.32	0.66	0.55	0.32	0.31	0.12	0.32	0.45	0.51	0.39	0.3
42	0.35	0.35	0.35	0.35	0.35	0.32	0.31	0.28	0.74	0.35	0.22	0.17	0.49	0.29	0.37	0.29	0.59	0.3
43	0.39	0.38	0.37	0.36	0.35	0.68	0.32	0.37	0.53	0.51	0.44	0.53	0.41	0.38	0.29	0.29	0.28	0.31
44	0.42	0.42	0.42	0.42	0.42	0.41	0.33	0.35	0.27	0.42	0.55	0.51	0.46	0.36	0.56	0.38	0.33	0.32
45	0.42	0.42	0.42	0.42	0.42	0.42	0.32	0.31	0.49	0.16	0.34	0.71	0.52	0.33	0.35	0.49	0.33	0.37
46	0.46	0.44	0.42	0.42	0.42	0.42	0.37	0.36	0.42	0.1	0.34	0.26	0	0.31	0.45	0.62	0.32	0.31
47	0.56	0.56	0.56	0.54	0.52	0.5	0.48	0.45	0.7	0.52	0.58	0.22	0.55	0.47	0.58	0.35	0.41	0.4
48	0.56	0.56	0.56	0.56	0.56	0.56	0.38	0.42	0.38	0.53	0.49	0.66	0.71	0.51	0.39	0.47	0.45	0.39
49	0.56	0.56	0.56	0.56	0.56	0.56	0.5	0.48	0.66	0.61	0.18	0.35	0.38	0.32	0.42	0.42	0.43	0.53
50	0.64	0.6	0.56	0.56	0.56	0.56	0.49	0.48	0.63	0.82	0.38	0.83	0.44	0.5	0.71	0.98	0.47	0.52
51	0.84	0.84	0.84	0.8	0.76	0.72	0.62	0.6	0.81	0.98	0.57	0.63	0.37	0.49	0.48	0.48	0.61	0.52
52	0.87	0.86	0.85	0.84	0.84	0.84	0.77	0.72	0.75	0.65	1.03	0.81	0.76	0.79	0.7	0.68	0.67	0.59

Appendix E
Evaporation (inches/week)

week	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	0.69	0.61	0.57	0.69	0.7	0.58	0.56	0.57	0.87	0.56	0.62	0.63	0.61	0.62	0.58	0.57	0.56	0.56
2	0.67	1.08	0.73	0.8	0.87	1.17	1.03	0.69	0.64	0.72	1.29	0.71	1.25	0.68	0.84	0.63	0.63	0.62
3	0.93	0.84	0.7	0.76	0.84	0.55	0.85	0.72	0.81	0.84	0.98	0.78	1.29	0.76	0.72	0.71	0.69	0.68
4	0.87	1.35	0.85	0.82	1.14	0.83	1.02	0.83	0.64	0.89	1.03	0.85	1.04	0.83	0.79	0.78	0.77	0.76
5	1.55	1.24	0.93	0.71	1.17	0.91	1.4	1.15	0.8	0.91	1.12	0.92	0.78	0.9	0.86	0.85	0.84	0.83
6	1.18	1.52	0.86	0.76	1.41	1.52	1.17	1.29	0.72	0.96	0.57	1	0.83	0.97	0.94	0.93	0.92	0.9
7	0.99	1.14	0.89	1.53	1.16	1.58	0.96	1.1	1.25	1.26	1.15	1.08	1.31	1.06	1.35	1	0.99	0.98
8	1.57	1.82	1.82	1.28	0.91	1.35	1.35	0.84	1.47	1.27	0.89	1.15	1.1	1.13	1.65	1.08	1.07	1.06
9	1.62	1.44	1.06	1.07	1.09	1.39	1.06	1.11	1.39	1.33	1.83	1.22	1.13	1.2	1.52	1.15	1.14	1.13
10	1.97	1.61	1.13	1.57	0.81	1.2	1.31	1.58	1	1.33	1.2	1.29	1.64	1.6	1.34	1.23	1.22	1.21
11	1.32	1.65	1.81	1.44	1.66	0.99	1.41	1.79	1.15	1.39	1.41	1.36	1.61	1.27	1.68	1.3	1.29	1.28
12	1.9	1.39	1.7	1.7	1.22	1.33	0.98	1.5	1.71	1.43	1.66	1.42	1.41	1.29	1.27	1.36	1.35	1.37
13	2.01	1.02	1.94	1.43	1.39	1.22	1.42	1.59	1.35	1.47	1.29	1.47	1.47	1.3	1.76	1.42	1.41	1.18
14	1.57	1.22	1.17	1.64	1.16	1.47	1.15	1.31	1.51	1.47	0.73	1.54	1.53	1.24	1.68	1.47	1.47	1.67
15	1.76	1.67	1.39	1.41	1.65	0.97	1.37	1.76	0.85	1.5	1.27	1.57	1.56	1.56	1.28	1.53	1.52	1.17
16	1.22	1.47	1.92	1.45	1.71	1.54	1.1	1.28	1.73	1.54	1.87	1.61	1.35	1.63	1.43	1.54	1.54	1.22
17	1.77	1.13	1.99	1.28	1.48	1.44	1.36	1.06	1.58	1.6	1.71	1.61	1.38	1.63	2.02	1.61	1.6	1.57
18	1.19	1.52	1.89	1.33	1.78	1.51	1.75	1.38	1.56	1.61	1.79	1.65	1.69	1.76	1.51	1.61	1.61	1.72
19	1.38	1.7	1.82	1.56	1.6	1.32	2.13	1.71	1.82	1.62	1.42	1.68	1.6	2.01	1.66	1.61	1.61	1.08
20	1.72	1.26	1.34	1.18	1.92	1.47	1.13	1.43	1.83	1.62	1.36	1.68	1.38	1.7	1.92	1.61	1.61	1.3
21	1.53	1.74	0.89	1.48	1.4	1.17	1.41	1.5	1.54	1.61	1.28	1.63	1.48	1.54	2.1	1.61	1.61	1.61
22	1.27	1.74	1.07	1.38	1.97	1.49	1.66	1.92	1.84	1.61	1.85	1.61	1.68	1.37	1.93	1.61	1.61	1.61
23	1.14	1.65	1.49	0.94	1.85	1.39	1.48	1.16	1.43	1.61	1.97	1.61	1.37	1.35	2.44	1.59	1.6	1.61
24	1.56	1.56	1.37	1.44	1.06	1.31	1.91	1.27	1.62	1.56	1.27	1.54	1.65	1.65	2.03	1.54	1.54	1.54
25	1.41	1.57	1.3	1.53	1.57	1.31	1.42	1.45	1.3	1.48	1.64	1.52	0.7	1.7	1.84	1.51	1.52	1.53
26	1.28	1.19	1.41	1.42	1.6	1.19	1.83	1.14	1.25	1.47	1.18	1.47	1.2	1.55	1.96	1.47	1.47	1.47
27	1.46	1.22	1.1	1.63	1.27	1.12	1.63	1.52	1.54	1.47	1.58	1.4	1.21	1.52	1.77	1.4	1.41	1.42
28	0.98	1.01	1.48	1.01	1.58	1.19	1.55	1.22	1.39	1.41	1.3	1.34	1.41	1.77	1.41	1.35	1.36	1.37
29	1.16	1.24	0.99	1.18	1.56	1.06	1.45	1.15	1.48	1.2	1.29	1.27	1.36	1.47	1.77	1.28	1.29	1.3
30	0.99	1.31	0.99	1.22	1.03	1.05	1.54	1.18	1.53	1.19	1.35	1.2	1.04	1.79	1.33	1.21	1.22	1.3
31	0.86	1.07	1.12	1.01	1.1	1.17	1.59	0.85	1.45	1.19	1.08	1.13	1.02	0.86	1.44	1.14	1.15	1.2
32	0.83	1.12	0.55	0.97	0.85	1.05	1.29	1.09	1.38	1.19	1.18	1.05	0.9	0.89	1.32	1.07	1.08	1.13
33	1.1	1.12	0.91	1	1.02	0.77	1.2	0.9	1.23	0.85	0.91	0.93	1.05	0.99	0.97	0.99	1	0.86
34	0.65	1.25	0.54	0.86	0.83	0.75	0.58	0.88	1.03	0.89	0.89	0.99	1.09	0.76	1.02	0.92	0.93	0.89
35	0.96	0.56	0.78	0.88	0.59	0.84	0.98	0.9	0.63	0.64	0.62	1.16	0.83	0.92	1.39	0.85	0.86	1.09
36	0.61	0.91	0.65	0.69	0.69	0.57	0.84	1.04	0.58	0.64	0.75	1.06	0.71	0.83	0.81	0.77	0.78	0.69
37	0.7	0.82	0.58	0.84	0.59	0.61	0.51	0.57	0.43	0.61	0.68	0.8	0.66	0.76	0.62	0.7	0.71	0.79
38	0.47	0.65	0.86	0.44	0.48	0.62	0.58	0.69	0.52	0.63	0.62	0.75	0.88	0.57	0.63	0.63	0.64	0.7
39	0.5	0.44	0.64	0.59	0.57	0.63	0.46	0.52	0.51	0.68	0.56	0.79	0.63	0.57	0.56	0.57	0.58	0.66
40	0.77	0.54	0.88	0.53	0.47	0.57	0.68	0.55	0.39	0.61	0.51	0.75	0.5	0.61	0.51	0.52	0.53	0.56
41	0.38	0.32	0.55	0.43	0.43	0.4	0.49	0.51	0.37	0.49	0.68	0.43	0.38	0.48	0.49	0.49	0.51	0.59
42	0.56	0.38	0.42	0.33	0.34	0.45	0.31	0.65	0.19	0.42	0.39	0.46	0.5	0.42	0.42	0.43	0.49	0.52
43	0.29	0.36	0.28	0.34	0.47	0.3	0.44	0.55	0.47	0.42	0.42	0.42	0.41	0.42	0.42	0.42	0.42	0.42
44	0.31	0.51	0.38	0.31	0.32	0.33	0.41	0.41	0.33	0.42	0.38	0.42	0.35	0.35	0.36	0.37	0.42	0.39
45	0.32	0.81	0.43	0.21	0.32	0.33	0.71	0.37	0.49	0.42	0.44	0.42	0.35	0.35	0.35	0.35	0.42	0.35
46	0.59	0.33	0.46	0.29	0.34	0.36	0.34	0.35	0.82	0.42	0.51	0.42	0.35	0.35	0.35	0.35	0.42	0.35
47	0.36	0.39	0.32	0.3	0.36	0.32	0.31	0.42	0.41	0.35	0.42	0.3	0.42	0.35	0.35	0.7	0.42	0.35
48	0.41	0.87	0.47	0.36	0.36	0.37	0.29	0.42	0.42	0.48	0.42	0.57	0.42	0.37	0.36	0.35	0.35	0.42
49	0.46	0.43	0.48	0.45	0.69	0.48	0.51	0.42	0.42	0.46	0.43	0.49	0.42	0.42	0.42	0.42	0.41	0.42
50	0.37	0.7	0.5	0.42	0.58	0.5	0.5	0.65	0.5	0.31	0.49	0.53	0.48	0.42	0.42	0.42	0.42	0.43
51	0.48	0.62	0.48	0.46	0.59	0.52	0.35	0.46	0.56	0.53	0.53	1.03	0.51	0.49	0.48	0.47	0.46	0.49
52	0.81	0.47	0.5	0.56	0.62	0.52	0.63	0.47	0.56	0.77	0.57	0.67	0.56	0.53	0.52	0.51	0.5	0.53

Appendix E
Evaporation (inches/week)

week	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	0.57	0.55	0.54	0.56	0	0.56	0.56	0.56	0.56	0.56	0.54	0.52	0.5	0.48	0.46	0.44	0.73	0.73
2	0.63	0.6	0.59	0.61	0	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.84	0.84
3	0.71	0.66	0.65	0.67	0	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.89	0.89
4	0.78	0.74	0.73	0.75	0	0.72	0.68	0.64	0.6	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.98	0.98
5	0.85	0.81	0.8	0.82	0	0.84	0.84	0.84	0.72	0.84	0.8	0.76	0.72	0.68	0.64	0.6	1.07	1.07
6	0.92	0.88	0.87	0.89	0	0.84	0.84	0.84	1.13	0.84	0.8	0.84	0.84	0.84	0.84	0.84	1.12	1.12
7	1	1.16	0.95	0.96	0	0.84	1.06	0.92	1.02	0.94	1.11	0.84	0.84	0.84	0.84	0.84	1.22	1.22
8	1.02	1.31	1.8	1.79	0.36	0.84	1.26	1.12	1.1	0.77	1.25	0.84	0.84	0.84	0.84	0.84	1.30	1.30
9	1.09	1.77	2.59	1.48	1.23	1.95	1.61	0.87	1.35	1.36	1.3	1.04	0.91	0.84	0.84	0.84	1.35	1.35
10	0.96	1.2	3.26	3.17	0.91	1.26	1.58	1.4	1.16	0.9	1.3	1.1	0.96	1.19	1.18	1.08	1.42	1.42
11	1.61	1.39	1.62	2.53	1.03	1.57	1.18	0.92	1.23	1	1.09	1.16	1.42	1.19	1.13	1.1	1.44	1.44
12	1.04	1.74	2.36	3.47	4.16	1.66	1.53	1.12	1.56	1.39	1.26	1.12	1.22	1.42	1.67	1.19	1.57	1.57
13	1.59	1.5	1.62	3.71	0.9	1.96	2.03	1.8	1.99	1.54	1.72	1.09	1.38	1.35	1.38	1.18	1.58	1.58
14	1.62	1.69	1.62	1.86	1.22	1.08	1.79	1.67	1.2	1.31	1.61	1.39	1.34	1.35	1.53	1.26	1.50	1.50
15	1.36	1.5	1.85	2.49	1.95	1.65	1.3	1.22	1.46	0.85	1.69	1.32	1.08	1.81	1.11	1.35	1.55	1.55
16	1.56	1.75	1.43	1.23	1.52	2.17	1.53	1.35	1.58	1.5	1.64	1.37	1.27	1.44	1.7	1.53	1.59	1.59
17	1.94	1.41	1.72	1.47	1.1	1.59	1.38	1.47	1.59	1.89	1.24	1.49	1.5	1.53	1.39	1.59	1.59	1.59
18	1.97	1.49	1.57	1.49	1.66	1.43	1.89	1.81	1.74	1.9	1.51	1.87	0.76	1.73	1.6	1.97	1.64	1.64
19	1.76	1.82	1.16	1.19	1.89	1.69	2.23	1.62	1.82	1.36	1.69	1.87	1.46	1.75	1.52	1.54	1.64	1.64
20	1.4	2.11	0.27	1.4	1.4	1.85	2	1.45	1.7	1.97	1.79	1.7	1.03	1.58	1.27	1.52	1.54	1.54
21	2.16	1.46	0.54	1.9	1.39	2.12	1.94	1.62	1.87	1.39	1.66	1.56	1.69	1.83	1.87	1.51	1.57	1.57
22	1.89	1.6	0.54	1.85	1.9	1.62	1.91	1.73	1.85	1.73	2.04	2.05	1.58	1.86	1.87	1.17	1.58	1.58
23	1.8	2.35	0.27	1.59	1.58	1.87	2.18	1.92	2.1	1.57	2.01	1.83	1.43	2.03	1.53	1.58	1.57	1.57
24	1.72	1.69	0.61	1.95	1.06	1.92	1.69	1.57	1.74	1.46	2.15	1.92	2.06	1.99	1.93	1.85	1.52	1.52
25	1.66	1.7	0.3	1.34	0.95	1.44	1.79	2.29	1.41	1.48	1.64	1.53	2.11	1.78	2.32	1.67	1.42	1.42
26	2.11	1.36	0.19	2.14	1.2	1.58	1.8	1.8	1.63	1.49	1.78	1.64	1.46	1.58	1.56	1.67	1.36	1.36
27	2.11	1.78	0.53	2.06	1.3	1.21	1.62	1.37	1.81	1.84	1.62	1.28	1.93	2.04	1.35	1.6	1.38	1.38
28	0.9	1.24	0.04	1.42	1.45	1.59	1.44	1.69	1.88	0.8	1.4	1.39	1.43	1.23	1.34	1.38	1.23	1.23
29	2.11	1.16	1.19	1.66	1.44	1.7	1.46	1.66	2.01	1.36	1.3	1.36	1.05	1.53	1.66	1.83	1.19	1.19
30	1.62	0.94	1.86	1.55	1.51	1.32	1.36	1.44	1.55	1.14	0.96	1.17	1.34	1.74	1.4	1.87	1.13	1.13
31	1.39	1.13	1.16	1.66	1.27	1.36	0.87	1.19	1.49	1.46	1.65	1.45	1.29	1.69	1.47	1.24	1.05	1.05
32	1.01	0.69	1.23	1.24	1.19	1.4	1.02	1.28	0.91	0.93	1.4	1.18	1.16	1.25	1.12	1.49	0.95	0.95
33	1.36	1.11	1.17	1.11	1.32	1.17	1.15	1.07	0.89	1.16	1.46	1.44	1.39	1.49	1.38	1	0.91	0.91
34	0.75	1.17	1.55	0.71	0.84	0.98	1.08	1.26	1.15	1.67	1.01	1.35	0.96	0.77	1.22	1.22	0.82	0.82
35	1.02	0.84	0.76	1.15	0.95	1.12	1.5	1.19	0.87	0.96	0.85	1.17	0.7	1.32	1.08	0.9	0.76	0.76
36	0.77	0.63	1.62	0.36	1.06	0.89	0.65	0.84	0.9	1.02	1.06	0.9	0.69	1.31	0.95	0.9	0.70	0.70
37	0.59	0.87	1.74	0.8	0.72	0.88	0.79	0.93	0.9	0.81	0.87	0.96	0.9	0.69	0.75	1.09	0.64	0.64
38	0.46	0.5	2.01	0.74	0.52	0.53	0.78	0.89	0.91	0.74	0.72	0.77	0.89	0.46	0.82	0.99	0.58	0.58
39	0.66	0.7	1.66	0.07	0.23	0.63	0.7	0.59	0.69	0.74	0.89	0.71	0.77	0.68	0.62	0.95	0.52	0.52
40	0.93	0.65	2.17	0	0	0.87	0.52	0.79	0.8	0.49	0.58	0.62	0.57	0.79	0.51	0.81	0.53	0.53
41	0.49	1.86	0	0	0.72	0.76	0.55	0.73	0.69	0.56	0.56	0.56	0.56	0.56	0.56	0.43	0.45	0.45
42	0.46	1.52	0	0	0.61	0.57	0.56	0.47	0.7	0.56	0.56	0.56	0.56	0.56	0.56	0.43	0.43	0.43
43	0.42	0.93	0	0	0.41	0.63	0.56	0.39	0.36	0.56	0.56	0.56	0.56	0.56	0.56	0.43	0.42	0.42
44	0.4	2.41	0	0	0.42	0.42	0.42	0.45	0.44	0.48	0.5	0.52	0.54	0.56	0.56	0.78	0.44	0.44
45	0.35	2.27	0	0	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.44	0.78	0.45	0.45
46	0.35	1.33	0	0	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.78	0.43	0.43
47	0.35	2.33	0	0	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.78	0.48	0.48
48	0.35	0.35	0.42	0	0.84	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.85	0.48	0.48
49	0.39	0.38	0.42	0	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.84	0.42	0.42	0.24	0.85	0.50	0.50
50	0.42	0.42	0.42	0	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.85	0.57	0.57
51	0.44	0.43	0.47	0	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.85	0.61	0.61
52	0.49	0.49	0.5	0	0.5	0.48	0.46	0.44	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.85	0.67	0.67

Appendix E
Evaporation (inches/week)

week	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943
1	0.80	0.80	0.80	0.80	1.24	1.9	0.64	0.08	1.53	1.07	0.99	0.54	0.99	0.29	0.61	0.3	1.16	1.66
2	0.97	0.97	0.97	0.97	0	0.13	0.86	1.19	2.73	2.09	4.75	1.45	1.02	0.3	0.71	2.46	0.55	0.41
3	0.85	0.85	0.85	0.85	0.77	0.61	0	1.59	0.47	0.06	0.62	0.58	1.55	0.52	0.38	1.59	0	0.12
4	0.97	0.97	0.97	0.97	0	1.49	0.62	0.53	0.49	1.43	0	0.51	0.02	1.26	1.42	0.77	1.48	0.82
5	0.98	0.98	0.98	0.98	0	0.47	0.4	0	0.01	0.32	0.54	1.76	0.14	0.36	1.31	1.37	0	2.97
6	0.87	0.87	0.87	0.87	0.65	1.62	0.5	1.17	0	0	0.05	0.67	0	2.23	0	0.45	0.13	0
7	0.73	0.73	0.73	0.73	1.65	0.57	0.3	0.14	0.16	1.67	0	0.22	0	0.19	0	0.34	0.69	0
8	0.78	0.78	0.78	0.78	0.08	2.1	0.3	0.9	2.25	2.04	0.16	0.96	1.39	1.15	0.51	0	1.76	1.13
9	0.82	0.82	0.82	0.82	0.62	0.14	1.6	0.61	0.64	0.16	0	0	1.64	0	1.06	0.37	1.64	0
10	0.70	0.70	0.70	0.70	1.01	0	0	0.42	1.81	0.65	0	0.01	1.31	0.53	0.82	0	0.45	0.9
11	0.88	0.88	0.88	0.88	0.56	0.05	2.04	0.36	1.73	0	3.49	0.91	1.35	0.32	0.55	1.96	0	0.04
12	0.75	0.75	0.75	0.75	3.22	1.59	1.1	0	2.39	0.13	0.18	0.42	0.75	1.71	0	0.27	1.38	5.07
13	0.86	0.86	0.86	0.86	0.59	0.26	0.01	0.53	0.16	0.32	3.83	0.52	2.66	0.45	1.02	0.53	0	0.49
14	1.00	1.00	1.00	1.00	0.24	1.86	0.49	1.71	2.15	0.08	0.14	0.03	1.37	0	0.06	1.16	0.82	0.92
15	0.82	0.82	0.82	0.82	1.65	0.2	0	0.03	0.25	0.46	1.21	0.44	0.47	1.85	0.27	0.66	1.22	1
16	1.22	1.22	1.22	1.22	1.35	0.18	0.21	1.16	0.5	2.68	0.87	2.99	0.18	2.89	0.23	3.84	0.66	2.85
17	1.20	1.20	1.20	1.20	0	1.64	0.16	0.73	1.45	1.2	3.76	0.13	2.44	1.38	1.04	3.36	1.01	5.33
18	1.13	1.13	1.13	1.13	0.45	2.1	0.39	0.96	0.41	0.74	0.38	3.44	3.82	3.24	0	0.05	0.09	1.25
19	1.20	1.20	1.20	1.20	0.81	0.92	1.16	1.94	0.33	0	2.63	2.76	0.94	1.15	0.78	0.47	2.51	1.29
20	0.88	0.88	0.88	0.88	0.36	2.55	0	0.56	1.52	0.14	3.12	1.41	0.34	0.98	0	1.3	0.95	0
21	1.22	1.22	1.22	1.22	0	2.3	0.57	0.48	0.39	1.01	0	1.06	0	2.17	3.52	0.43	0.87	0.58
22	0.87	0.87	0.87	0.87	0.08	0.04	0	0.8	3.07	0.25	0.07	2.91	0.25	2.59	0.37	1.12	3.68	0.07
23	0.98	0.98	0.98	0.98	1.36	0	0	0.1	0.15	1.52	0.59	3.45	0.67	3.06	0	0.96	0.7	0
24	1.17	1.17	1.17	1.17	0.83	0	0	0.33	0.89	4.86	0.2	1.14	4.18	0.05	0.06	0	1.74	2.57
25	1.03	1.03	1.03	1.03	0.61	0	0.23	0.04	2.2	0.56	0.97	0.19	0.04	0	0.74	0.17	3.59	0.29
26	0.77	0.77	0.77	0.77	0	0.18	0.3	0	0	0.04	0.06	0	2.2	0.3	0	0	0	0
27	0.90	0.90	0.90	0.90	0	0	0.52	0	0.04	0.96	1.11	0	0	0.85	0.34	0	0	2.49
28	0.62	0.62	0.62	0.62	0.21	0	2.07	0	0.8	0.28	0.47	1	0.59	0.8	0	1.21	2.33	0
29	1.09	1.09	1.09	1.09	1.31	0.55	4.32	0.1	0.12	0.02	3.3	0.51	0.46	0	0.07	0	0.33	0
30	0.91	0.91	0.91	0.91	0.16	0	0	0.6	0	0	0.93	0.4	0	0.64	0	0	2.16	0
31	0.73	0.73	0.73	0.73	0.92	0.66	1.18	0	0.19	0.33	0.07	0.58	0.93	0	0	0	0.84	0
32	0.77	0.77	0.77	0.77	0.5	0	1.2	0.69	1.05	0.53	0	0	0.21	0.78	0.18	2.46	0.46	0.38
33	0.52	0.52	0.52	0.52	0.76	0	0.28	0.86	0.56	2.51	0.49	0.06	0.88	0.59	0.61	0.31	0.07	0.03
34	0.79	0.79	0.79	0.79	0.04	0	1.16	0	0	0.61	1.12	1.96	0	0	3.5	0	0.49	1.17
35	0.70	0.70	0.70	0.70	0.49	0.11	1.45	0.09	0.93	0.06	0.31	0.06	2.52	1.03	1.15	0	0	0
36	0.61	0.61	0.61	0.61	0.68	1.68	0	0.18	3.99	0.5	0.12	0.15	0.42	0.17	0.45	0.48	1.3	0
37	0.81	0.81	0.81	0.81	0	1.59	1.88	0.31	0.01	0.22	1.57	0.37	1.03	0.04	0.06	0	0.71	0.36
38	0.92	0.92	0.92	0.92	1.4	0.75	1.71	0.05	0.04	1.9	3.33	0.21	0.3	0.08	0	1.1	1.36	0.63
39	0.79	0.79	0.79	0.79	0.55	0.86	0.68	0.6	1.26	0.4	0.44	0.03	0.16	0.38	1.2	0.92	0.9	0.57
40	0.73	0.73	0.73	0.73	0.4	0.37	0.16	0.65	1.9	1.04	0.26	1.48	1.49	1.86	0.96	1.22	1.18	0
41	0.80	0.80	0.80	0.80	0.6	2.86	0.73	0.05	0	3.81	0.29	0.45	0.88	0.19	0.24	1.34	2.66	0.33
42	0.82	0.82	0.82	0.82	0.48	0.1	1.13	0.18	1.33	0.89	0.54	1.63	0.36	0.75	0.72	0.67	2.02	0.76
43	0.77	0.77	0.77	0.77	0	0.13	0	0.28	0.29	2.75	0.74	0.02	1.21	1	0.72	0	0.68	0.6
44	0.94	0.94	0.94	0.94	0	0.82	1.27	0.28	0.9	0.2	1.23	0.49	0.62	1.03	0.2	0.19	2.28	1.8
45	0.76	0.76	0.76	0.76	0.09	0.99	0.78	1	0	2.02	2.56	0.39	0.52	0	0.7	0.2	1.06	0
46	0.75	0.75	0.75	0.75	0.28	0.84	1.51	0.71	0.21	1.6	0.9	0.05	1.62	0.64	0	0.15	0.25	0
47	0.82	0.82	0.82	0.82	0.78	0.53	0.91	0.54	1.49	1.53	0.32	0.18	3.76	0.59	0.3	0.77	1.11	1.62
48	1.00	1.00	1.00	1.00	0.28	0	0.3	1.07	0.03	0.21	1.35	0.17	1.28	1.24	0.97	1.77	0	2
49	0.86	0.86	0.86	0.86	0.54	1.5	0.27	0.62	2.1	0.17	0.78	0.41	2.57	0.4	0.03	0.22	0.12	0.9
50	0.96	0.96	0.96	0.96	0.04	0	0.17	0.76	0.35	1.04	0.45	0.28	1.68	0.4	0.5	1.36	0.25	0.94
51	0.86	0.86	0.86	0.86	0.45	0.83	0.74	1.3	1.31	2	0.69	1.22	0.21	1.08	1.77	1.71	1.77	1.84
52	0.82	0.82	0.82	0.82	0.49	0.31	0.05	0.81	1.65	0.93	0.33	0.26	0.24	0.82	0.22	0.15	0.26	1.6

Appendix E
Precipitation Input (inches/week)

week	1944	1945	1946	1947	1948	1949	1950	1951	1952
1	2.79	0.46	0.88	0.2	0.34	0.43	0.95	1.6	1.52
2	1.24	0.24	0.02	0.43	0.94	0.76	1.58	1.03	0.64
3	0.6	0.05	0.42	0.59	1.5	0.38	0.22	0.14	1.36
4	2.04	0	1.14	0.06	0.38	0.56	0.09	1.91	1.27
5	0.96	0.85	0.59	1.51	1.96	0.67	0	2.02	0.04
6	1.32	1.79	0.71	0	0.17	0.63	0.43	0.5	0
7	0	0.44	1.16	0	0.04	1.01	0	0.99	2.95
8	1.17	0.05	0.18	0.17	0.59	1.52	1.67	1.09	0.2
9	0.4	1.26	1.13	0	1.41	2.3	1.27	0.13	0.48
10	1.62	0.13	1.39	0.86	0.17	0	1.63	0.55	0.27
11	1.18	0.88	1.89	0.73	1.74	1.41	0.5	0.46	2.27
12	0	0.25	0.21	0.35	1.12	0.28	0.79	0	0.18
13	0	0.13	0.67	0.16	0.56	0.22	0.87	1.27	0
14	1.06	0.84	1.06	2.65	0.07	0.62	0.12	0.62	0.31
15	0	0.86	3.05	1.85	0	0.01	1.6	0.75	1.07
16	0.19	2.53	2.6	1.14	0.94	2.61	2.17	0.63	0.87
17	2.37	0.97	1	1.29	0.27	1.14	0.98	1.17	0
18	4.26	4.46	0	0.43	1.68	1.07	2.37	0	2.19
19	0.01	3.93	1.17	0.54	0.52	0.79	1.86	1.72	1.52
20	2.54	0.84	0.31	1.08	0.92	0	0.82	0.12	0.16
21	2.13	0.8	1.02	1.93	2.31	1.99	0.46	2.49	1.06
22	0.02	0.51	0.48	0	0.35	0.07	0.05	0.31	3.38
23	0.18	5.09	0.62	0.2	0.69	2.72	0.43	0.25	1.1
24	0.25	0.29	0.81	0.12	0	1.1	2.21	0.58	1.49
25	0	1.76	0	0.06	0.2	3.68	0.31	0.06	2.88
26	1.29	0.07	0.67	1.28	0.44	0.61	2.26	0.26	0.25
27	1.99	12.66	0.72	0.28	0	1.74	1.04	0.95	0.05
28	0	0	2.01	2.04	0	1.15	0.81	0.69	0.63
29	4.7	0.13	0.53	0	3.75	0.25	0.3	0.13	2.05
30	0.12	1.78	1.95	2.72	1.78	1.07	0.7	0	0.41
31	1.57	0.39	0.3	1.45	0.05	0	0.31	1.18	0.84
32	0.32	0.58	0.14	0.67	0.23	0.05	1.31	0.05	0
33	0	0	0.65	0.61	0	1.2	0.71	0.12	0
34	0.26	0.63	0.66	1.91	2.56	3.84	0.07	2.08	0
35	0.28	0.35	0.1	2.41	1.53	0.2	0.05	0.12	0.11
36	0.8	0.34	1.58	1.89	1.35	0.09	0.03	0.77	1.51
37	2.09	0.46	0.1	0.68	1.35	0.68	0.57	0	4.56
38	0.85	2.84	0	0.05	2.77	0.06	0	0.28	0.01
39	0.31	1.24	0	0.21	0.36	0	2.17	1.25	0.52
40	0.1	0.67	0.68	0.48	0.1	0.16	0.03	0.33	0.51
41	1.36	0.24	0.24	1.25	0.1	0	2.72	0.54	1.73
42	2.03	1.04	0.21	1.71	0.7	0.46	0.28	0.05	0.27
43	0.82	0.53	0.34	0.02	0.97	0.12	0.19	1.94	0.44
44	0.53	2.23	2.53	1.72	0	0.46	0.55	0.99	0.74
45	0.33	0	1.8	0.28	0.67	1.32	0.67	0	0.16
46	0	0.96	0.04	0.9	0.22	0.42	0.37	1	2.34
47	0.69	0.08	0.15	1.12	0.97	0.09	0.48	1.93	0.41
48	1.43	2.51	0	2.71	0.95	0.85	0.79	1.45	1
49	2.91	0.6	0.98	0.05	0.88	0.34	0.38	0.55	2.37
50	0.88	0	0.16	0.53	0.17	0.61	0.22	0.54	0.85
51	0.62	0.28	0.2	0.89	0.45	0	0.05	1.93	0.05
52	0.08	0.22	1.68	1.7	0.33	0.33	0.39	2.94	1.21

week	1953	1954	1955	1956	1957	1958	1959	1960	1961
1	1.91	1.25	0.05	0.4	0.45	0.38	1.55	1.55	0.22
2	0.78	0.57	1.29	2.82	0.43	0.4	0.19	0.72	0.84
3	2.41	0.6	0.04	0.02	1.91	0.57	0.12	0.82	0.48
4	1.42	1.3	0	0.15	0.05	2.01	1.18	0.03	2.11
5	1.81	1.32	0.47	0.94	0.47	1.28	1.1	4.39	1.69
6	0.7	0.89	2.6	2.02	0.12	1.45	3.18	0	0.6
7	0	0	0	0	0	0.5	1.1	0.16	1.12
8	1.04	0.09	0.83	0.01	1.2	2.13	0.79	0.25	0
9	0.94	1.46	0	1.39	0.75	1.66	0.24	2.16	1.34
10	0	1.65	0.64	0.54	1.27	2.27	0.6	0.78	0
11	0.2	0.59	0.25	0.02	1.01	0.39	0.93	0.61	3
12	0.04	0.09	0.56	1.28	0.69	0.93	1.06	0	0.13
13	2.04	0	0.06	1.71	0.28	0.82	0.34	3.25	0.95
14	0.23	0.99	0.41	0	2.32	0.09	2.54	1.38	0
15	1.2	1.48	0.16	0	0.02	0.29	0	0	1.27
16	1.32	0.06	0.85	0.24	0.73	0.43	0	0.46	0.83
17	0	0.07	0	0.06	1.53	0.79	1.58	0.2	2.69
18	0.48	0.1	2.93	0.76	0	0.52	2.23	2.03	0.31
19	0	2.22	1.4	0.69	0	3.21	3.45	1.33	0.46
20	0.8	0.76	0.48	1.43	1.27	0.91	0.44	0	1.17
21	0	1.07	1.09	1.87	1.37	1.89	1.62	0.7	1.35
22	0.83	1.47	0.05	0.48	0.83	0.08	1.64	2.92	0.3
23	0.39	0.05	3.41	0.74	0.21	0.02	1.03	2.63	1.84
24	0.55	1.25	4.57	1.81	3.56	2.19	0	0.23	0.29
25	0	0.96	0	1.19	3.9	1.47	0.15	1.38	1.98
26	1.97	0	3.41	0.59	0.08	1.19	2.35	0.18	1.8
27	0.36	0	0.41	1.51	0.95	0	3.02	0.03	0
28	0	0	0	0	0.03	0	0	1.58	0.41
29	3.76	0.21	1.81	0.09	2.33	0.76	0.02	0.68	0.26
30	0	0.1	1.7	3.57	2.25	0.15	0	0	0.12
31	0.04	0.05	0.35	1.65	0.52	1.9	1.35	1.32	0.13
32	0	4.6	0.52	0	0	0	1.42	1.39	0.12
33	0	0.31	0.02	3.96	0.23	0	1.95	0.48	0.06
34	0.54	0.58	0.3	0.3	0.34	0.4	1.61	0.67	1.55
35	0.39	1.18	0.1	0.67	0.53	0.84	0.43	0.38	0
36	0	0	1.01	0.59	0.47	0.03	1.8	0.02	0.22
37	0.62	0.63	0.95	0.11	0.84	0.02	0.04	0.06	0.48
38	0.49	0.73	0.4	0.21	3.03	0.02	0.18	0.02	0.42
39	1.36	0.43	0.14	0.26	1.92	0.83	1.62	0.37	1.15
40	1.72	1.46	0.11	0	1.73	0.08	0.18	0.1	0.01
41	0.83	0.02	1.82	0.1	0.93	0.48	1.21	1.79	1.1
42	0	0	1.15	0.64	0	1.71	0.06	2.46	0
43	0.39	0.2	0.17	0.8	3.74	0.03	0.43	0.28	0.69
44	0.08	0	0	0.25	0.61	1.19	1	1.44	1.86
45	3.62	0.69	0.31	0.2	0.51	0.27	1.03	0	3.03
46	3.17	0.58	0.42	0.35	1.58	0.17	0.19	1.29	0.63
47	0	0.59	0.73	0.78	2.13	0.49	0.04	0.23	0.53
48	0.15	1.7	1.83	3.89	0.5	0.07	2.59	0.5	1.78
49	0	2.28	1.63	1.05	1.2	1.88	1.65	0.6	0
50	1.19	0.05	0.86	0.02	0.25	1.27	1.69	1.72	0.28
51	0.25	1.3	0.98	0.78	0	0.41	0.92	1.88	1.08
52	1.09	0.54	0.67	3.59	1.65	0.53	0.66	1.98	1.85

Appendix E
Precipitation Input (inches/week)

week	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	0.56	0.81	0.62	1.26	3.12	0.06	0	0.58	0.54	0.69	0.73	0	0.7	0.88	0.05	0.47	0.62	0.03
2	1.58	1.41	0.11	1.46	1.76	0.3	0.34	1.33	1.44	2.1	0.52	0.67	0.62	0.45	0.34	0.7	0.6	3.88
3	0	1.82	1.53	0.05	0	0.38	2.37	1.19	0.26	0.25	0.1	1.67	0	0.18	0	2.06	2.53	3.05
4	1.57	0.45	0.74	2.85	0.13	0.76	0.64	1.49	0.81	0.42	0.55	0.76	0.78	2.74	1.22	0.93	1.94	0.59
5	1.61	0.27	1.01	0.78	0.08	0.07	0.46	0.47	1.42	0.38	0.54	0.96	1.32	2.77	0.77	0.95	0.28	0.76
6	2.76	0.72	1.71	0.24	0.13	0	0.36	0	2.1	1.26	0.64	0.34	0.54	0.83	0.13	1.3	0	1.07
7	1.32	0.35	1.99	0.1	0.11	0.05	0.95	0.68	0.52	1.37	0.39	2.51	2.05	1.14	1.06	0.99	1.19	0.2
8	0	0.06	0	0.76	0.51	1.94	0.11	1.03	2.41	0	1.05	1.45	0.49	0	0	1.43	0	1.76
9	0.24	1.37	0.67	0.96	1.18	1.21	0.48	0.64	0.07	0.23	0.05	0	1.1	1	0	0	0.22	0.74
10	0.02	0.04	0.45	0	3.72	1.22	0.82	0.02	0.58	0.8	1.27	2.1	0	0	0.01	0.33	0.72	0
11	0.16	0	0.39	0.23	0.12	0.86	0.12	0	1.42	0.02	1.75	0.54	1	0.49	0.77	0.46	4.65	1.22
12	0	0.54	0.27	0.46	0.12	1.51	1.11	0.59	0.03	0.82	0.81	0.84	2.08	0.48	0.7	0.42	1.58	0.47
13	1.04	2.11	0.3	0	2.49	1.86	0.84	1.28	0.6	2.28	3.23	0.24	1.57	1.07	0.51	0.35	2.08	1.02
14	3.68	1.06	2	1.33	0.57	0.11	2.66	0.59	1.18	0.03	1.6	0.76	3.02	1.07	1.92	0	0.8	2.56
15	0.39	2.36	0.19	0.44	0.02	0.31	0.56	1.08	0.06	2.34	0.23	0.77	1.25	1.36	0.34	2.22	0.06	0.72
16	1.43	0.61	0.37	5.86	0.8	0	2.67	0.9	2.76	0	0	0.23	0.58	1.49	2.26	0.02	0	0.58
17	2.16	1.21	1.85	0.01	2.29	1.53	0.29	0.9	0	0.65	0	1.3	0.23	0.23	0	0.63	3.24	2.99
18	0.88	1.13	0.54	1.19	0	0.27	0.05	0.12	0.36	0.13	4.07	3.02	1.41	0.15	2.89	0.17	0	0.12
19	3.69	0.61	0.17	1.26	1.2	0.95	0.96	0.4	1.44	0.26	0.63	8	0.76	0	0.74	0.53	0.8	1.52
20	0.5	0.42	2.58	1.97	0	0.27	0.96	0.36	0.51	1.5	0.23	2.9	1.06	0.18	0.05	0.11	0.4	0
21	0.77	0.35	0.78	2.59	1.12	1.64	1.8	1.62	1.65	0.02	0.91	0.07	0.89	1.77	0.35	0	0.16	1
22	0.87	3.99	1.66	0.73	0	0.21	0.18	0.02	1.57	0.39	0.56	0.67	0	6.6	0	0.23	1.48	0.31
23	2.63	0.61	0.88	0.49	1.04	1.55	0.22	0.68	0.34	0.61	0.02	0.18	0.45	0.04	0	0	2.6	1.45
24	0.49	0.48	0.63	0.81	0.65	1.54	0.03	4.32	0.44	3.77	3.47	2.87	0.08	0	0.19	0.04	0.74	1.33
25	0.74	1.13	1.27	0.07	1.09	0.37	0.23	2.2	2.71	0.3	0.74	0.98	7.27	0.63	0.36	0.92	0.26	0.72
26	0.23	1.02	0.37	1.16	0.54	2.1	0.88	0.39	0.74	1.85	1.95	0.47	0.38	0.36	0.21	0.4	4.67	0
27	0.02	0.02	2.6	0.09	0.01	2.54	0	0	1.52	1.02	0.09	0.37	0.57	0.84	1.41	2.68	0.03	0.26
28	0.74	0.85	0	0.15	0.2	0.15	0	0.34	0.04	0.9	0.26	0.26	0.23	0.11	0.06	0.04	0	0.11
29	2.39	2.6	2.19	1.34	0.3	0.77	0.23	0.05	0.53	0.16	1.3	0	1.51	0.13	0.34	0	4.1	0.64
30	0	0	0	0	2.74	0.01	0	0.46	0	3.75	0	2.32	1.09	1.45	0.18	4.42	0.92	4.96
31	1.29	1.22	0.01	0.7	0.23	0.89	0	3.28	0	2.2	1.06	0.63	0.35	0.66	1.59	0.79	0	0.22
32	0.92	0	4.56	0.19	0.61	0.77	0.03	0.2	1.15	0	0.63	0.09	0.15	7.17	0	0.04	0.25	1.89
33	0	0	0	1.64	0	0.68	0.72	1.33	0	4.14	2.45	0.19	0.3	0	1.03	0	0.02	0.67
34	0.03	0	1.17	0	0.97	1.32	0.39	0	0.04	1.8	0.15	0	0	0.46	1.57	0.71	1.48	1.9
35	0	0.6	0	0.16	1.73	0.01	3.96	0	1.36	0.87	0.37	0	0.69	0	0.1	2.46	0	0.38
36	1.67	0.58	0	0	0.03	0.17	0.17	0.45	0.04	2.67	0.05	0.02	0.34	0.77	2.24	0.02	0	0.26
37	5.6	4.07	0.85	0	0.25	0.12	0.32	0.09	3.48	0.68	1.19	0.36	0	0	0.31	2.16	0.14	0.51
38	0.61	0	0	1.03	0.68	0	2.56	0.21	1.45	0.08	1.67	0	0	0	0.17	0.29	0	1.78
39	1.45	0.31	0.95	0.67	0	0.02	0.86	0.32	0.62	0	2.52	0	0.3	1.98	0.18	1	0.76	0.05
40	0.05	1.86	0.51	0	0.62	1.07	0.29	0	0.13	1.31	0.95	0.38	1.49	0	0.95	0.01	1	3.23
41	0.28	1.2	0	0	0.91	0.82	0	0.01	0.59	1.84	0.17	0.26	0.62	0.12	0.49	0.45	0	0.76
42	1.39	0.42	0.03	0.78	1.12	0.1	1.97	0	0.49	0.27	0.11	1.38	0	1.05	0.55	1.71	2.12	1.25
43	0.65	0.54	0	0	0.87	0.65	0.02	1.31	0.24	2.33	2.65	1.47	0.87	1.25	0.6	1.34	0.39	0
44	0	1.59	0.28	0.97	1.22	0.63	1.01	1.1	0.67	3.23	2.97	0.78	0.29	1.6	0.85	0.48	0.18	0.64
45	0.02	1.29	0.05	0.77	1.47	1.28	1.18	0.05	0	0.42	0.05	0.65	1.19	0.34	1.23	0.81	0	0.18
46	0.81	1.66	0.37	1.05	0.58	1.29	0.01	0.61	3.07	0.74	1.63	0.98	0.94	0.4	0.61	0.9	0.39	0.8
47	1.94	0.47	0.61	1.09	0.52	1.71	0	0	0.64	1.27	1.53	0.87	1.56	0.73	0.58	1.52	0.38	0.09
48	0.1	0.97	0.4	2.04	0.26	0.01	1.64	0.41	0	0.15	0	0.04	3.1	0.2	2.16	2.96	0.97	0.38
49	1.05	0.16	0.48	1.2	0.04	0.12	0.37	0.2	0.85	0.43	0.51	1.21	0.73	0	0	2.63	0.44	2.23
50	0.87	2.08	2.87	0	1.01	0.24	1.64	1.67	0.77	1.48	3.91	1.88	1.05	1.37	0.25	2.24	3.45	0.78
51	0.49	1.24	1.1	1.98	0.8	0	1.15	0.17	2.71	0.4	0.9	2.45	1.82	1.05	0	0.1	0.11	0.33
52	1.03	0.77	0.01	0.41	2.25	0	0.22	2.1	0.96	1.38	0.83	0.33	0.05	0	0	0.05	1.31	0.25

Appendix E
Precipitation Input (inches/week)

week	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	0.84	1.28	0.69	1.61	0.68	0.72	0.5	0.21	1.47	1.03	0.18	0.13	0	0	1.04	0.79	0.80	0.80
2	0.36	0.89	0.77	1.54	2.45	0.86	0.35	0.05	0.56	0.11	1.65	0.23	0	0.14	0.41	0.36	0.97	0.97
3	1.15	0.05	1.65	0.9	1.93	0.09	0.28	1.65	0.39	2.64	1.93	0.57	0.77	1.2	1.7	0.48	0.85	0.85
4	1.34	0.66	0.65	0.76	1.1	1.18	0.48	3.17	0.05	2.74	0.32	0.11	0.87	0.94	0.37	3.33	0.97	0.97
5	0.56	0	1.01	1.35	3.09	0	0	0.27	0.05	2.15	0.69	2.14	1.63	0.72	2.96	1.51	0.98	0.98
6	2.89	0.07	1.11	2.27	1.28	0.01	2.39	0.12	0.94	0.47	0.09	0.25	2.14	3.27	0.69	0.85	0.87	0.87
7	0.78	1.22	0	1.8	1.16	1.6	0.85	0.61	0.37	0.83	0.61	1.59	0	2.18	0.83	1.44	0.73	0.73
8	0.27	0.46	0.22	1.48	2.4	0.02	0	0.46	0.53	2.55	0.04	0	0.61	0.86	0.44	0.49	0.78	0.78
9	0.66	0.63	0.87	0.59	2.06	0.03	0.27	1.12	0.14	0.96	3.2	2.08	0.78	1.52	2.36	0	0.82	0.82
10	1.05	0.05	0.53	2.11	1.27	0.07	0	0.45	0.48	1.89	0.83	0.03	0.15	2.25	0.42	0.05	0.70	0.70
11	0.17	0.45	0.33	1.6	1.65	0.6	0.6	1.89	1.6	0.58	0.82	0.42	0.18	1.01	0.21	0	0.88	0.88
12	0.33	0.02	2.08	0.01	0	0.25	0.2	0.73	0.56	0.17	0.14	0.84	2.23	0.75	1.25	0.72	0.75	0.75
13	0	0.38	0.15	0.32	0.41	2.23	0	0.01	0.28	3.57	0.76	0.45	0.17	0.12	0	0.41	0.86	0.86
14	2.41	1.22	0	0.87	0.8	0.14	0.06	0.05	1.03	2.03	2.45	0.36	0.18	0.74	1.77	0.77	1.00	1.00
15	1.67	1.21	4.52	2.39	0	0.99	0.23	0.41	0.49	0.6	0.33	0	0.92	0.58	0.74	0.6	0.82	0.82
16	0.22	1.02	2.43	1.31	1.56	2.33	2.09	3.29	1.79	0	0.31	2.34	0.27	0.57	0.38	0.77	1.22	1.22
17	2.92	2.54	3.94	0.1	3.64	0.1	0.17	0.05	0.11	0.27	3.09	0.03	0.98	1.3	0.05	0.42	1.20	1.20
18	0	0.18	2.06	1.68	0	0.52	0.58	0.57	0.15	1.96	0.18	0.75	0.95	1.8	0.22	3.01	1.13	1.13
19	0.77	0.32	1.97	0	0.94	0.65	0	0.19	0.79	0.92	0.01	0	3.69	0.17	0.35	2.07	1.20	1.20
20	5.98	0.11	0.14	0.66	0.34	0.21	0	0.09	2.29	1.39	1.58	0.12	2.44	0.25	0.81	0.7	0.88	0.88
21	1.28	4.67	1.39	0.65	2.35	1.57	0.89	2.46	0.31	2.29	0.99	2.57	1.02	0	0.91	1.08	1.22	1.22
22	0.97	0.17	1.34	0.07	1.43	0.49	0.38	0.38	0.01	0.41	0.09	0	1.57	0.16	0.5	1.04	0.87	0.87
23	2.28	0.78	1.52	0	0.58	0.67	1.79	0.12	0.04	0.68	0	1.84	0.65	1.76	0.3	3.77	0.98	0.98
24	0.96	1.35	2.04	0.68	1.61	0.7	0.76	0.05	0.09	3.81	1.92	1.86	0	0.08	0.27	1.07	1.17	1.17
25	0.96	0.12	0.7	0.35	3.37	3.92	1.67	0.07	0.92	0.1	1.38	0.39	0.02	1.11	0.99	0.02	1.03	1.03
26	0.25	1.73	0.04	1.54	0.59	0.26	0.11	1.16	0.12	0.81	0	2.33	1.3	0.22	0.49	0.65	0.77	0.77
27	0.05	1.41	2.38	0.72	0.2	0.2	0.2	1.74	0.79	0	0.69	0.1	0.45	2.78	1.52	0.3	0.90	0.90
28	0.32	3.31	1.31	0	0.54	5.9	1.92	0.7	0	0.36	0.27	0.69	0.96	0.43	0.5	0.2	0.62	0.62
29	0	0.32	0	1.51	0	1.5	3.99	0.54	0.15	3.6	1.83	1.02	3.53	0.6	2.01	0	1.09	1.09
30	1.61	1.89	0.01	0.01	0.47	1.44	1.3	1.02	2.95	0.8	0.28	0.08	0.9	0.02	0.71	0.81	0.91	0.91
31	0	1.75	0	0	0.1	0	0.66	1.88	1.22	0.02	0.07	0.58	0.4	0.66	1.33	5.12	0.73	0.73
32	0.79	0.09	0.29	1.14	0.31	0.02	0.12	2.45	0.57	0.11	0.03	0	1.04	3.06	1.73	0.32	0.77	0.77
33	0.35	0	0.5	0.67	0	0.22	0.02	0.1	0.8	0.27	0.04	0	0	0	0	0	0.52	0.52
34	2.41	0.18	0.5	1.03	2.33	0	0	0	0.66	2.19	0.02	1	0.68	0.33	0.11	0.22	0.79	0.79
35	0.88	0.04	0.21	0.39	0	1.79	0	1.06	2.6	2.97	0.02	3.35	0.73	0	0.55	0.88	0.70	0.70
36	0.05	0	1.21	1.73	0	0	0.2	0.56	0.01	0	0.45	0.6	2.83	0.01	0.01	0.14	0.61	0.61
37	0.47	0.62	0.06	0.8	0.64	0.19	0.71	0.03	0	0	3.15	0	0.32	0.77	0.42	3.3	0.81	0.81
38	0.82	2.12	2.68	2.22	0.04	0.38	0.8	0	1.31	2.46	4.75	0.98	0	0.13	4.85	1.28	0.92	0.92
39	0.34	0.31	0.95	0.2	0.1	5.19	0.18	2.07	3.38	0.04	1.22	0	0.13	0.68	0.61	1.78	0.79	0.79
40	0.36	0	1.26	0.71	0.58	0.7	0.82	0	0.29	1.17	0	0.02	2.58	2.6	0.47	1.01	0.73	0.73
41	0.11	0.26	1.22	0.06	0.07	1.49	0.41	0.05	1.75	1.56	1.14	0.72	0.79	0	2.85	0.83	0.80	0.80
42	0.29	0.1	3.22	0.14	5.58	0.56	0.37	0.3	0.5	0.05	0	1.22	0.01	0.07	1.64	0.83	0.82	0.82
43	0.19	1.04	1.17	2.03	1.75	0.36	2.21	1.27	1.26	0.04	0.18	1.28	0.04	1.14	0	0.83	0.77	0.77
44	0	2.26	2.11	1.34	0	0.8	0	0	0	1.58	0.05	1.73	3.38	1.09	0.51	0.99	0.94	0.94
45	2.29	1.44	1.78	0.04	0.82	1.04	0.44	0.32	2.12	0.42	0.59	0.01	1.01	0.21	0.17	0.99	0.76	0.76
46	1.24	0.02	1.24	0.17	0	0.08	0.87	0.02	0.74	0.07	0.06	1.22	0.69	0.41	1.39	0.99	0.75	0.75
47	2.1	0.97	0.87	0	0	1.99	1.6	0.01	0.1	1.1	0.48	0.59	1.35	0.16	0.41	0.99	0.82	0.82
48	0.2	0.77	0.69	0.01	3.99	1.16	1.46	1.28	0.44	0.81	1.56	0.75	0.59	0.48	0	0.93	1.00	1.00
49	0.01	1.33	0.05	2.59	0.02	0	0.18	0.87	0.34	1.02	1.82	3.56	0.99	0.3	0.15	0.93	0.86	0.86
50	0.66	1.52	0.92	1.39	0.51	0.33	1.86	0.28	0.73	0.02	2.29	0.18	2.17	0.9	1.38	0.93	0.96	0.96
51	0.32	0	0.15	0.26	0.07	0.69	2.87	0.61	0	0.78	0.98	0	0.33	0.64	2.08	0.93	0.86	0.86
52	0.65	1.36	1.66	0.63	3.02	0.13	0.02	0.54	0	0.59	0	1	1.74	0.03	0.61	0.93	0.82	0.82

Appendix E
Precipitation Input (inches/week)