University of Nevada

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Dendrochronologic Reconstruction of Water Levels for Pyramid Lake, Nevada

1745 to 1904 A.D.

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science
in Hydrogeology

by

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1.0 ABSTRACT

The objective of this study is to reconstruct a lake level hydrograph of Pyramid Lake, Nevada over the period of 1745 to 1904 by using tree-ring widths.

Validation of the model reproduced the observed elevations of the lake to within five percent using observed inflows, and to within twenty percent using tree-ring generated inflows.

Modeling the lake between 1745 and 1904 indicates the fluctuations of the lake were relatively subdued, with the maximum range in elevation being only sixteen feet. It is expected from various limitations within the model that this range of elevation should be twenty-five to fifty percent greater. The mean elevation of the lake in this period is the spill elevation of 3863 feet. This mean elevation would largely be determined by the average long term climatic conditions which the tree-ring data suggest were fairly stable.

2.0 ACKNOWLEDGMENTS

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3.0 INTRODUCTION

The objective of this study is to reconstruct the history of the surface elevation fluctuations of Pyramid Lake, Nevada prior to the scattered written records that begin in 1844, as well as the complete records which begin in 1932. To achieve this a correlation has been developed between the annual streamflow of the Truckee River and the annual growth-ring in drought sensitive trees. This tree-ring generated streamflow has been used as input to a mathematical model of Truckee River-Pyramid Lake.

The Truckee River (Figure 1) drains a large area of the east flank of the Sierra Nevadas as well as a portion of the western Great Basin. Precipitation over the area rapidly decreases from west to east because of orographic and rain shadow effects. For instance, the Truckee Ranger Station (No. 10, Figure 1) on the western edge of the basin, receives an average of 2.70 feet of water per year, while at Nixon, Nevada, (No. 1, Figure 1) the average precipitation is only 0.59 feet. Most of the flow of the Truckee River comes from the winter snows on the Sierra Nevadas.

The present terminus of the Truckee River system is Pyramid Lake. Prior to the completion in 1903 of the Truckee Canal (No. 6, Figure 1) as part of the Newlands Project, Pyramid Lake would periodically rise above the lip of its basin, at 3863 feet, and overflow into Winnemucca Lake through Winnemucca (Mud) Slough (near Nixon, No.1, Figure 1).

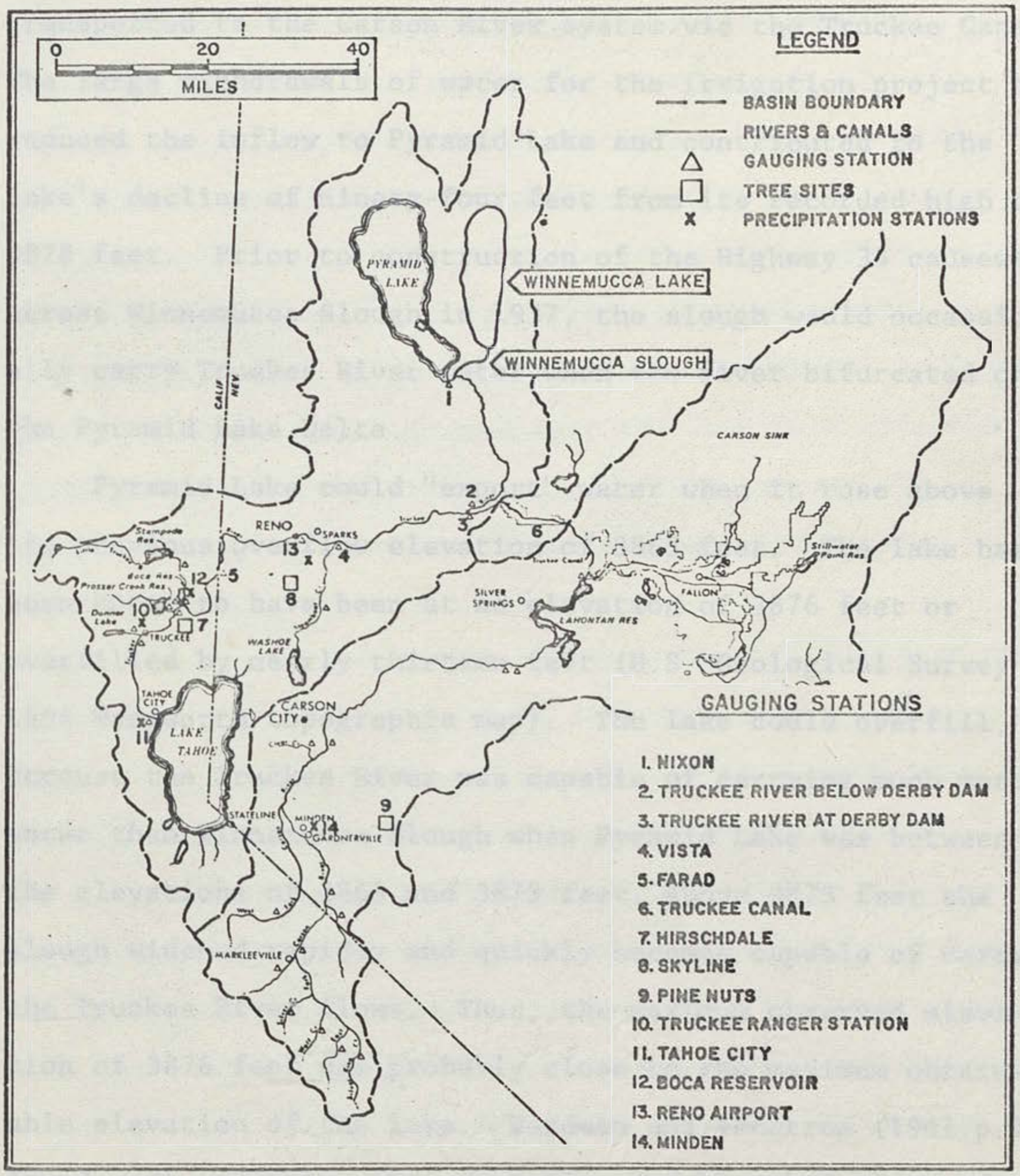


FIGURE 1. Truckee and Carson River System

adapted from BATEMAN, ET AL (1976)

The Newlands Project is an irrigation project which has brought under cultivation thousands of acres of desert surrounding Fallon, Nevada. A large portion of the water used by this project is diverted from the Truckee River at Derby Dam and transported to the Carson River system via the Truckee Canal. The large withdrawals of water for the irrigation project has reduced the inflow to Pyramid Lake and contributed to the lake's decline of ninety-four feet from its recorded high of 3878 feet. Prior to construction of the Highway 34 causeway across Winnemucca Slough in 1937, the slough would occassionally carry Truckee River water when the river bifurcated on the Pyramid Lake Delta.

Pyramid Lake could "export" water when it rose above its previous overflow elevation of 3863 feet. The lake has been known to have been at an elevation of 3876 feet or overfilled by nearly thirteen feet (U.S. Geological Survey 1894 Wadsworth topographic map). The lake could overfill, because the Truckee River was capable of carrying much more water than Winnemucca Slough when Pyramid Lake was between the elevations of 3863 and 3873 feet. Above 3873 feet the slough widened rapidly and quickly becomes capable of carrying the Truckee River flows. Thus, the maximum observed elevation of 3876 feet was probably close to the maximum obtainable elevation of the lake. Hardman and Venstrom (1941, p.77) found upon examining the vegetation and bleached algae around Winnemucca Lake that the lake "has not exceeded a level of about 3855 feet in recent years". This is eight feet below the lip of the slough. Based upon the same lines of evidence, as well as photographs taken by Russell in 1882 they found "the highest recent elevation of Pyramid Lake was not greater than 3879 feet" (1941, p. 75). It is apparent from Hardman and Venstrom's observations that Winnemucca Lake had not filled up and therefore would have been an infinite sink for any water spilled from Pyramid Lake. Thus, Pyramid was free to establish a mean elevation that is not influenced by Winnemucca Lake. This mean elevation would apply as long as the long term climatic conditions remained stable.

The stability of the climate is a fundamental assumption of this study. It is assumed that the long term climatic conditions which have existed during this century are representative of the conditions which occurred during the period to be reconstructed.

It is known that during the last ice age, about 10,000 years ago, the climate was much different than today because both Pyramid and Winnemucca Lakes were only a small part of Lake Lahonton which covered much of the western Great Basin. There have probably been similar, though smaller magnitude wet periods since this last glacial period, but their frequency and severity are unknown. The tree-ring data, plotted in Appendix A, gives some climatic information about the last 450 years. These data show no major long term changes in the rate of growth of the trees from 1745 to 1972. This implies that the climatic conditions were relatively stable from 1745 through 1972. (The correlation between tree growth and precipitation will be discussed later). Thus, it is realistic to make the assumption that the mean climatic conditions have been stable over the past 232 years. Prior to 1745, the Skyline chronology suggests a rather radically changing climate existed, but the Hirschdale chronology does not show the same magnitude of shifts.

Virtually all water that enters these two terminal lakes is ultimately evaporated. Harding (1962) has determined the average evaporation rate for Pyramid Lake to be 4.02 feet per year per acre of surface area. This evaporation rate can be used in conjunction with the U.S. Geological Survey's surface area-elevation rating table for Pyramid Lake to compute the average volume of water that has evaporated. Thus, all of the components are available for developing a mathematical model to compute changes in the lake surface elevation as a function of inflow, evaporation, and overflow.

A tree-ring generated synthetic inflow to the lake can be developed from correlations between tree growth and annual runoff. A regression analysis of the tree-ring widths and runoff volumes gives an equation which allows the tree-rings to be used in the model to generate statistically likely inflows.

This model can be used to reconstruct the fluctuations of Pyramid Lake surface elevation to an accuracy that is largely determined by the statistical correlation between annual growth-ring widths and precipitation.

4.0 DENDROCHRONOLOGY

The methodology used for the interpretation of tree-rings in drought sensitive trees from the Southwest and their conversion into a time series chronology, as well as a growth chronology, has been presented by Schulman (1945b) and others. A short summary of the process is given here.

Most of the growth of the cambrian layer, the wood just under the bark, usually takes place in May, June, and July in the Southwestern United States (Schulman, 1945a, p. 63). The three month period produces the light colored part of a tree-ring or spring wood and is characterized by large, but thin walled cells. The dark colored part of the ring or summer wood has smaller, thicker walled cells (Stallings, 1960, p. 4). The spring wood is the period of rapid growth of the tree and is usually the major part of the ring.

The width of a tree-ring is controlled by the local environment: the length of the growing season, as determined by the temperature; nutrients in the soil; hours of sunlight; and availability of moisture. If one or more of the environmental factors is reduced below normal levels the width of a ring will be less than optimum for that year. The growing season stops when an environmental factor falls below its critical lower limit.

In the forests at the highest latitudes and at the upper timberline, temperature has been found to be the critical factor for tree growth. In this environment moisture is usually in abundant supply from the deep snow packs, but the season is short and cold.

In middle zones, Schulman has found the chronologies (width of the tree-rings versus time) tend to have similar size rings, because only rarely will the supply of any one component become short enough to slow growth and it may not be the same factor from year to year.

Only near the lower limit of the forest can a strong correlation of tree-ring growth to precipitation (or streamflow) be found. The growth of the drought-sensitive trees will not show a perfect correlation because: (1) the growth in any particular year could be controlled by the other environmental factors (for instance, a deep snow pack would provide a good water supply but it might be too cold to allow full growth); (2) a difference in the precipitation that fell at the metorological stations and at the trees due to distance between sites, elevation, exposure, slope, etc.; (3) the carryover effects of excess or deficient soil moisture from preceeding years; (4) a difference in the months when precipitation occurred and the growth of the trees took place (for instance, late summer rains affect the growth of a tree as a soil moisture residual carried over for the next year's growth); and (5) the incomplete elimination from the ring chronologies of local effects, such as release from suppression by other trees, insect injury, erosion, deposition of soil, fire, lightning injuries, etc. (Schulman, 1945a, p. 30).

In addition to studying trees at the dry, lower boundary of the forest, Schulman found by trial and error that drought sensitivity could be enhanced by choosing trees that: 1) were long-lived conifers of non-erratic growth characteristics; and 2) grew on steep slopes underlain by pervious rock and soil so that moisture conservation would not affect the next year's growth (Schulman, 1945a, pp. 62, 64).

Two erratic growth characteristics of many trees are locally absent rings and false rings. A locally absent ring is caused by an environmental stress so severe that a patch of the cambrian layer within the tree does not grow at all that year. If the core sample, from which the chronology is made, happens to pass through one of these zones there is a missing ring. These can be located only with other chronologies and matching growth patterns. A false ring is a one season growth that goes from early wood to late wood and then repeats itself. These are most easily identified by crossdating and can be recognized in the wood by the fact that the first late wood grades back into the next early wood without the usual sharp break. The false ring is caused by a slowing of growth early in the season, then a reactivation of rapid growth.

The trees in the present study as well as most of the studies cited here were sampled using a Swedish Increment

Borer which only extracts a small core from each tree. The trees were bored on a side perpendicular to the downhill direction of the slope to eliminate the distortion a tree undergoes as it bends and grows upright. The cores were dried, then glued to a slotted lath to give the fragile core support. The cores were then sanded to a flat, smooth finish on the exposed face. This facilitates accurate measuring of the rings.

In order to use the tree-ring series for dating and reconstruction purposes a chronology must first be built. First, each core must be crossdated by accurately checking each one against the others for false or missing rings. To facilitate this, a skeleton plot is first made. The plots are made from long strips of graph paper with the horizontal scale representing time in years and the vertical scale reflecting the tree-ring thickness. It has been found that the narrower ring patterns can be more easily recognized than the average, or thick rings. To facilitate the recognition of the patterns on the skeleton plot a thick vertical line is marked on the skeleton plot for each narrow ring such that, subjectively, the narrower the ring the longer the line. Average and overaverage rings are ignored except to mark a "B" (by convention) for those rings that are unusually thick. This process eliminates the tree-ring thickness from the horizontal scale and allows two plots to be slid past one another to match up the thickness patterns on the vertical scale year by year.

When matches are formed in some sections, but are displaced a year or more in other sections, false and missing rings are looked for inbetween. When a match can be made down the entire length of all plots, allowing for recognized false and missing rings, all plots may be dated starting from the known date of the outer ring under the bark.

As a tree grows, the mean tree-ring width becomes smaller, which means the early growth of a tree cannot be directly compared to its later growth. In order to use the tree-rings for reconstruction purposes this individual age trend must be eliminated. This trend is removed by fitting an exponential equation of the type

$$Y_t = ae^{-bt} + k \qquad (1)$$

where

Y_t is the observed ring width

t is time in years

a,b,k are positive constants determined by a least squares fit of the measured ring widths (Fritts, Mosimann, and Bottoroff, 1968).

Indicies of growth can be calculated using an equation of the form

$$I_t = (Y_t / \bar{Y}_t)\ 100 \qquad (2)$$

where

Y_t and t are as in equation 1

I_t equals the calculated index

$\bar{Y}_t$ is the expected mean growth as predicted by the equation 1 at time, t.

Thus, each tree-ring can be converted to a percent of the mean growth such that anything between 0 and 100 is less than mean growth, and anything above 100 exceeds the mean growth.

An average chronology can be established for a given type of tree or locality by averaging all of the tree-ring indices of growth from all of the trees within the category to provide a single master time series plot or chronology. This chronology is the most useful for correlation studies because it tends to average out any unusual growth patterns of a single tree.

In the present study twenty-four trees were sampled by Professor Alfred Cunningham and Dr. Richard Bateman of the Water Resources Center between 1972 and 1973. The laboratory of Tree-Ring Research at the University of Arizona analyzed the cores, crossdated the samples, computed the indicies of growth, and developed the following three chronologies by the methods described above.

The trees were sampled in three areas, as shown on Figure 1. The Hirschdale chronology consists of six Pinus ponderosa (yellow pines) from an elevation of 5600 feet near Hirschdale, California above the Truckee River. The Skyline set is made up of seven yellow pines from 4800 feet on the lower slopes of the Carson Range above Skyline Boulevard, Reno, Nevada. The last set is nine Pinus monophylla (pinyon pines) from an elevation of 4300 feet in the Pine Nut Range east of Gardnerville, Nevada.

5.0 DENDROHYDROLOGY

Stockton (1971, p.89-93) has expressed the theory of the relationship of tree-ring growth and runoff to climate in some detail. The following is a summary of his discussion.

The underlying assumptions in relating tree-ring growth to runoff are: 1) the precipitation which falls on the soil must satisfy any soil moisture deficit before substantial runoff can occur, and 2) the growth of the trees responds to the availability of soil moisture more closely than any other environmental factor.

The climatic and hydrologic factors that affect runoff and tree growth are precipitation, evaporation, and changes in soil moisture. Precipitation is obviously the dominant factor in controlling the volume of runoff. However, when a soil moisture storage deficit exists there will be little runoff unless the storm is very intense. Under the conditions of a soil moisture deficit the growth of the trees will similarly be retarded. The form of precipitation is important particularly if snow accumulates to great depth. Evaporation of any water after it has landed on the ground and foliage reduces not only the runoff but the water available for infiltration. Furthermore, during periods of high evaporation, the accelerated rate of transpiration will increase the draw upon the soil moisture. This in turn will increase infiltration as well as reduce ground water outflow.

It is apparent that both the tree growth and the runoff are similarly affected by the precipitation which represents a positive component, and evaporation and transpiration representing negative components. The soil moisture storage is usually considered to be negligible when water years are used (Stockton, 1971).

6.0 PREVIOUS INVESTIGATIONS

The first attempt to determine a relationship between streamflow and tree-rings is thought to have been done by Kapteyn in the year 1880 (Kapteyn, 1914, cited by Stockton, 1971). Hardman and Reil (1936) were the first to try to extend the hydrologic record based on tree-rings. They collected their samples from the Truckee River Basin. Hardman and Reil recognized that there were probably carryover effects on runoff from the preceeding years precipitation. This would include retarding effects on the ground water component of flow. They smoothed the data with a five year moving average in order to integrate the effects of the preceeding and following years runoff (Table 1). The authors were primarily interested in trends, so they placed the smoothed value in the middle of the group.

Hardman and Reil (1936) ran correlations of tree-rings with six of the major rivers in the area (Table 1). Interestingly, the Feather and American Rivers have the same level of correlation as the Truckee River although they lie on opposite flanks of the mountains. Presumably this is caused by the head waters lying on either side of a common ridge. Hardman and Reil (1936, p. 24) found a poor visual correlation of the water year precipitation from six stations on the west side of the Sierra Nevadas with the combined indices of forty-six trees on the east side. This is

TABLE 1

Runoff Correlations, Past Studies

Tree Index*	Correlated With	Remarks	# of Trees	Done by	Time Base	# of Years	r un-smoothed	r smoothed
T.R.B.	Truckee River	Same Basin	46	Hardman & Reil, 1936	Oct-Sept.	26	-	0.89[5]
"	Feather River	Trees on east side of Sierra Nevada Mtns. and the Rivers on west side	46	" "	Oct-Sept.	25	-	0.89[5]
"	American River		46	" "	Oct-Sept.	22	-	0.89[5]
	Mokelumne River		46	" "	Oct-Sept.	22	-	0.82[5]
	Tuolumne River		46	" "	Oct-Sept.	31	-	0.73[5]
	Yuba River		46	" "	Oct-Sept.	24	-	0.79[5]
	Bear River		46	" "	Oct-Sept.	22	-	0.54[5]
E.O.	Columbia River		340	Keen, 1937	Oct-Sept.	57	0.56	-
M.V.	Animas River		?	Schulman, 1945a	Oct-Sept.	47	0.73	-
S.J.	Kings River		6	"	Oct-Sept.	47	0.59	-
"	San Gabriel R.		6	"	Oct-Sept.	46	0.57	-
C.R.B.	Lees Ferry Flow	Comp.of tree indices	109	Schulman, 1945b	Oct-Sept.	94	0.66	0.81[4]
B.S.	Kings River	From 6 sub-basins	60	Schulman, 1947	July-June	94	0.52	0.62[1]
"	" "		60	"	July-June	94	0.52	0.64[4]
"	San Gabriel R.		60	"	July-June	49	0.61	0.81[1]
"	" "		60	"	July-June	49	0.61	0.79[2]
"	" "		60	"	July-June	49	0.61	0.87[3]
"	" "		60	"	July-June	49	0.61	0.86[4]

1) $b' = (a+b)/2$ 2) $b' = (a+2b)/3$ 3) $b' = (a+b+c)/3$ 4) $b' = (a+2b+c)/4$ 5) $f' = (d+e+f+g+h)/5$

where b' and f' = one years index; a,d,and e = preceding years indices; and c,g,and h = following years indices.

* T.R.B.-Truckee River Basin; E.O.-Eastern Oregon; M.V.-Mesa Verde; S.J.-San Jacinto; C.R.B.-Colorado River Basin; B.S.-Big Cone Spruce

probably caused by the physiographic location of the precipitation stations, which are well west of the trees and separated from them by the crest of the mountains. The amount of precipitation east of the mountains is substantially less than on the west, because the vast majority of the storms approach from the west-which places the trees in the "rain shadow" of the mountains.

Keen (1937) studied the relationship of precipitation and tree growth in eastern Oregon to determine if the recession of the tree line up the mountains was climatically controlled (Table 2). He examined the tree-ring widths in an attempt to extend the precipitation and streamflow records. From these records he hoped to determine if there had been a shift in the weather pattern. He found the best correlation (0.82) for the historic period by using smoothed precipitation data (b^1=(a+b), b= one years data, a=the preceeding year's, and b^1=the smoothed data; Table 1). Keen concluded this indicated a strong influence on one year's growth by the preceeding year's precipitation. The unsmoothed precipitation and tree-ring growth gave a correlation of 0.50. In the case of the correlation of precipitation to streamflow, Keen found a correlation coefficient of 0.56 without smoothing. He did not give a smoothed equivalent.

Schulman (1945a, 1945b, 1947, and 1951), tried to determine the degree of correlation that could be expected between streamflow, precipitation, and tree-rings for

TABLE 2

Precipitation Correlations, Past Studies

Tree Index*	Correlated With	Remarks	# of Trees	Done by	Time Base	# of Years	r unsmoothed or quality	r smoothed
Truckee R. Basin	6 Western Sierra Stations	Trees on east side	46	Hardman & Reil,1936	Oct-Sept	64	poor	-
Eastern Oregon	Eastern Oregon	----	340	Keen,1937	Oct-Sept	66	0.50	0.82[1]
Mesa Verde	Durango	(Arizona)	?	Schulman, 1945a	Oct-June	48	0.78	-
Okanogan	Okanogan	(Wash.)	26	"	Oct-June	32	0.57	-
So.Calif.	San Diego	----	6	"	July-June	91	0.44	-
Bigcone Spruce	S. Coast Rainfall	----	60	Schulman, 1947	July-June	94	0.65	0.82[2]
Bigcone Spruce	S. Coast Rainfall	----	60	"	July-June	94	0.65	0.85[3]
Fox Mtn.	Jewett	----	10	Stockton, 1971	Oct-Sept	38	-	0.89
Alpine	Jewett	----	20		Oct-Sept	38	-	0.82
Luna	Jewett	----	10	"	Oct-Sept	38	-	0.89
Tularosa Divide	Jewett	----	10	"	Oct-Sept	38	-	0.95
Rainy Mesa	Reserve	----	10	"	Oct-Sept	38	-	0.85

1) $b' = (a+b)$; 2) $b' = (a+b)/2$; 3) $b' = (a+2b+c)/4$; b = one years index, a = the preceding years

c = the following years index; b' = the smoothed index several areas of the West (Tables 1 and 2). His 1945a paper was a review of the available literature and a reconnaissance level sampling of trees from various areas to determine if a significant correlation between precipitation and runoff could be established. In general, he found significant visual correlations, but he did not give correlation coefficients as he did in later papers.

Schulman's Colorado River basin study (1945b) used sets of trees from many sub-basins to establish correlations with streamflow for each sub-basin. Each sub-basin was then weighted and integrated into one chronology for the entire basin. The reconstructed streamflow from this chronology was then checked against the streamflow at Lee's Ferry.

In southern California, in a similar investigation, Schulman (1947) sampled bigcone spruce trees in the coast ranges. He correlated the spruce's growth to flows of the San Gabriel River from the San Gabriel Mountains and also for the King's River in the southern Sierra Nevadas. He used precipitation stations from over the entire area but most were not in the mountains (Table 2). The correlations (Table 1) to the King's River are lower than those for the San Gabriel Mountains. This is understandable, because the trees are located within the San Gabriel Mountains and quite removed from the King River. Schulman also found that the correlation of the water year (October-September) precipitation to bigcone spruce, r=0.85, is best with a three year moving average (b' = (a+2b+c)/4; b= one year's index, a= the previous years, c= the following years, and b'= the smoothed index). A two year average (b'= (a+b)/2) gave only a slightly lower correlation coefficient of r=0.82 and the unsmoothed correlation was lower still at r= 0.71 (Table 2). Schulman believes this to indicate that there is a cumulative effect of precipitation on growth that lasts for more than one season. The correlation coefficients of tree-rings to streamflow are r= 0.86, and 0.81 for the respective smoothing schemes and 0.61 for the unsmoothed data (See Table 1).

In a paper in 1951, Schulman points out that rivers which are subject to flash floods, such as the Gila River in Arizona, have a much lower correlation between tree-rings and runoff than do the rivers that are dominated by springtime snowmelt runoff.

Stockton (1971, p.8) reports that Potts (1962) in an unpublished paper attempted

> to use the time distribution of tree-ring series to improve the estimates of drought recurrences in the upper South Platte River Basin in Colorado. As Water Rights Engineer for the Denver Water Department, he hoped to predict or at least improve the advance estimate of runoff of the South Platte River, which provides the water supply for the city of Denver. His objective was to estimate the storage required to provide a firm water supply for the city. Consequently, the ring-width series were used subjectively in determination of reservoir storage requirements.

Gatewood, Wilson, Thomas, and Kester (1964) used Schulman's published data to test whether a fifty year base period (1904-1953) was representative of the runoff in the Southwest for the last 154 years. They concluded that the mean runoff in the 1904-1953 period closely approximated the mean runoff of the last 154 years, 1800-1953.

Stockton (1971) collected tree-ring samples from the Bright Angel Creek watershed on the Colorado River in Arizona and the Upper San Francisco River watershed on the Gila River near the Arizona-New Mexico border. These data, along with the records of precipitation, temperature, and runoff from nearby stations were analyzed statistically by correlation analysis to test whether one value depends strongly on the preceeding value, and spectral analysis was used to identify the frequencies of the various cycles in the data. In addition, he used cross spectral analysis to test the correlation between the two series at each frequency defined above, and analysis of variance of components to give the percent of the total variance that can be ascribed to four sources of variance in the tree-ring width data. Principle component analysis was used to transform the data into orthogonal eigenvectors for use in analyzing the significance of each component used in the multiple linear regression which gives the reconstruction equation.

Fritts, Smith, and Stokes (1965) have shown by use of a physiological model of trees that the most probable climatic season affecting growth is a fourteen-month period from the June preceeding the growth of an annual tree-ring through the July of the year that the growth takes place (Stockton, 1971, p. 96). Stockton (1971, p. 109) used this period of time for his correlations of precipitation and temperature to growth and found that it gave only a ten percent improvement over a water year (October-September) time base. He concluded that this improvement did not justify the work involved in making the additional computations (Stockton, 1971, p. 109). The correlations of runoff and precipitation with tree-rings in his study are shown in Tables 1 and 2. He has used much more sophisticated statistical methods to improve his correlation, which tends to increase his r values relative to the techniques used by the other workers.

Stockton concludes from his study that dendrohydrology holds great promise, but that it is dependent on carefully selected trees, growing in basins that cause sufficient environmental stress to reflect the hydrologic conditions. Furthermore, each basin must be studied separately, with the equations from one basin having no applicability in any other.

A recent paper on dendrohydrology is by Stockton and Fritts (1973). They attempt to correlate tree-ring width data from six sites along the natural levees of the river channels in the Lake Athabasca Delta of Alberta, Canada, with the 1935-1967 observed lake levels. They were attempting to see if the closure of the W.C.A. Bennett

Dam on one of the main tributaries had significantly affected Lake Athabasca. They found a negative correlation of tree growth to lake levels, which they ascribed to higher river stages when the lake was high. This caused saturation of the root systems of the trees which slowed growth. They worked with three time periods for each year, May 21-30, July 11-20, and September 21-30 corresponding to the times when the lake level was rising, full, and falling. They concluded that the drop in lake levels since closure of the dam upstream has been caused in part by climatic fluctuation, but also by the impoundment of the water at the dam.

7.0 PRESENT INVESTIGATIONS

Due to the yearly growth cycle of the trees, an October through the following September water year is considered by Stockton (1971) to be the most satisfactory time base for dendrohydrology. Thus, the maximum resolution of any tree-ring reconstructed streamflow event will be one year. All precipitation and streamflow records in this paper are in water years with the water year dated in the January-September period.

7.1 INDICES OF PRECIPITATION AND RUNOFF

For use in this paper all precipitation records and streamflow records have been converted to indices by using Equation 2

$$I_t = (Y_t/\bar{Y}_t)100$$

where

t equals the water year (October through the following September)

I_t equals the index of precipitation or flow for year t, dimensionless

Y_t equals the depth of precipitation or volume of flow at year t, vertical feet per acre per year or acre feet per year

$\bar{Y}$ equals the mean of the data, acre feet per year.

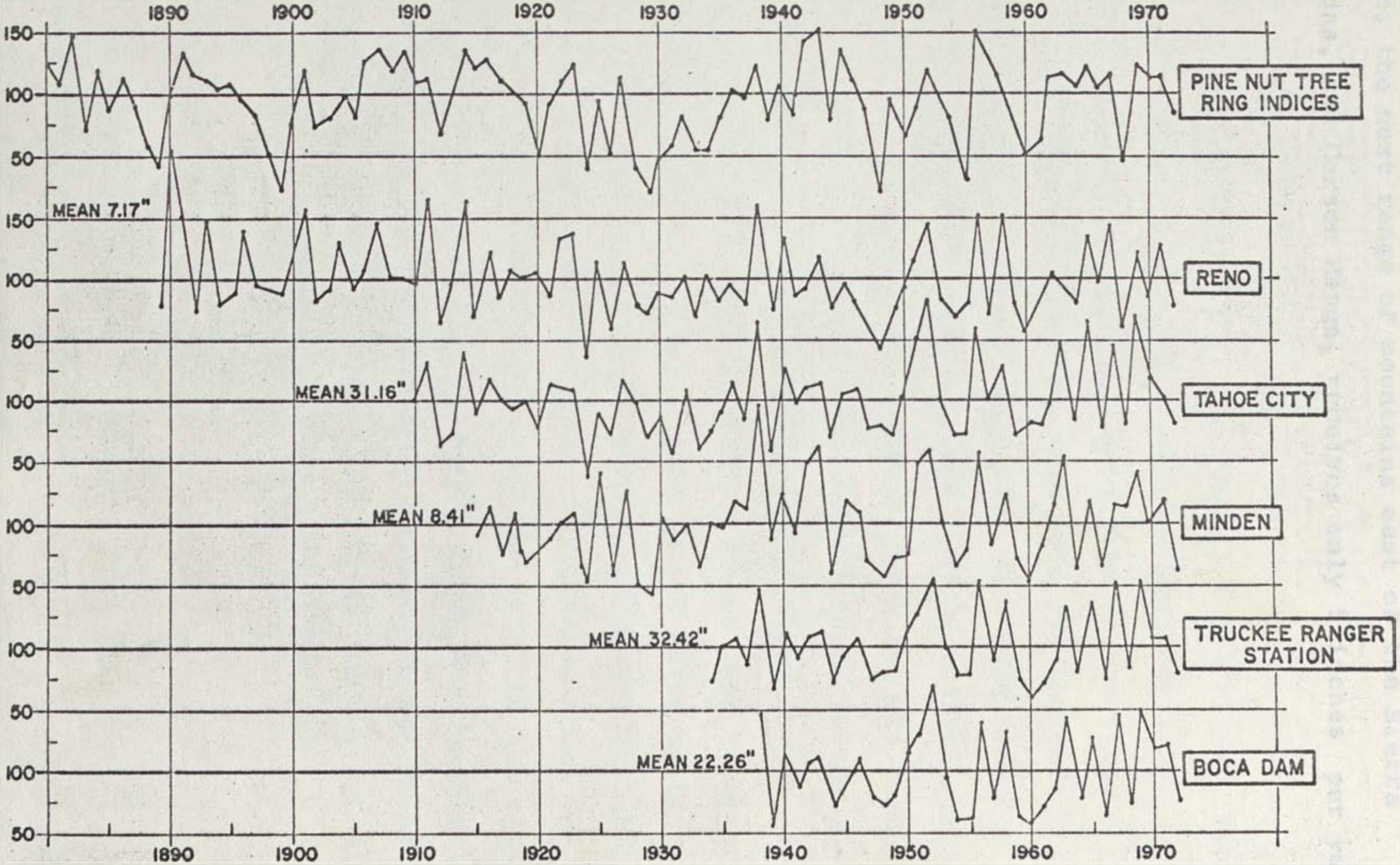
Using the data in this form facilitates interpretation of plots of the data, because all curves are plotted to the same scale. Furthermore, by having both the tree-rings and flows as indices it simplifies the reconstruction equation developed from the linear regression.

7.2 PRECIPITATION RECORDS

Five relatively long term precipitation stations in proximity to the tree sites, are shown in Figure 1. Their records, shown in Figure 2, were chosen because they represent the range of conditions in the vicinity of the trees. The average precipitation decreases very rapidly as one goes from 2.70 feet at the Truckee Ranger Station to 0.64 feet at Reno, a distance of 24 miles with an elevation loss of only 1329 feet (Figure 1 and Plate 1). This dramatic drop in precipitation is caused by the drying of the air masses as they move from west to east across the Sierra Nevadas. This "rain shadow" is caused by the cooling of the air masses as they rise up the west flank of the mountains. The cooling of the air brings it to saturation and results in precipitation. When the air mass decends the eastern slope, the air is warmed by compression, which results in a loss of saturation and a reduction in the amount of precipitation which falls on the east side of the mountains. The effect of the "rain shadow" is to have high precipitation near the crest of the ridge, i.e. Truckee Ranger Station, with less occurring the further away one is from the crest of the ridge on the leeward side, i.e. towards Reno. There is approximately 15 inches of precipitation at the Hirschdale tree site as compared to the 10 inches at the Skyline site.

PRECIPITATION INDICES AND PINE NUT TREE INDICES

FIGURE 2



The Pine Nuts site, which is located on the Pine Nut Range, the next range of mountains east of the Sierra Nevadas, and Carson Range, receives only 5 inches per year.

7.3 RUNOFF RECORDS

7.3.1 Nixon

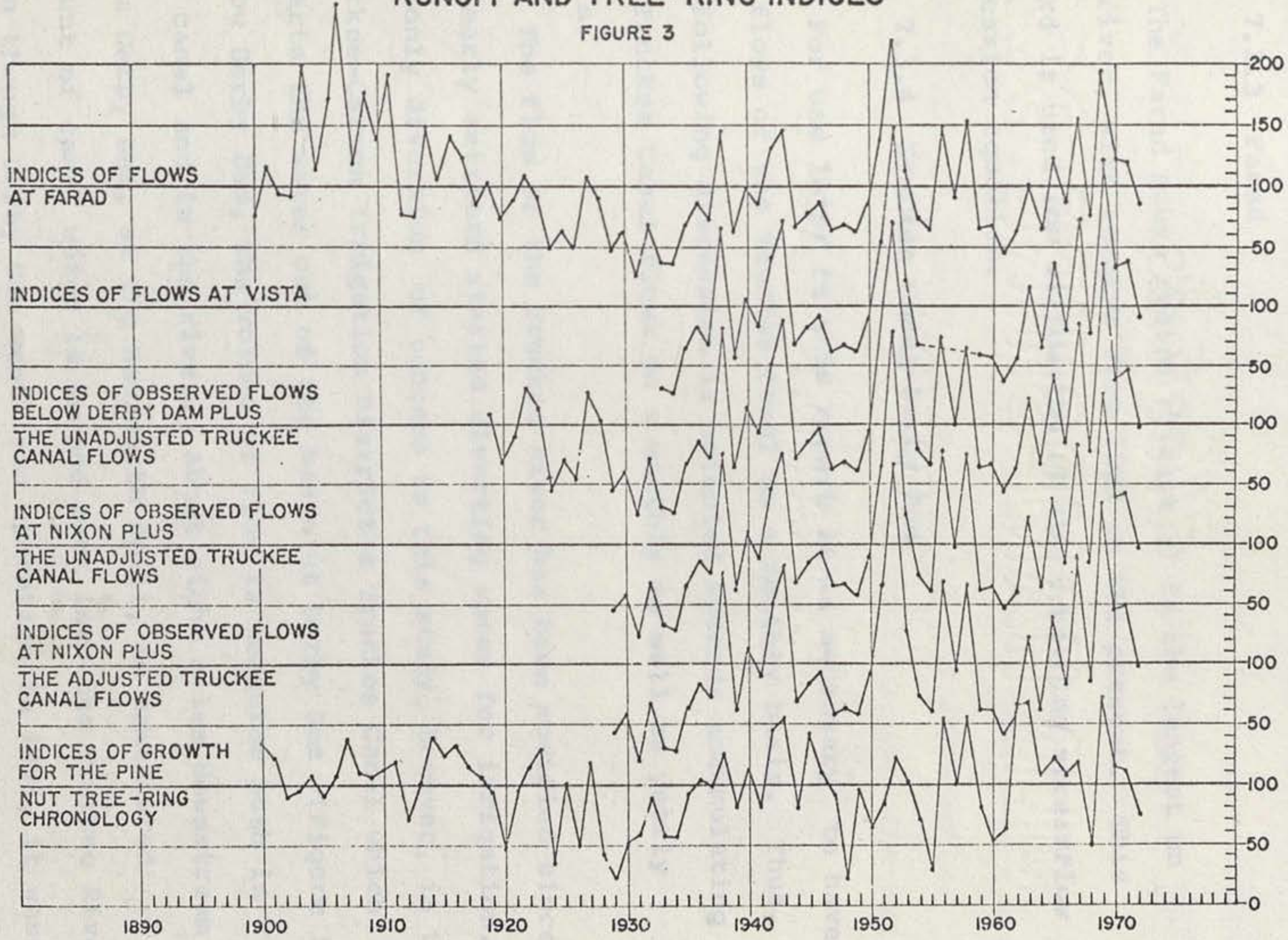
The observed flows at Nixon, Nevada on the Truckee River have been recorded by the Federal Water Master, Reno, Nevada office, between October 1928 and December 1957 (Appendix B). These records are on file in the Water Master's office, Reno, Nevada. The 1955 readings are not complete, therefore, flows below Derby Dam were used for that year. From October, 1957, the U.S. Geological Survey has operated a gauge about two miles above the old site. Data from the new site have been adjusted back to the old site by subtracting the recorded monthly flows in the Bureau of Indian Affairs-Nixon Ditch, which lies in between. The records of these flows are also in the Water Master's office. The diversion records are not accurate, but this does not cause a serious problem. While these flows represent a substantial proportion of the water in the river in low flow summer months, the summer flows are usually a small portion of the yearly flow. Figure 3, which shows a plot of the Nixon plus Truckee Canal flows, approximates the streamflow record if the Truckee Canal had not been built.

7.3.2 Vista

Streamflow records at Vista have been used for determining the average monthly hydrograph in the Pyramid

RUNOFF AND TREE-RING INDICES

FIGURE 3



Lake model. This record runs from January 1933 to December 1955 and from October 1958 to the present (Figure 3). The missing data were not recorded.

7.3.3 Farad

The Farad gauge record (Figure 3) is the longest on the river, with records from 1900 to the present. This record is used for validation of the tree-ring streamflow regression equation.

7.3.4 Truckee Canal-Derby Dam

For use later in this report it is necessary to have the flows of the Truckee Canal on a monthly basis. Thus, the following discussion is oriented towards accumulating the Truckee Canal flows on a monthly as well as yearly basis.

The flow of the Truckee River has been modified since the early settlers started diverting water for irrigation. The only diversion of concern to this study, however, is the Truckee-Carson Irrigation District's Truckee Canal which diverts the water out of the basin at Derby Dam (Figure 1). Below Derby Dam, the volume of flow is measured both in the canal and in the river. About eight miles downstream from Derby Dam, at the Wadsworth spill, an unmeasured amount of canal water is dumped back into the Truckee River. Even though Derby Dam went into operation in 1903, it wasn't until January 1916 that flow records were kept for the

Truckee Canal and the Truckee River below Derby Dam. The calendar year 1917 for the Truckee River was not recorded. The canal record has three obvious errors in June, July, and August, 1917. In these three months the reported flow exceeds the estimated capacity of the canal by two to three times. For these three cases the appropriate average monthly flow of the canal is computed from all the records less these three months. In 1966 the USGS installed a new gauge on the canal downstream from the Wadsworth spill, and in 1969 the old head gauge was discontinued. The new gauge has been used in this study for Truckee Canal flows since 1966, because it is a more accurate measure of the volume of exported water. The head gauge records shown in Appendix C are on file at the Truckee-Carson Irrigation District offices in Fallon, Nevada.

There is a problem in using the Truckee Canal data because the quantity of water dumped back into the river is unknown. This leads to double counting of the dumped water when the Nixon flows are added to the Truckee Canal flows. An attempt has been made to correct for the double counting of the dumped water by subtracting the flows at the Truckee River below Derby Dam gauge from the flows at the Nixon gauge for each month that both records exist. Each of the positive values represents a gain to the river in the reach and is assumed to be caused by the dumping of the Truckee Canal waters at the Wadsworth spill. Each of these gains in this reach of the river has been subtracted from the measured flow of the Truckee Canal and is hereafter called the adjusted Truckee Canal flows. Since the smaller losses in the reach of the river can be attributed to consumptive use, they were not added back in.

Truckee River flows at Farad, Vista, below Derby Dam, and at Nixon from 1956 to present, as well as at the new gauge on the Truckee Canal have been published in the USGS Water Supply Papers 1314 and 1734 and in the USGS Stream Flow Records for the State of Nevada.

7.3.5 River Flow Data Requirements

In order to use the flow records at Nixon or Derby Dam in a regression analysis, all of the flow data must be in a form that eliminates the export of water through the Truckee Canal. This is accomplished by adding the yearly unadjusted Truckee Canal flows to the yearly flows at Nixon and Derby Dam. However, adjusted Truckee Canal flows can only be added to Nixon flows. These flows, and the indices of these flows, are called Nixon plus unadjusted Truckee Canal, Derby plus unadjusted Truckee Canal, and Nixon plus adjusted Truckee Canal flows, respectively. In this form these three records reflect the total flow of the river for each water year just as the Vista and Farad gauge records do.

Figure 3 is a plot of all five sets of flow indices plotted along with the Pine Nuts chronology. These five flow patterns are nearly identical. The only significant difference is that high flows tend to increase down river. This is expected, because there would be substantial runoff from the normally dry tributaries to the Truckee River below Reno during extremely wet years.

7.4 TREE-RING INDICES, PRECIPITATION, AND RUNOFF

Correlation coefficients obtained for comparisons of the tree rings to precipitation and runoff at various locations are shown in Tables 3 and 4. These two tables show clearly that the precipitation and runoff correlate best with the Pine Nuts chronology and least with the Hirschdale chronology. It would seem, at first glance, that the Hirschdale and Skyline chronologies correlate better and more consistently with runoff than they do with precipitation. The numbers are misleading because orographic effects cause substantial variation between the five precipitation stations. On the other hand, the four stream gauges show almost no variation because the bulk of the runoff originates upstream from the highest gauge.

The differences in the correlation coefficient of streamflow and the three tree-ring chronologies reflects how much better the Pine Nuts chronology is for reconstructing streamflow and precipitation, than the other two chronologies. The poor correlation of the Hirschdale chronology would seem to result from the location of the trees in the interior of the Carson Range where the amount of precipitation, 15 inches, is more nearly sufficient to prevent any severe water stress from affecting the trees. The Skyline trees lie on the eastern flank of the Carson Range where the rain shadow effect reduces the precipitation to 10 inches and puts the Skyline trees under a somewhat

TABLE 3

Precipitation Correlations, Present Study

Time Base; October-September, Water Year

Tree index	Correlated with	Number of trees	Number of events	r unsmoothed
Hirschdale	Reno	6	84	0.26
"	Tahoe City	6	63	0.45
"	Minden	6	59	0.22
"	Truckee R.S.	6	39	0.31
"	Boca	6	35	0.23
Skyline	Reno	7	84	0.31
"	Tahoe City	7	63	0.45
"	Minden	7	59	0.47
"	Truckee R.S.	7	39	0.39
"	Boca	7	35	0.42
Pine Nuts	Reno	9	84	0.60
"	Tahoe City	9	63	0.68
"	Minden	9	59	0.72
"	Truckee R.S.	9	39	0.60
"	Boca	9	35	0.66

TABLE 4

Runoff Correlations, Present Study

Time Base; October-September, Water Year

Tree Index	Correlated with	Number of trees	Number of events	r unsmoothed
Hirschdale	Nixon + UTCan[1]	6	44	0.49
"	Nixon + ATCan[2]	6	44	0.49
"	Derby + UTCan	6	54	0.48
"	Vista	6	40	0.45
"	Farad	6	73	0.47
Skyline	Nixon + UTCan	7	44	0.57
"	Nixon + ATCan	7	44	0.57
"	Derby + UTCan.	7	54	0.58
"	Vista	7	40	0.55
"	Farad	7	73	0.56
Pine Nuts	Nixon + UTCan	9	44	0.65
"	Nixon + ATCan	9	44	0.65
"	Derby + UTCan	9	54	0.66
"	Vista	9	40	0.63
"	Farad	9	73	0.64

[1] Nixon plus unadjusted Truckee Canal

[2] Nixon plus adjusted Truckee Canal

more severe water stress. The Pine Nut trees lie the farthest east and consequently, receive the least precipitation, 5 inches, of the three sets. The strikingly better correlations of the Pine Nuts chronology with both streamflow and precipitation dictate that only the Pine Nuts chronology will be used in the regression of tree-rings to streamflow, described next. Inclusion of the other two chronologies would only increase the random error component of the reconstruction equation.

Table 4 indicates that at the accuracy justified by the tree-ring data, there is no difference between the correlations of the tree-ring chronologies to the Nixon plus unadjusted Truckee Canal or Nixon plus adjusted Truckee Canal flows. Since the adjusted data represent the extreme case (subtracting all gains in the river from Derby Dam to Nixon) no further refinement of the adjusted data is warranted, and the unadjusted Truckee Canal data will be used to develop the reconstructive equation.

It is convenient to note at this point that the correlation coefficients between streamflow and tree-rings would probably be better if it were not for a persistent error during high streamflow years. During very wet years the trees tend to have near average growth due, presumably, to the excess water "drowning" the trees (although other environmental limits, such as temperature, may also come into play). The most obvious case of this occurred in 1890 when the precipitation at Reno was 220 percent of normal, while the Pine Nut tree growth was only 100 percent (Figure 2). If the tree-ring indices could be doubled to match the precipitation during that year, the error would be reduced.

7.5 SIMPLE LINEAR REGRESSION

In order to use tree-ring indices to reconstruct the flow of the Truckee River at Nixon, a linear regression was used on the forty-four years of Nixon plus unadjusted Truckee Canal flow indices (dependent variable) against the tree-ring indices (independent variable) for the same period. Since only one tree-ring variable was used in this study the principle component analysis procedure suggested by Stockton (1971) was not considered necessary. The regression equation is

$$I_t = 10.6296 + PNT_t\ (0.9255) \qquad (4)$$

where

I_t equals the synthetic flow index for the year t

PNT_t equals the Pine Nut tree-ring index for year t

To convert the synthetic index into a reconstructed flow in acre feet per year, the index must be multiplied by the mean of the Nixon plus unadjusted Truckee Canal flows, 506,570 acre feet per year.

Checking of the tree-ring streamflow equation was accomplished by developing the regression equation over the forty-four years of data at Nixon and testing it against the seventy-three years of data at Farad. There is almost a 1:1 correlation between the historic flows at these stations.

A regression using all forty-four years (1929-1972) of the observed Nixon plus unadjusted Truckee Canal flows against the Pine Nut chronology yields a correlation coefficient of r=0.72. The correlation coefficient between the reconstructed Nixon plus unadjusted Truckee Canal flows and the Farad flows for the period of 1900-1972 is 0.70. This indicates that the reconstructed flows over the longer period have similar variance to the calibration period and thus, the regression equation is valid for the longer period.

It must be noted that due to climatic cycles of short to moderate length, the data used in the regression must be representative of all of the cycles. In this case it was found that a regression developed from the 1951-1972 Nixon plus unadjusted Truckee Canal data gave a much different set of regression coefficients than the regression developed from all forty-four years of data. However, if a regression was developed from twenty-two years of data selected by using every other year from the forty-four, the coefficients were nearly the same as those from all forty-four years of data. Thus, one must be aware that it is possible, in fact likely, that the historic period is not fully representative of the long term climatic cycles. The 450 years of tree-ring data (Appendix A) used in this study shows that the historic period is similar to the 1745 to 1904 period, and therefore, the assumption that the historic period is representative of that time interval is reasonable.

7.6 PYRAMID LAKE MODEL

The Truckee River empties into the closed basin of Pyramid Lake. The only other inflow to the lake is from small ungauged ephemeral streams and ground water inflow from the surrounding mountains. Both are small compared to the annual flow of the Truckee River. The three modes of water loss from Pyramid Lake are 1) as overflow of Pyramid Lake into Winnemucca Lake through Winnemucca Slough when Pyramid Lake reaches an elevation of 3863 feet or greater; 2) division of the Truckee River on its delta after gauging, but before it enters the lake, sending all or part of its flow to Winnemucca Lake, usually for short periods of time; 3) evaporation directly from the lake which Harding (1962) has computed to be 4.02 vertical feet per acre. Evaporation is by far the most important factor.

Ignoring the fact that division of the Truckee River on its delta takes place (there is no way to include this unrecorded, random phenomanon), Pyramid Lake is for all practical purposes a non-leaky closed basin for lake surface elevations below 3863 feet. This simplifies any outflow equations and allows Harding's evaporation rates to be used in conjunction with volume versus elevation, and surface area versus elevation rating tables to develop an elevation model based on inflow to the lake.

7.6.1 Pyramid Lake Levels

Measured elevations of Pyramid Lake from 1869 -1960 have been published in the U.S. Geological Survey's Water Supply Paper summaries 1314 and 1734. Since 1960 they have appeared in the USGS, Water Supplies for the State of Nevada. All of the published elevations prior to October, 1955 are referenced to the 1929 datum for benchmark N-21 at elevation 3940.04 feet. The supplemental adjustment of 1956 places the elevation at 3940.29 feet to which all published lake elevations since October, 1955 have been adjusted +0.25 feet to the 1956 datum.

Timing of observations of the level of the lake has been rather sporadic. To bring these random observations to the monthly time base of the Pyramid Lake model, the observed elevations were plotted on year by day graph paper and a smooth curve drawn through the points. The value for middle of the month on this curve was used as the observed elevation (Appendix D). When the time between observations was longer than two or three months, interpolation was not attempted. Prior to 1926 the observations were spotty, and only in those cases where two or more observations were relatively close together was interpolation attempted. For many of these early observations the day of the month was not recorded, and in six cases, the month of the year was not even noted. In both situations, the observation was placed in the middle of its period. This should be kept in mind when examining the errors in the lake model. Interpolated elevations, as well as those placed in the middle of their time period, are listed in Appendix D.

The smoothed lake elevation curves yielded some interesting information on how fast the lake can rise. For instance, in 1969 the lake rose 8.00 feet in five months for an increase in volume of 870,000 acre feet. Only during the times when the lake's elevation rises rapidly does the interpolation of the lake elevations become important. In this case there would have been an 0.85 foot error in the elevation assigned to each of these five months without the interpolations. The recession of the lake through summer and fall plots as a very uniform event. The rate of fall of the lake's elevation is nearly always the same, indicating that summer and fall Truckee River inflows, as well as evaporation rates, are nearly always the same.

A review of the 1844-1960 lake elevations, which includes some reconstructed lake elevations from old records, has been published by S.T. Harding (1965). It is assumed here that all of Harding's elevations are relative to the 1929 datum and are adjusted accordingly. A brief review of Harding's discussion of the observations should give a feel for the quality of each.

In January of 1844, John C. Fremont traveled down the east side of Pyramid Lake. He noted in his diary that "by marks of the waterline along the shores, the spring level is about 12 feet above the present water". The waterline he referred to is the white line which has been caused by recent tuffa deposits and/or mechanical scouring of the older tuffa deposits when the lake stood at those elevations. According to Harding this places the lake elevation at 3860.8 feet. Fremont's report contains a high quality sketch of Pyramid Island and the adjacent inshore rocks. Harding (1965) took the sketch to the island and identified the waterline on the rocks. By surveying this waterline on the rocks he determined, independently, the elevation to have been 3860.8 feet.

The Surveyor General of California in 1856, described his trip down the Truckee River to Pyramid Lake. Harding interprets his description of the division of the Truckee on its delta, with flow into both lakes to mean that Pyramid Lake was at 3860 feet in 1856.

In 1867 and 1871 the King survey (1878) passed by Pyramid Lake. On one of these two occasion a photograph was taken of Pyramid Island and the inshore rocks. Harding as well as Hardman and Venstrom (1941) had determined the elevation of the lake in the photograph to be 3876 feet. The King report states that the lake rose nine feet between 1867 and 1871. Based on other indirect evidence Harding, as well as Hardman and Venstrom, have concluded that the picture was taken in 1871, making the 1867 elevation 3867 feet, and the 1871 elevation, 3876 feet. The USGS Water Supply Paper 1314 lists these elevations at some nine feet higher on the basis of the photo being taken in 1869. The USGS recently has published a revision stating that the lake could have been at the lower elevation.

Russell (1885) extensively surveyed the lake and took several photographs of the rocks. Harding interprets these photos to give an average elevation of 3867.2 feet during the time Russell worked in the area. Harding also notes that Russell reported a specific elevation for September 9, 1882 which, after allowing for the change in datum, becomes 3867.02 feet.

Harding (1965) gives elevations for 1889 and 1890 that were determined from rocks that Sutcliffe, who was an early settler in the area, said were covered by the rising lake from 1889 to 1890. The elevation difference was estimated at 17 feet after the water had again receded. This apparent 17 foot rise in the lake was during the very wet winter of 1889-1890. Harding (1965) also notes that Mud Slough was closed during much of this period by a brush and rock dam maintained by the Indian Service. This would substantially contribute to this very large change in elevation. Thus, in 1889 and 1890, the elevations were 3861 feet and 3878 feet respectively.

The 1890 elevation is substantiated by the U.S. Geological Survey's 1894 Wadsworth topographic map (topography done in 1890) which shows the elevation of Pyramid Lake as 3880 feet. This reduces to 3876 feet when the -3.93 feet is allowed for the change in datum. Since the USGS probably surveyed the lake's elevation, their elevation will be used for the 1890 observation.

The USGS Water Supply Paper 1314 shows an elevation of 3878.2 feet for 1891. There is no explanation of who made this observation by either the USGS or Harding. Harding does attribute the 1904 elevation at 3861 feet to the U.S. Bureau of Reclamation. Presumably, this was a surveyed elevation.

7.6.2 Harding's Evaporation Rates

Harding (1962) calculated monthly evaporation rates for Pyramid Lake as shown in Table 5. To do this he used the monthly recorded inflow to Pyramid Lake (1928-1960), the precipitation records at Nixon (1928-1953), or Lahontan Dam precipitation records when the Nixon records were not available (1954-1960), as well as rating curves for elevation versus volume and elevation versus surface area, developed by Russell in 1882 (Figure 4). To derive monthly evaporation, Harding first plotted available lake elevations and drew a smoothed curve through the data. From the curve he used the elevation for the first of each month, then calculated evaporation in feet per acre of surface area for each month that records were available during the years 1928 through 1960. He averaged each month's evaporation for all of the years to get monthly means and totaled the means for the yearly average. These means are shown in Table 5, together with the average

TABLE 5

Evaporation and Precipitation Rates

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEARLY TOTAL
Harding's (1962)[4] evaporation rates[1]	.47	.38	.30	.24	.23	.20	.22	.25	.32	.39	.50	.52	4.02[2]
Average precipitation[5] at Nixon, Nevada[1]	.05	.06	.07	.07	.07	.05	.04	.05	.06	.02	.02	.03	.59[2]
Average net evaporation[1]	.42	.32	.23	.17	.16	.15	.18	.20	.26	.37	.48	.49	3.43[2]
Adjustments made in this report[3]	-.01	-.01	-.01	.00	.00	.00	.00	.00	.00	-.01	-.01	-.01	-.06[2]
Average net evaporation used in the Pyramid Lake Model[1]	.41	.31	.22	.17	.16	.15	.18	.20	.26	.36	.47	.48	3.37[2]

---

[1] Monthly rates are in feet per month

[2] Feet per year

[3] See Section 7.6.11 - observed Truckee River Flows as Input.

[4] For the period 1928-1960.

[5] For the period 1928-1953 and 1962-1972.

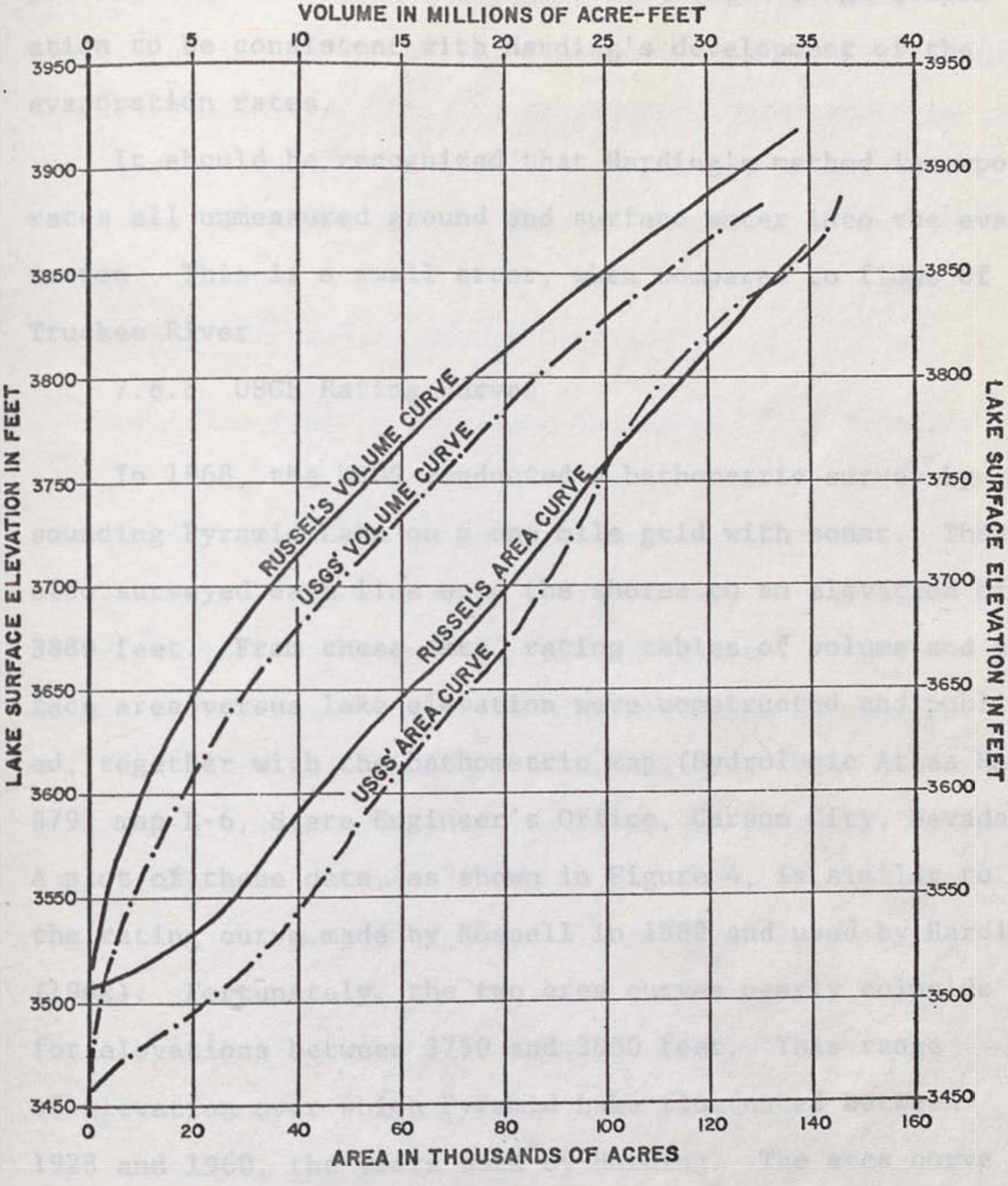


Figure 4
Rating Curves for Pyramid Lake.
Russel's (1882) data adapted from Harding (1965). USGS data plotted from Hydrologic Atlas HA-379, Map L-6.

precipitation for thirty-four years of record at Nixon. Before inclusion in the Pyramid Lake model, the average precipitation has been subtracted from the average evaporation to be consistent with Harding's development of the evaporation rates.

It should be recognized that Harding's method incorporates all unmeasured ground and surface water into the evaporation. This is a small error, when compared to flows of the Truckee River.

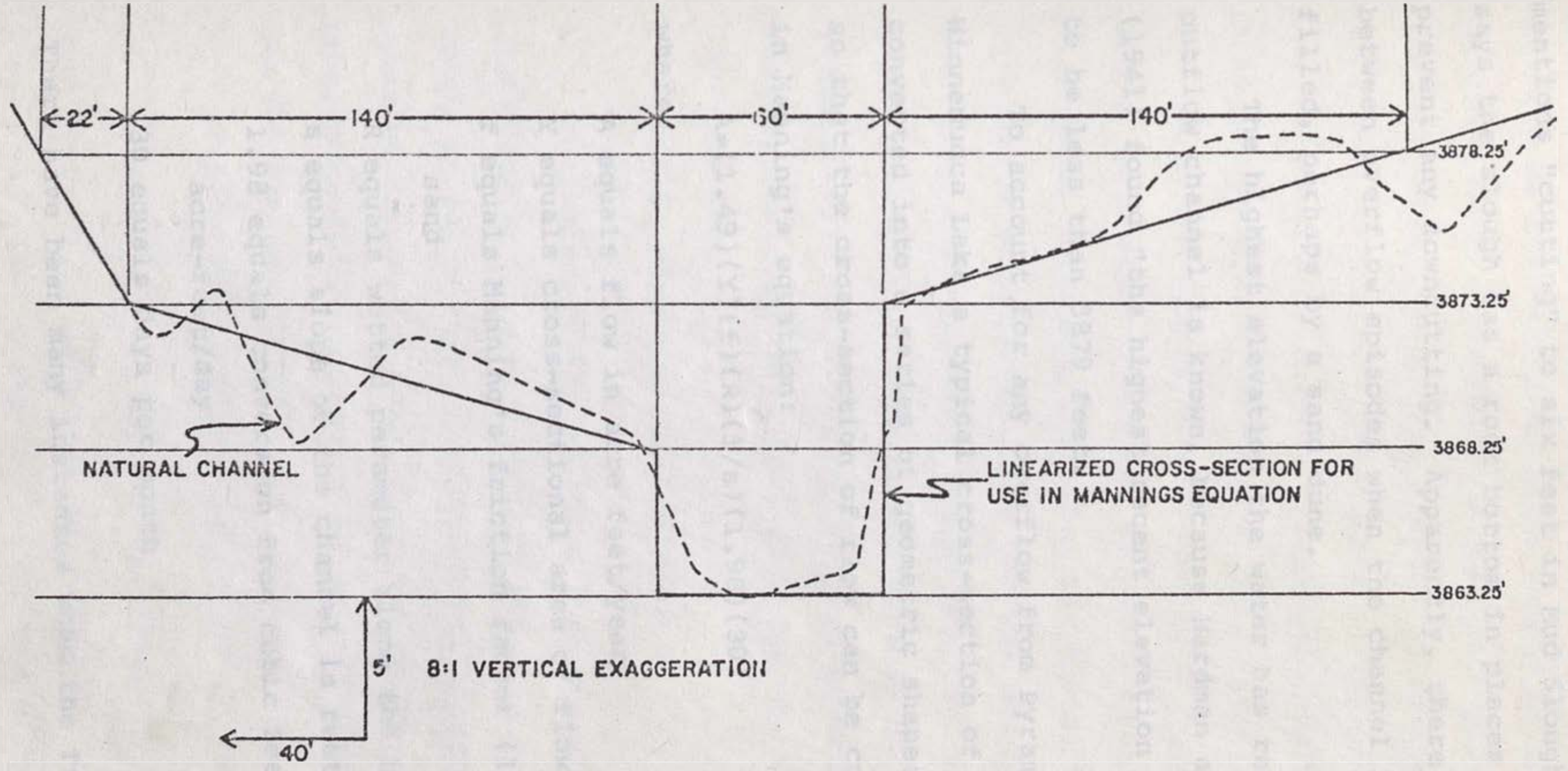
7.6.3 USGS Rating Curves

In 1968, the USGS conducted a bathometric survey by sounding Pyramid Lake on a one mile grid with sonar. They also surveyed each line onto the shores to an elevation of 3880 feet. From these data, rating tables of volume and surface area versus lake elevation were constructed and published, together with the bathometric map (Hydrologic Atlas HA-379, map L-6, State Engineer's Office, Carson City, Nevada). A plot of these data, as shown in Figure 4, is similar to the rating curve made by Russell in 1882 and used by Harding (1962). Fortunately, the two area curves nearly coincide for elevations between 3750 and 3850 feet. This range of elevation over which Pyramid Lake fluctuated between 1928 and 1960, the years used by Harding. The area curve was the critical curve for Harding's determination of volume of water evaporated per acre of surface area. If the curves had been as far apart in that elevation zone, as they are for lower elevations, Harding's evaporation rates would have been considerably less accurate. For the model in this study, a series of fifteen linear equations, joined end to end, were developed to approximate the rating curves. The sixteen segments were chosen so that the shortest segments occurred at the zones of greates curvature and the longest segments, where the curves were nearly straight.

7.6.4 Winnemucca Slough Overflow

Overflow from Pyramid Lake is handled as a function of lake elevation. Hardman and Venstrom (1941) surveyed the ground elevation around Winnemucca Slough and found the elevation of the slough, where it leaves the Truckee River, to be 3863 feet (3863.25, 1956 datum). The slope of the slough was found to be eight feet in 4.5 miles.

A typical cross section of the slough, about two miles down stream of the bifurcation, was measured during this study and is shown in Figure 5. The present channel shows a little natural deterioration since the last reported flow in 1937. The bottom of the essentially rectangular channel is nearly flat and shows no evidence of wind blown siltation, and only minor fluvitile deposition. Thus, the channel has remained essentially clear for the last thirty-eight years. Harding (1965, p. 102) however, notes that the Gibson report to the Indian Service in 1888



A CROSS-SECTION OF WINNEMUCCA SLOUGH

FIGURE 5

mentions "cutting" to six feet in Mud Slough, but he also says the slough has a rock bottom in places which should prevent any downcutting. Apparently, there have been times between overflow episodes when the channel has been backfilled, perhaps by a sand dune.

The highest elevation the water has reached in the outflow channel is known, because Hardman and Venstrom (1941) found "the highest recent elevation of Pyramid Lake" to be less than 3879 feet.

To account for any overflow from Pyramid Lake to Winnemucca Lake a typical cross-section of the channel was converted into a series of geometric shapes (Figure 5) so that the cross-section of flow can be computed for use in Manning's equation:

$$A=(1.49)(Y)(f)(R)(1/s)(1.98)(30) \qquad (5)$$

where

A equals flow in acre feet/year

Y equals cross-sectional area of flow in feet^2

f equals Manning's friction factor (1.49) for medium sand

R equals wetted perameter along the banks in feet

s equals slope of the channel in feet/feet (8:23760)

1.98 equals conversion from cubic feet per second to acre-feet/day

30 equals days per month

There have been many instances when the Truckee River divides on its delta, but this cannot be incorporated into the model because the timing and volume of these flows are not known, except for a short period between 1903 and 1905 when a gauge was maintained on the slough.

Hardman and Venstrom (1941) and Harding (1965) note that the Federal Government's Indian Service had a rock and brush dam placed across Winnemucca Slough in 1888 or 1889. This effectively cut off Winnemucca Lake until some time after February, 1891 when the Nevada Legislature complained to Congress. The dam was not maintained after this time and eventually became ineffective. This may have caused higher than normal Pyramid Lake levels for the years of 1890 and 1891, and perhaps several more. For this reason, the model disallows flow through the slough in 1890 and 1891.

7.6.5 Time Base of the Model

Inclusion of the overflow term necessitates building the model to work on a monthly basis in order to limit the error in calculating the Winnemucca Slough overflows. The base period of one year, dictated by the tree-rings, is too long because the volume of water overflowed is a function of the average elevation of the lake over the time period.

7.6.6 Yearly Flows Distributed to Months

Since the time base of the tree-ring flow equation is one year, it is necessary to distribute the yearly tree-ring generated flow of the river over the twelve month period

(Table 6). This is done by multiplying the reconstructed yearly flow by each month's average percentage of the annual flow. The month's average percentage of the annual flow was determined from the thirty-six years of flow records at Vista.

The process of breaking the reconstructed yearly flows into monthly flows using the average flow percentages can create errors in some months if the distribution of the flows for a particular year does not match the average hydrograph used in the program. This was found to give only a slight discrepancy between Pyramid Lake model runs using as input the monthly observed flows at Nixon, and runs redistributing the yearly total of the same monthly flows via the average flow percentages.

7.6.7 Truckee Canal Flows

In order to use one regression equation to predict flows before and after 1903 (when the canal went into operation) it is necessary to subtract the monthly observed Truckee Canal flows during the 1903-1972 period. Unfortunately, from 1903-1917 no calculations can be made because Truckee Canal flow was not recorded. Prior to 1903 the reconstructed flows need no adjustment. Thus, for the years 1917-1972, the monthly observed Truckee Canal flows are subtracted from the product of the tree-ring generated Nixon plus unadjusted Truckee Canal flows and the distribution percentages to convert the yearly flows

TABLE 6

Decimal percentages of the yearly flow at Nixon (Nixon plus Truckee Canal). Determined from 44 years of data.

OCT	.0436
NOV	.0605
DEC	.0768
JAN	.0784
FEB	.0867
MAR	.0924
APR	.1494
MAY	.1873
JUN	.1181
JUL	.0407
AUG	.0304
SEP	.0357
YEARLY TOTAL	1.000

to the appropriate months.

7.6.8 Seed Values

To make the first calculation of the lake level the model is started on a month with a known lake elevation. This elevation is the "seed value". Prior to 1926, the observed elevations are spotty and often only the month or even the year of the observation is known. This creates a problem because once the model is started with an error this error will grow larger throughout the run.

To start the model in mid water-year, for instance, January 1844, the seed values for volume and area at that elevation must be calculated by the linear equations in the program that approximate the rating curves and inserted as the seed values for October 1844. The gain in volume to the lake can then be internally set equal to zero for the intervening months between the first month of the water year and the month for which the elevation is known. By setting the gain in volume equal to zero, all internal calculations of evaporation and overflow are nullified. If the seed value for volume and area are calculated from the USGS rating curves rather than the linear equations that approximate the rating curves, the model will calculate a different final area each time the gain is set equal to zero. This will give a slightly different elevation from that which would be calculated by using the linear equations over the period when zero change is desired.

To run the model from 1844 to 1903, when the Truckee Canal began operation, it was decided for convenience to run to 1904 when an observed elevation was available. The error introduced by not removing the 1903-1904 Truckee Canal flows is thought to be small, because the canal was apparently not operated at full capacity for the first several years.

7.6.9 The Program

The model is a straight forward monthly calculation of a new volume contained in the lake based upon the amount of inflow to the lake, less the evaporation and overflow (See flow chart and discussion Appendix F). This final volume is used to calculate the surface area and lake elevation that correspond to that volume. The final volume, area, and elevation from one step become the initial values for the next step. The evaporation is calculated as a function of the average surface area of each step and the overflow is a function of the average elevation for each step (See Appendix F for a further discussion of this point).

7.6.10 Instability in the Model

The Pyramid Lake Model is capable of giving the same artificial elevations when it is run both forward and backward in time, provided that the seed values for the reverse run are the final calculated values from the forward run. If the model is run forward in time, starting from a known elevation, it will probably produce an elevation at the end of the run which is near, but not exactly the known elevation on that date (as is expected). Running the model backward in time, starting from what was the ending observed elevation (which is different from the last calculated elevation of the forward run) the model will continue to deviate in the direction of the original difference, and the deviation will get larger. This problem arises from the calculation of the evaporation and the volume of water overflowed, both of which are a function of the initial and final volumes in the lake. The model tends to be self-correcting when it is run forward in time because both the evaporation and overflow are abstractive components of the change in volume equation. Let us assume, as an example, that during the course of the forward calculations the reconstructed lake has become slightly too large in comparison to the actual lake in a given time step. Under this situation both the evaporation and overflow tend to take more water out of the lake, because the surface area is larger and elevation is higher. This tends to lower the lake for the next time step which correctsthe error. Now, let us use the same example during a run backwards in time, when the evaporation and overflow are additive components of the change in volume equation. The slightly larger lake has a larger surface area and elevation which results again in an increase in evaporation and overflow. In this instance, however, these components make the lake larger in the next time step. Thus, the error tends to get worse rather than better, as in the forward case.

This lack of stability prevents using the model to go backwards in time with any reliability, particularly when the lake is overflowing through Winnemucca Slough. It is possible however, to start the model prior to 1844 by assuming successive elevations until a fit with little deviation from the data in the 1844-1904 time span is obtained.

7.6.11 Observed Truckee River Flows as Input

The Pyramid Lake Model was validated using the forty-four years of observed monthly flows at Nixon. These data are completely independent of the tree-ring information, and as such, test the program's ability to reproduce lake levels.

It was found when using Harding's (1962) evaporation rates in the model that a plot of the observed elevations and calculated elevations had slight but distinctly different slopes over the forty-four years. By trial and error, it was found that the October, November, December, July, August, and September evaporation rates could be adjusted -0.01 feet per acre to eliminate the divergence (see adjusted factors in Table 5). These adjustments to Harding's evaporation rates are done simply to correct this apparent discrepancy in the model. This discrepancy could just as well be in another section of the model. It is not known that Harding's evaporation rates are in error, but they are suspect because of his use of Russell's less accurate 1882 curve . It should be noted that Harding's evaporation rates do work very well and are still a good approximation to the evaporation from Pyramid Lake despite these slight changes.

A plot of the synthetic and observed elevations as shown (Figure 6) indicates a generally good reproduction of the lake levels with a maximum deviation of three feet over a gross change in lake level of sixty feet. Figure 6

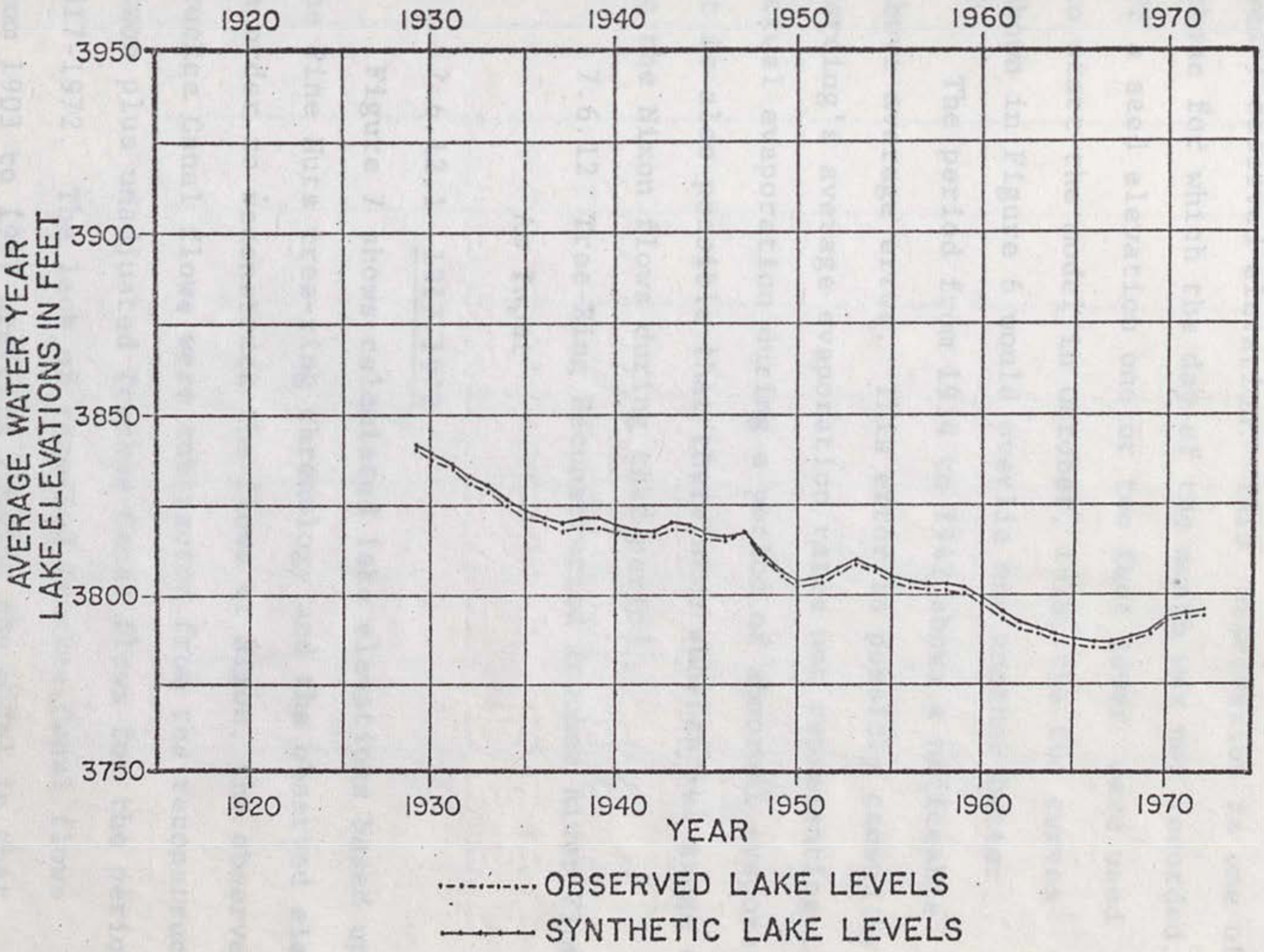


Figure 6

Comparison of the observed Pyramid Lake levels to synthetic lake levels using the observed flows of the Truckee River at the Nixon Dam flow gage as input to the model.

shows that the calculated elevation is consistently above the observed elevation. This appears to be caused by starting the model with the October, 1929 (October, 1928 calendar year) observed elevation. This observation is one of those for which the day of the month was not recorded. If a seed elevation one or two feet lower were used to start the model in October, 1929, the two curves shown in Figure 6 would overlie one another better.

The period from 1934 to 1942 shows a noticeable above average error. This error is possibly caused by Harding's average evaporation rates not representing the actual evaporation during a period of abnormal evaporation. It is also possible that there were substantial gauge errors in the Nixon flows during that period.

7.6.12 Tree-Ring Reconstructed Truckee River Flows As Input

7.6.12.1 1917-1972

Figure 7 shows calculated lake elevations based upon the Pine Nuts tree-ring chronology and the observed elevations. In order to reconstruct the flows at Nixon, the observed Truckee Canal flows were subtracted from the reconstructed Nixon plus unadjusted Truckee Canal flows for the period of 1917-1972. The lack of recorded Truckee Canal flows from 1903 to 1917 prevents running the model in that period. Prior to 1903, the model can be operated with just the reconstructed flows because the Truckee Canal did

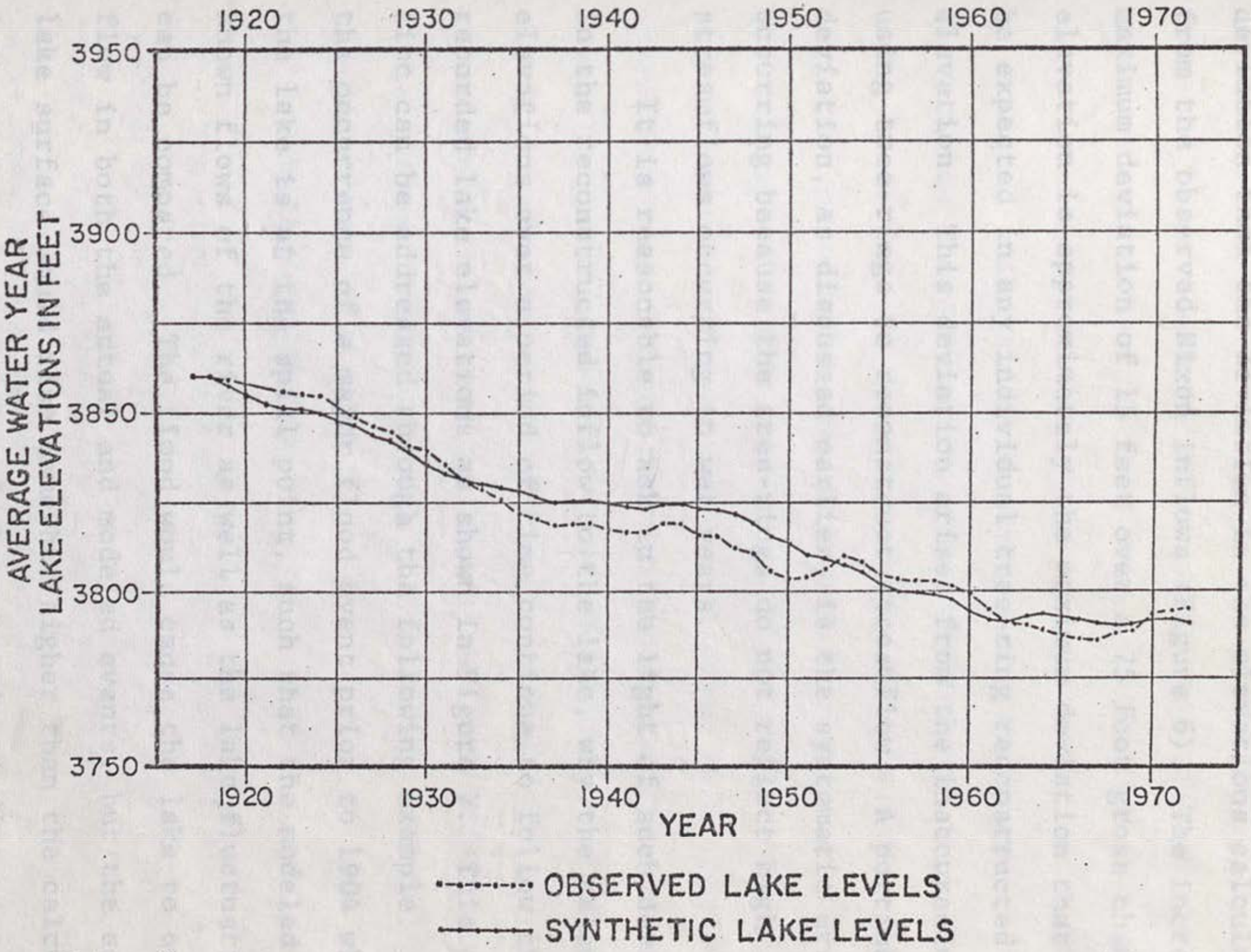


Figure 7

Comparison of the observed Pyramid Lake levels to synthetic levels using the Pine Nut Tree Ring chronology as input to the model.

not exist.

A comparison of Figures 6 and 7 shows that the tree-ring reconstructed elevations (Figure 7) have a larger deviation than the deviation in the elevations calculated from the observed Nixon inflows (Figure 6). The increased maximum deviation of 15 feet over a 75 foot gross change in elevation is approximately the maximum deviation that can be expected in any individual tree-ring reconstructed elevation. This deviation arises from the inaccuracies of using tree-rings to reconstruct streamflow. A portion of this deviation, as discussed earlier, is the systematic error occurring because the tree-rings do not reflect high streamflows occurring in wet years.

It is reasonable to ask in the light of such deviation in the reconstructed inflow to the lake, why the calculated elevations over a period of time continue to follow the recorded lake elevations as shown in Figure 7. This question can be addressed through the following example. Assume the occurrence of a major flood event prior to 1904 when the lake is at the spill point, such that the modeled and known flows of the river as well as the lake fluctuations can be compared. The flood would cause the lake to overflow in both the actual and modeled events, but the actual lake surface would rise somewhat higher than the calculated lake surface as a result of the tree-ring indices not reflecting the high flows. Following the event, the actual lake surface would recede faster than the calculated because it has a larger surface area and consequently, a larger volume of evaporation. More importantly, the real lake, due to its higher elevation would have a larger outflow cross-section through Winnemucca Slough than the modeled lake. Both of these larger extractions would cause the real lake to fall more rapidly than the modeled one, thus bringing the two to approximately the same elevation. Similarly, for long droughts, which bring the lake below the spill point, the modeled and real lakes will tend to merge. It does not matter in this case whether the real or modeled lake is lower in elevation; the lower of the two will have a smaller volume evaporated each month relative to the other, which will bring them together again. Even with these errors between the calculated and actual lake levels it should be noted that Figure 8 shows that the model is capable of following the actual lake elevations throughout its 78 foot decline, even when eleven years more inflow is modeled than the tree-ring streamflow equation was built upon.

7.6.12.2 <u>1844-1904</u>

The nine observed elevations (Table 7) during the period of 1844 to 1904 have a range of elevation of 18 feet. Although these are widely scattered points they give some feeling for the maximum range of elevation for the actual lake. The modeled lake (Table 7) over this same period has a maximum elevation fluctuation of slightly

TABLE 7

Comparison of the reconstructed elevation and observed elevations 1844 to 1904. The reconstructed elevations are the average of the 12 monthly values. The observed are single observations.

Date	Reconstructed Elevation	Observed Elevation	Difference	Date	Reconstructed Elevation	Observed Elevation	Difference
1844	3860.54	3860.75[2]	-.21	1874	3866.98	-0	-0
1845	3859.81	-0	-0	1875	3868.41	-0	-0
1846	3859.35	-0	-0	1876	3870.08	-0	-0
1847	3859.48	-0	-0	1877	3870.69	-0	-0
1848	3860.76	-0	-0	1878	3870.81	-0	-0
1849	3861.70	-0	-0	1879	3870.26	-0	-0
1850	3862.75	-0	-0	1880	3869.94	-0	-0
1851	3863.04	-0	-0	1881	3869.87	-0	-0
1852	3863.67	-0	-0	1882	3870.20	3867.15	3.05
1853	3865.57	-0	-0	1883	3869.58	-0	-0
1854	3867.07	-0	-0	1884	3869.64	-0	-0
1855	3867.86	-0	-0	1885	3869.69	-0	-0
1856	3866.68	3860.25[1]	6.43	1886	3869.39	-0	-0
1857	3865.19	-0	-0	1887	3869.09	-0	-0
1858	3863.61	-0	-0	1888	3868.05	-0	-0
1859	3861.54	-0	-0	1889	3866.46	3861.07[1]	5.39
1860	3860.89	-0	-0	1890	3865.98	3876.07[1]	-10.09
1861	3861.09	-0		1891	3867.11	3878.15[1]	-11.04
1862	3861.75	-0	-0	1892	3868.09	-0	-0
1863	3862.52	-0	-0	1893	3868.41	-0	-0
1864	3862.19	-0	-0	1894	3868.54	-0	-0
1865	3862.06	-0	-0	1895	3868.65	-0	-0
1866	3862.64	-0	-0	1896	3868.52	-0	-0
1867	3863.71	3867.25[1]	-3.54	1897	3868.07	-0	-0
1868	3865.55	-0	-0	1898	3866.93	-0	-0
1869	3866.71	-0	-0	1899	3864.94	-0	-0
1870	3866.37	-0	-0	1900	3863.91	-0	-0
1871	3865.11	3876.25[1]	-10.96	1901	3864.58	-0	-0
1872	3865.29	-0	-0	1902	3864.83	-0	-0
1873	3866.36	-0	-0	1903	3864.60	-0	-0
				1904	3864.77	3862.07	2.70

[1] The month of the year when the observation was taken is not known.

[2] The day of the month when the observation was taken is not known.

more than eleven feet. The probable reasons for this reduced range of fluctuation of the modeled lake has been discussed previously. The maximum range of the difference between the calculated and the nine observed elevations (Table 7) is a little more than seventeen feet. This range of deviation, although poorly documented due to few data points, gives some feel for the error that can be expected.

This similarity of the magnitude of the deviation in the tree-ring calculated lake levels and the overall change in the real lake level is expected for several reasons. The deviation of 7 feet is about the same in this time period, using tree-ring inflows only, as the 15 foot range of error found in the 1917 to 1972 period using the reconstructed Nixon minus Truckee Canal flows. This suggests that there is no fundamental difference in the quality of the data. In addition, two lines of evidence point towards Pyramid Lake having its mean elevation under the prevailing climatic conditions near the spill point. First, Winnemucca Lake is known to have had water in it several times prior to 1904. It is not known though, whether the water came from overflow of Pyramid Lake or bifurcation of the Truckee River. The apparently large fluctuations in surface area, and therefore volume, of Winnemucca Lake noted by Hardman and Venstrom (1941), and Harding (1965), would suggest that Winnemucca inflows are sporadic Pyramid Lake overflow events. Therefore, if overflow were occurring, even occasionally, Pyramid Lake must have been close enough to the spill point to allow the flood water to spill. Secondly, the upper limit of Pyramid's elevation was well established by the rapidly increasing cross-sectional area for outflow. This had kept the lake from rising above 3879 feet according to Hardman and Venstrom (1941). Conversely, the volumes of water that Truckee Canal has prevented from reaching Pyramid Lake (Appendix C), and the resulting drop in elevations (Appendix D), suggest the magnitude and time duration of a drought that would be necessary to drop the lake ten or fifteen feet below the spill elevation.

In short, Winnemucca Lake would have to be filled before Pyramid Lake could rise to an elevation of 3879 feet and a very long and severe drought would be necessary to lower the lake substantially below the spill point. This suggests reasonable limits of perhaps 25 to 30 feet as the maximum range in fluctuation that Pyramid Lake would have had prior to the opening of the Truckee Canal in 1903, and that its mean elevation was near the spill point elevation. The tree-ring information used in this report sheds some light on the time-frame over which these limits apply. The tree-ring data for the three chronologies do not show any long term changes in their growth patterns from 1745 to 1972 which suggests that the climate has remained fairly stable for that period. Assuming this to be true the range of elevations and the mean elevation of the lake would apply to this period also. Between 1742 and the end of the last ice age they may apply also, but this can not be said with certainty.

7.6.12.3 1745-1904

Under the assumption that the tree-ring streamflow equation is valid prior to 1900, the lake model can be used to test the 1745 to 1904 period for the probable range of lake levels that will keep the computed lake surface within the bounds of the known data between 1844 and 1904. The model can be started in 1745 (the beginning of the Pine Nuts chronology) using various seed values and run forward in time.

Figure 8 shows three runs using a spill elevation of 3863 feet and seed elevations of 3893 feet, 3863 feet, and 3823 feet. The middle trace on Figure 8 used a seed elevation equal to the spill elevation. This can be considered a baseline case that shows an overall fluctuation of sixteen feet from 1745 to 1904. This fluctuation is about the same as the observed range in elevation from 1844 to 1904. The highest trace on Figure 8 represents a run using 3893 feet as a seed elevation for 1745. This clearly shows the rapid discharge of the thirty vertical feet of excess water in Pyramid Lake. When overflowing ceases, the lake levels merge with the baseline case. Without some provision in the model for filling Winnemucca Lake, any higher seed elevation would be pointless. Thus, the 3879 feet noted by Hardman and

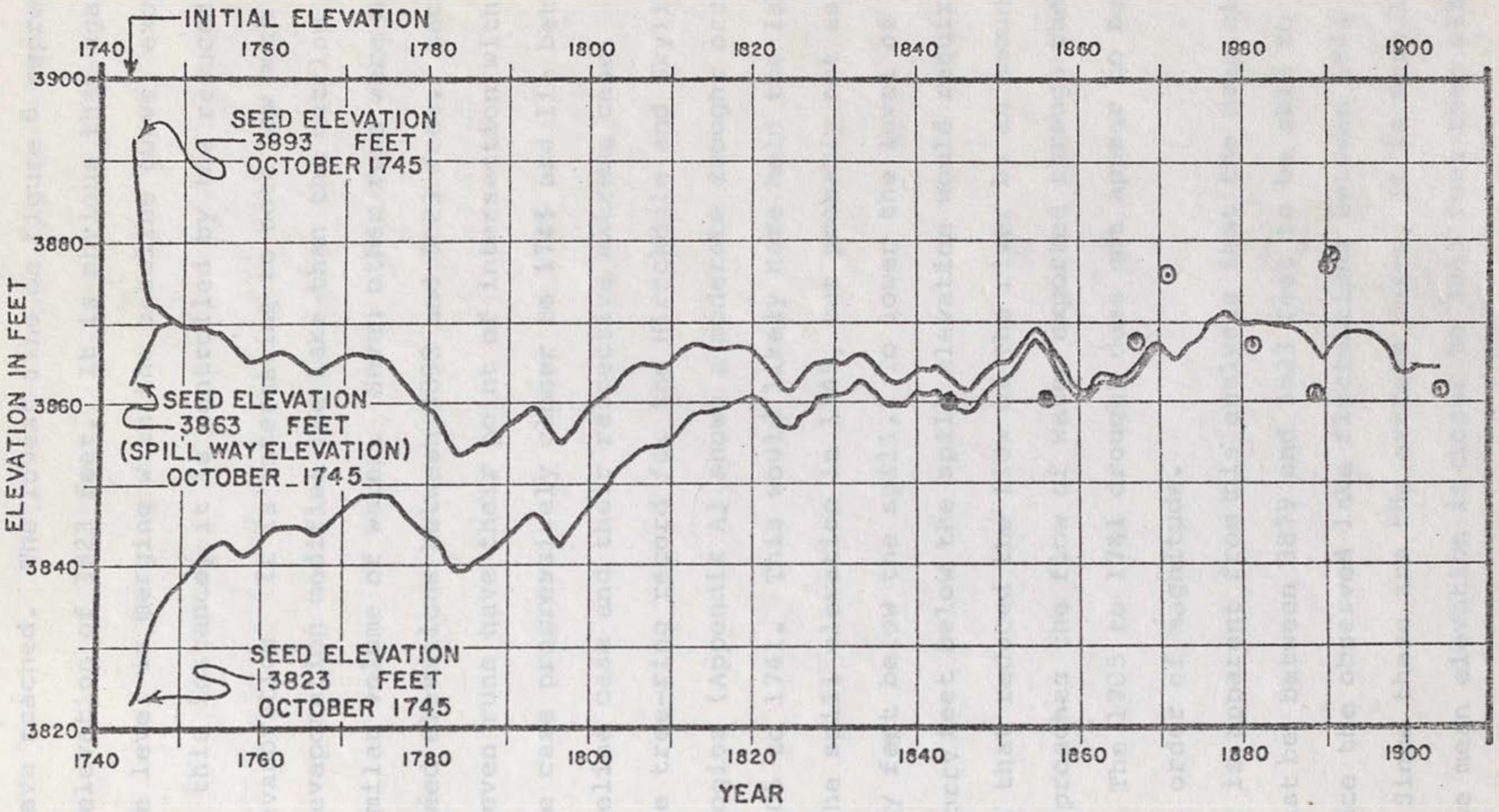


Figure 8

Plots of the tree-ring generated lake elevations starting at October 1745 and running forward in time. The results were checked against known elevations shown with circles from 1844 to 1904.

Venstrom (1941) can be taken as the highest the lake could have reached. The lowest line on Figure 8 represents a seed elevation of 3823 feet. It is obvious that again the lake level is merging with the baseline curve, except that in this instance, it is controlled by the reduced volume of evaporation. It is interesting to note how much more slowly evaporation modifies the lake than the outflow of a similar volume of water. Seven other runs were made using seed elevations between 3893 and 3823 feet. Each of these seven runs have their point of intersection with the baseline case progressively closer to 1745 and lie between the baseline case and their respective extreme case.

The tree-ring record for the Hirschdale and Skyline chronologies (Appendix A) shows a moderate drought occurred from 1705 to 1741. This would likely have held the lake below the spill elevation in 1745, but probably not as low as forty feet below the spill. To lower the level of the lake forty feet below the spill elevation would require a drought that reduced the flow of the river by an amount that approaches the flow of water exported through the Truckee Canal. The 1705 to 1741 drought does not appear to be of that order of magnitude.

It is apparent from this analysis that the mean elevation must be between 3879 and 3823 feet to be able to reproduce the observed lake fluctuations between 1844 and 1904. Since these are the extreme cases, it is more likely that the mean elevation is closer to 3863 feet than either extreme. Thus, the model, despite its inaccuracies on a short term basis, confirms that Pyramid Lake has its mean elevation near the spill point elevation of 3863 feet due to the physical-evaporative constraints upon the lake. Furthermore, the modeling suggests that during the 1745 to 1904 period, the lake had a limited range of fluctuations of sixteen feet. It is likely, though, that this range should be twenty-five to fifty percent greater (20 to 24 feet), due to the inability of the model to reproduce the high river flows.

8.0 SUMMARY AND CONCLUSIONS

The methodology used in the conversion of tree-rings from drought sensitive trees into indices of streamflow have been presented by Schulman (1945b), Stockton (1971), and others. The trees used in this report are nine Pinus monophylla (Pinyon pine) from an elevation of 4300 feet in the Pine Nut Range east of Gardnerville, Nevada. For this study, the indices of streamflow were computed for the Nixon plus Truckee Canal flows. These flows represent virtually all of the water in the Truckee River as it would have been prior to the construction of the Truckee Canal. A regression equation was developed between the tree-rings and the Nixon plus Truckee Canal flows. In this form the regression equation can be used to estimate the flow history of the river. The regression equation was derived from forty-four years of data at the Nixon gauge and tested against seventy-two years of streamflow records at the Farad gauge, upstream. The correlation coefficient between the reconstructed flows at Nixon and it's historic flows is r=0.72, while the correlation coefficient between the reconstructed flows at Farad and it's historic flows is r=0.70 for the longer period. This demonstrates that the regression equation is valid over the longer period.

A computer model of Pyramid Lake was built that uses as input, the inflow of the Truckee River to the lake at the Nixon gauge and computes the new elevation of the lake after accounting for evaporation and outflow. The model was tested by using historical river inflows as input and comparing the calculated and observed elevations from 1929-1972. The model estimated the lake elevations to within three feet of the actual lake over a total lake level decline of sixty feet. When the tree-ring regression equation was coupled to the model the deviation increased to fifteen over a seventy-eight foot decline during the period of 1917 to 1972. It is apparent that the use of tree-rings to reconstruct streamflow has its limitations, but that this type of data can be useful as an approximation to otherwise unobtainable information on streamflow prior to the written records.

Running the model from 1844 to 1904 allowed the calculated elevation to be checked against nine widely scattered observations of the lake's elevation. The range in elevation of the actual lake is eighteen feet, while the modeled lake fluctuated eleven feet. The maximum range of the difference between the calculated and the nine observed elevations is a little more than seventeen feet. This range of deviation, although poorly documented due to the small number of points, is about the same as found for the 1917-1972 data, but during the 1844-1904 period the lake did not experience the 68 foot decline of the 1917-1972 period. Thus, similarity of the deviation and the total fluctuation of Pyramid Lake is largely a function of the stability of the lake. It is likely that this limited fluctuation of of Pyramid Lake is caused by the physical evaporational environment of the lake. For instance, whenever the lake is above the spill point elevation of 3863.25 feet, water is discharged into Winnemucca Lake through Winnemucca Slough. This process has effectively kept the lake from rising above the 3879 level since the last time Winnemucca Lake was filled. (Although it is not known when this last occurred, the tree-ring growth data suggest that this was at least 450 years ago). Secondly, whenever the lake level drops below the spill elevation the overflow is stopped and evaporation becomes the only extraction. Assuming that the mean long term climatic conditions remain the same, any short term drought has a limited ability to lower the lake's surface, because as the lake level drops the volume of evaporation is reduced. Therefore, the lake stays near its spill point elevation as long as the mean long term climatic conditions remain the same.

It is possible through the use of the climatic information correlated to the tree-ring record and the lake level model to reconstruct the long term trend in the elevation of Pyramid Lake and see the approximate location of the mean elevation of the lake under the prevailing climatic conditions.

Running the model forward in time from 1745 (the beginning of the Pine-Nuts tree-ring chronology) using various seed elevations, demonstrated that any seed elevation above the spill point elevation very rapidly converges on the case where the model was started at the spill elevation. Seed values below the spill point converge more slowly. Starting the model in 1745 from an elevation forty feet below the spill elevation only causes a slight disturbance in the 1844-1904 period. Since it is known that Winnemucca Lake received inflows from Pyramid Lake and/or the Truckee River in this later period, it is unlikely that any lower seed elevation could be used in 1745 and have the model stay within the bounds of the known data. Furthermore, if the lake had been strongly depressed in 1745, there should have been a severe drought prior to then. The Skyline and Hirschdale tree-ring data (Appendix A) show a moderately severe drought from 1705 to 1741 which would have had the lake's elevation relatively low in 1745, but it is not likely that it was as much as forty feet below the spill way elevation. Thus, the equilibrium elevation must be near or slightly below the spill point elevation of 3863 feet. The lake model shows the lake as having a maximum range in elevation of sixteen feet. However, due to the inability of the model to reproduce high flows, this could be twenty-five to fifty percent larger. The model can not reconstruct a discreet event, particularly a flood event, but over an extended period of time the model gives a reasonably good approximation to the hydrograph of Pyramid Lake.

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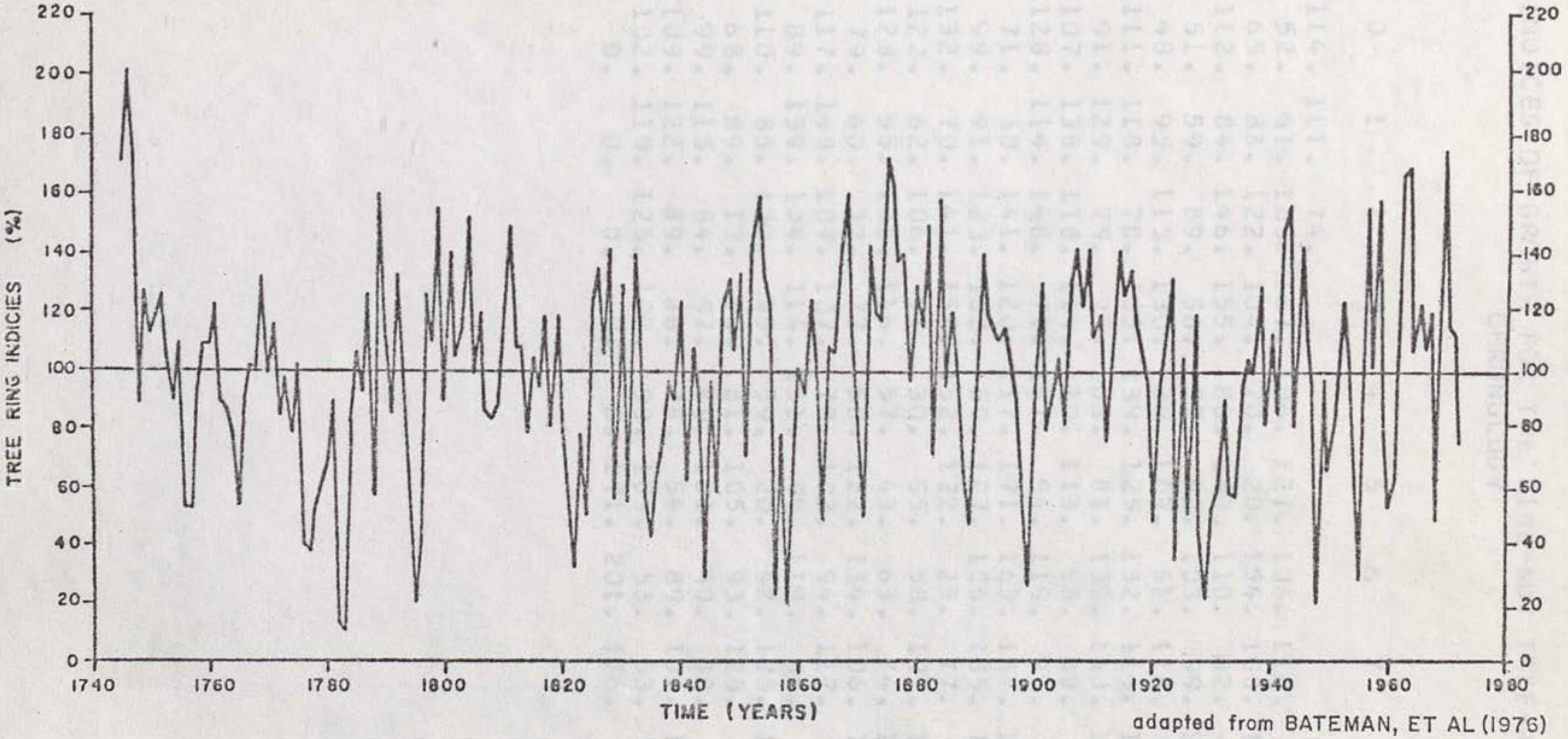
APPENDICES

10.0 APPENDIX A

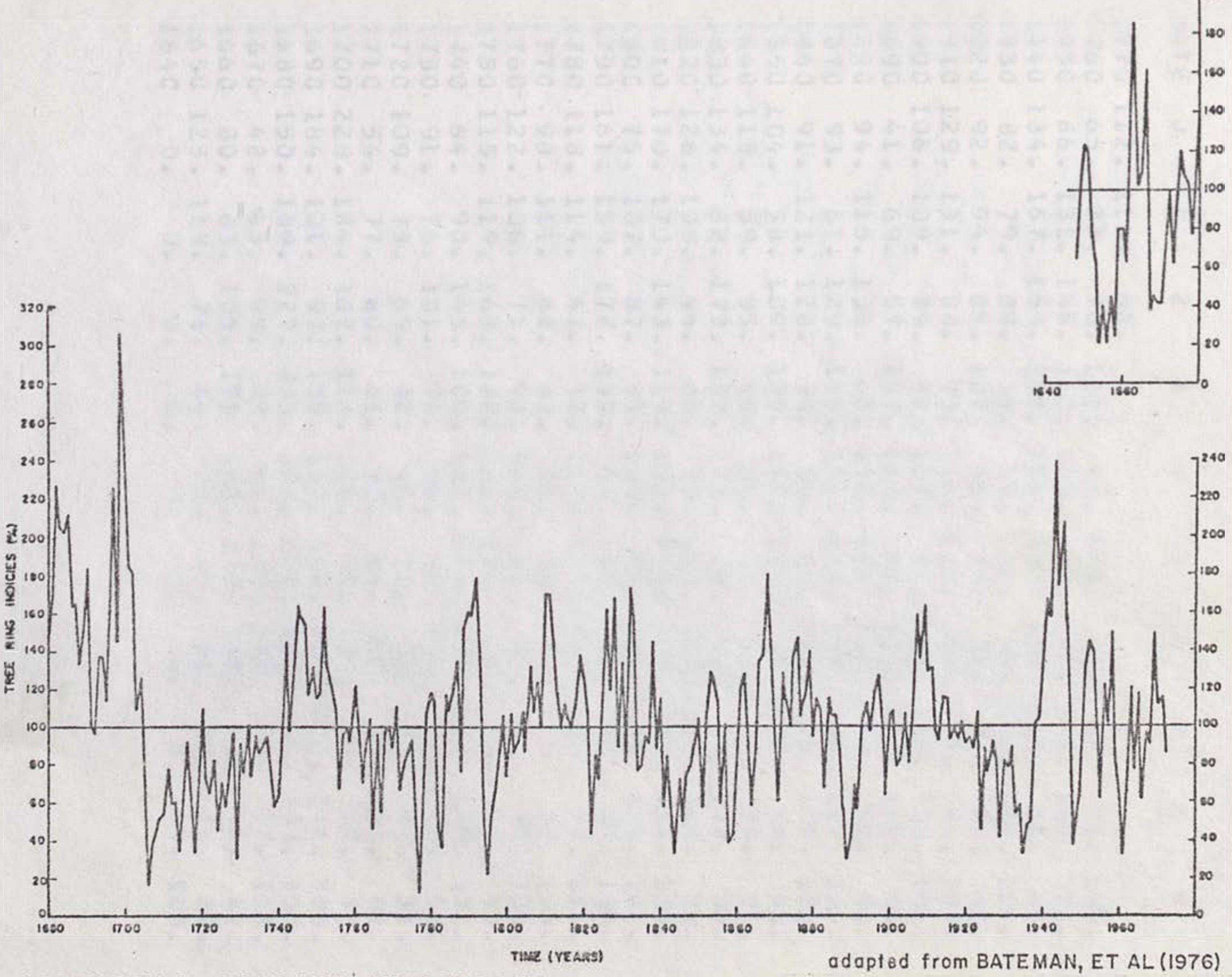


APPENDIX A. PINE NUT CHRONOLOGY

APPENDIX A

INDICES OF GROWTH FOR THE PINE-NUT TREE-RING CHRONOLOGY

DATE	0	1	2	3	4	5	6	7	8	9
1970	114.	111.	74.							
1960	52.	61.	165.	167.	106.	121.	106.	118.	48.	173.
1950	65.	83.	122.	104.	70.	28.	154.	100.	156.	80.
1940	112.	84.	146.	155.	80.	140.	110.	92.	20.	96.
1930	51.	59.	89.	58.	57.	92.	103.	99.	127.	81.
1920	48.	95.	115.	130.	35.	103.	51.	118.	43.	22.
1910	111.	118.	70.	103.	139.	125.	132.	114.	105.	95.
1900	91.	129.	79.	93.	103.	81.	130.	140.	121.	140.
1890	107.	138.	118.	114.	110.	113.	98.	89.	53.	26.
1880	128.	114.	148.	71.	157.	94.	119.	95.	64.	47.
1870	71.	50.	141.	120.	117.	171.	163.	137.	139.	96.
1860	99.	91.	123.	103.	59.	107.	106.	135.	159.	112.
1850	132.	70.	141.	158.	132.	122.	23.	77.	20.	34.
1840	122.	62.	106.	91.	30.	95.	58.	121.	130.	106.
1830	128.	55.	138.	116.	57.	43.	63.	74.	116.	110.
1820	79.	60.	32.	77.	50.	122.	134.	106.	140.	56.
1810	117.	148.	107.	107.	78.	103.	94.	117.	81.	117.
1800	89.	139.	104.	114.	151.	99.	119.	86.	83.	88.
1790	110.	85.	132.	93.	59.	20.	42.	125.	110.	154.
1780	68.	89.	13.	10.	81.	105.	93.	125.	57.	159.
1770	99.	115.	84.	97.	79.	101.	40.	38.	53.	59.
1760	109.	122.	89.	86.	78.	54.	89.	101.	101.	131.
1750	102.	119.	125.	102.	90.	109.	53.	53.	90.	108.
1740	0.	0.	0.	0.	0.	171.	201.	176.	89.	126.



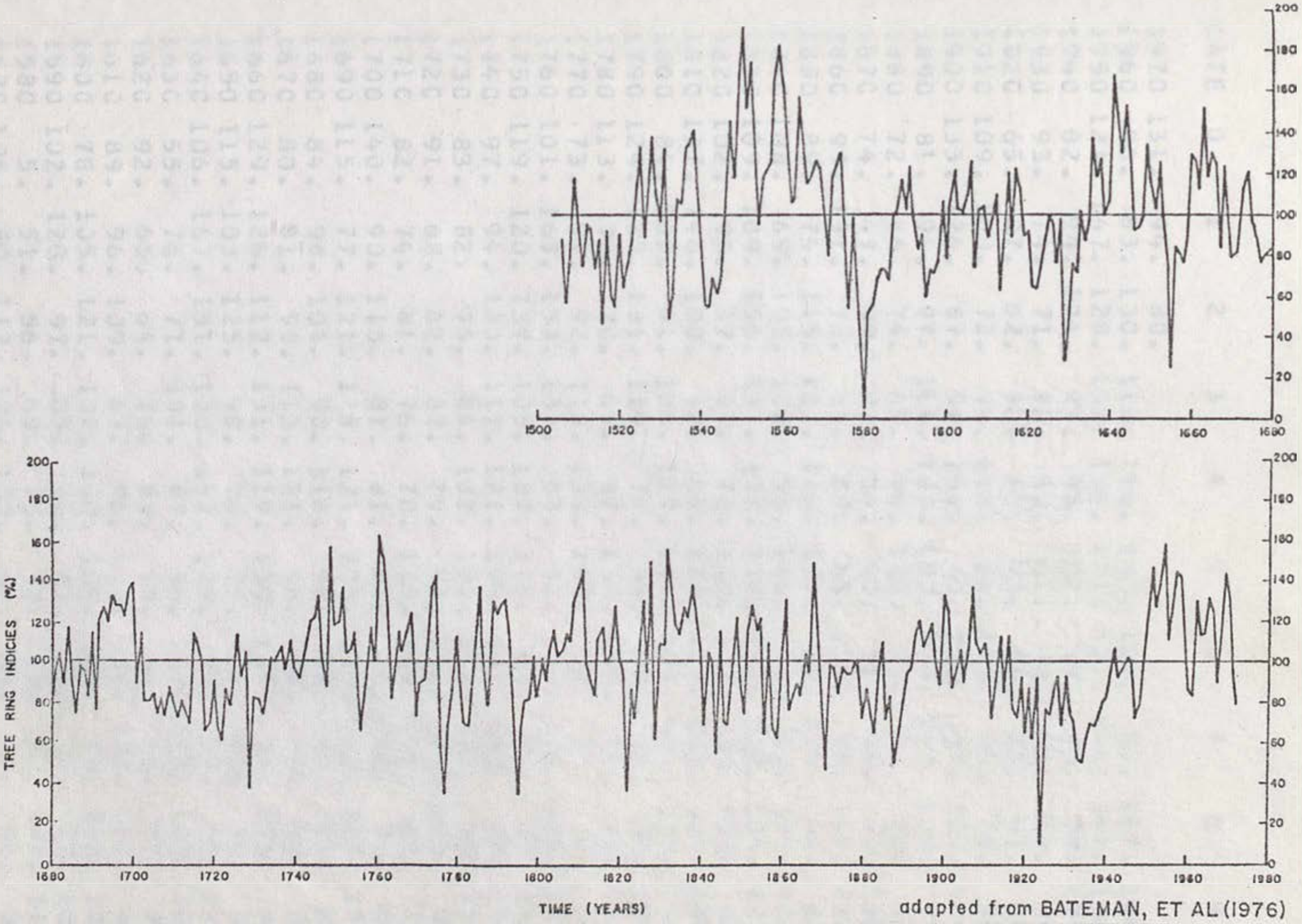
adapted from BATEMAN, ET AL (1976)

APPENDIX A. SKYLINE CHRONOLOGY

APPENDIX A CONTINUED

INDICES OF GROWTH FOR THE SKYLINE TREE-RING CHRONOLOGY

DATE	0	1	2	3	4	5	6	7	8	9
1970	112.	116.	86.							
1960	65.	33.	70.	121.	78.	118.	62.	97.	91.	149.
1950	86.	131.	145.	140.	103.	62.	122.	102.	149.	83.
1940	134.	167.	158.	238.	174.	207.	158.	116.	38.	63.
1930	82.	79.	89.	54.	59.	34.	48.	50.	102.	104.
1920	92.	94.	89.	107.	46.	89.	76.	92.	84.	42.
1910	129.	131.	88.	93.	116.	115.	93.	99.	94.	103.
1900	106.	109.	79.	83.	107.	81.	102.	159.	136.	164.
1890	41.	69.	57.	103.	113.	98.	118.	127.	102.	54.
1880	94.	115.	109.	68.	115.	106.	106.	90.	57.	30.
1870	93.	61.	129.	115.	101.	137.	147.	106.	117.	139.
1860	91.	121.	128.	94.	59.	88.	134.	138.	179.	132.
1850	104.	58.	109.	129.	125.	114.	60.	101.	39.	43.
1840	115.	59.	85.	48.	34.	72.	51.	74.	79.	91.
1830	134.	82.	173.	159.	77.	79.	95.	91.	145.	89.
1820	126.	108.	44.	85.	73.	129.	162.	120.	168.	90.
1810	170.	170.	143.	119.	101.	112.	105.	100.	111.	138.
1800	75.	107.	87.	93.	108.	88.	132.	109.	124.	102.
1790	161.	159.	178.	135.	54.	23.	52.	66.	81.	106.
1780	118.	114.	47.	37.	117.	109.	117.	135.	77.	151.
1770	90.	111.	68.	83.	86.	94.	51.	13.	55.	108.
1760	122.	106.	71.	90.	104.	47.	96.	56.	97.	100.
1750	115.	119.	163.	132.	122.	111.	68.	96.	99.	93.
1740	64.	90.	145.	100.	121.	164.	158.	155.	118.	132.
1730	91.	76.	101.	74.	96.	86.	90.	95.	77.	58.
1720	109.	73.	65.	82.	46.	71.	59.	78.	97.	31.
1710	54.	77.	60.	61.	35.	64.	92.	70.	34.	62.
1700	228.	184.	182.	110.	126.	71.	17.	37.	47.	52.
1690	184.	101.	97.	138.	137.	114.	165.	226.	146.	306.
1680	150.	169.	227.	205.	203.	212.	165.	166.	134.	150.
1670	42.	63.	99.	63.	97.	120.	108.	103.	77.	113.
1660	80.	63.	105.	155.	102.	110.	141.	38.	46.	42.
1650	123.	119.	76.	64.	20.	40.	21.	45.	24.	80.
1640	0.	0.	0.	0.	0.	0.	0.	0.	65.	103.



adapted from BATEMAN, ET AL (1976)

APPENDIX A. HIRSCHDALE CHRONOLOGY

APPENDIX A CONTINUED

INDICES OF GROWTH FOR THE HIRSCHDALE TREE-RING CHRONOLOGY

DATE	0	1	2	3	4	5	6	7	8	9
1970	131.	94.	80.							
1960	86.	83.	130.	113.	114.	132.	125.	90.	117.	144.
1950	121.	147.	128.	139.	158.	111.	127.	144.	141.	108.
1940	82.	94.	106.	93.	98.	102.	99.	72.	79.	104.
1930	93.	74.	71.	52.	50.	61.	69.	68.	72.	79.
1920	65.	87.	62.	92.	10.	77.	74.	86.	93.	69.
1910	109.	100.	72.	94.	112.	85.	113.	76.	73.	93.
1900	133.	126.	87.	94.	106.	90.	106.	137.	109.	104.
1890	81.	94.	97.	114.	121.	107.	112.	119.	100.	89.
1880	72.	86.	74.	65.	96.	110.	71.	83.	50.	66.
1870	74.	47.	99.	97.	84.	97.	94.	94.	99.	101.
1860	99.	131.	76.	84.	89.	83.	104.	95.	149.	110.
1850	89.	74.	115.	127.	116.	122.	64.	109.	66.	62.
1840	108.	69.	105.	100.	55.	116.	70.	68.	105.	122.
1830	109.	109.	156.	137.	118.	113.	127.	122.	138.	121.
1820	102.	95.	37.	87.	72.	110.	131.	95.	150.	62.
1810	137.	146.	100.	92.	84.	111.	117.	101.	104.	128.
1800	84.	102.	91.	106.	117.	104.	106.	114.	110.	130.
1790	124.	129.	131.	114.	78.	35.	68.	81.	82.	104.
1780	113.	94.	70.	69.	97.	118.	137.	94.	80.	130.
1770	73.	91.	92.	115.	139.	143.	58.	35.	71.	89.
1760	101.	163.	153.	133.	83.	95.	115.	106.	116.	125.
1750	119.	120.	137.	105.	107.	115.	67.	80.	99.	118.
1740	97.	94.	100.	111.	121.	123.	133.	102.	88.	157.
1730	83.	82.	75.	84.	102.	101.	104.	107.	97.	111.
1720	91.	68.	62.	87.	79.	92.	114.	94.	105.	38.
1710	82.	74.	81.	76.	70.	115.	110.	101.	67.	70.
1700	140.	90.	115.	81.	81.	84.	75.	82.	74.	88.
1690	115.	77.	121.	128.	121.	133.	129.	129.	123.	137.
1680	84.	98.	104.	90.	118.	92.	76.	99.	97.	84.
1670	80.	81.	99.	113.	121.	96.	89.	76.	80.	82.
1660	129.	126.	112.	151.	119.	130.	125.	84.	123.	84.
1650	115.	103.	125.	98.	74.	25.	84.	81.	76.	88.
1640	106.	167.	151.	130.	152.	129.	93.	94.	99.	134.
1630	55.	76.	71.	101.	87.	96.	137.	118.	127.	100.
1620	92.	65.	64.	75.	88.	98.	95.	76.	97.	28.
1610	89.	96.	109.	63.	96.	120.	88.	122.	113.	89.
1600	78.	105.	121.	102.	100.	109.	125.	74.	102.	103.
1590	102.	123.	97.	83.	90.	57.	73.	71.	77.	106.
1580	5.	51.	56.	69.	73.	72.	68.	100.	101.	117.
1570	105.	80.	117.	125.	130.	90.	54.	98.	66.	39.

APPENDIX A CONTINUED

INDICES OF GROWTH FOR THE HIRSCHDALE TREE-RING CHRONOLOGY CONTINUED

DATE	0	1	2	3	4	5	6	7	8	9
1560	164.	135.	105.	107.	157.	133.	115.	118.	127.	123.
1550	191.	152.	173.	142.	95.	117.	121.	125.	165.	182.
1540	79.	56.	55.	69.	61.	71.	106.	145.	118.	166.
1530	97.	132.	49.	59.	107.	105.	132.	134.	141.	112.
1520	90.	64.	74.	86.	113.	133.	89.	114.	138.	110.
1510	92.	75.	95.	93.	74.	88.	47.	92.	60.	55.
1500	0.	0.	0.	0.	0.	0.	88.	57.	77.	118.

11.0 APPENDIX B

OBSERVED NIXON FLOWS

CUBIC FEET PER SECOND

APPENDIX B

OBSERVED NIXON FLOWS. CUBIC FEET PER SECOND.

DATE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1972	40680	8420	20270	33050	32390	45730	13605	13777	5794	1787	6438	3250
1971	7650	4700	35070	59610	51580	53150	45800	75880	103800	27710	14700	29860
1970	2900	2180	21210	128300	127300	90450	31447	12228	16716	26684	4799	3818
1969	2860	2580	10430	79140	90570	135100	201800	212400	206400	25167	1650	2127
1968	25750	19170	27860	33030	51860	51430	13750	4180	3120	1606	3156	4090
1967	2246	2960	3620	9650	4410	67280	36310	191600	225800	72547	4983	17290
1966	2522	17280	45340	36360	20040	12950	3777	2976	1602	1119	1488	2039
1965	1990	2040	95140	73250	55450	35240	34500	81470	29610	2434	18499	2792
1964	2630	3730	2230	1930	1520	12750	3180	4195	1682	160	1126	1626
1963	13648	2030	2510	4250	128600	8990	10910	85510	55080	3300	2006	2520
1962	356	1140	1120	1140	2690	1520	18265	13045	700	225	89	250
1961	1710	1730	1780	1390	1340	1380	634	328	81	0	1420	311
1960	1450	1440	1560	1640	4580	2520	1386	2802	0	333	225	1019
1959	375	3580	2170	3180	3410	1840	1250	1610	1130	1280	1570	1780
1958	1012	2310	3220	2040	6950	4590	153218	261858	69342	1059	4919	0
1957	1891	3208	3315	3315	8536	28302	3366	25027	41026	535	0	950
1956	261	8	64940	89282	65399	67906	77531	104102	107963	6789	111	356
1955	1976	2744	2517	307	277	307	665	1120	1510	1430	1330	1030
1954	1489	2627	2509	2332	1663	7580	11018	14832	1624	172	1053	1327
1953	5061	6162	17463	36002	43613	6530	14268	52310	75761	19652	317	659
1952	1697	2435	9892	47001	113642	107207	211296	329630	178952	22352	1875	8326
1951	2226	94788	198135	113236	64627	41232	11935	10231	5795	564	673	1301
1950	79	1247	1719	1608	1552	1719	20772	46011	20119	647	0	970
1949	1453	1188	1630	1228	1109	1287	1556	5289	487	57	53	40
1948	1948	1733	1535	1228	1148	1228	1768	4269	15826	297	0	776

APPENDIX B CONTINUED

DATE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1947	1818	10807	17117	29379	11039	3122	1168	4651	578	0	311	847
1946	3297	6423	21521	24920	28740	18798	52488	49791	4944	588	327	1000
1945	1616	4378	2629	2184	13139	7744	23690	67655	18929	1647	662	1436
1944	10452	9639	4283	2629	3789	30033	14927	7429	2610	909	616	584
1943	2726	8528	28207	94054	145201	137764	163675	85813	29938	2515	1790	2079
1942	1536	9043	39117	57161	73260	45655	86436	86259	135586	15198	111	1432
1941	3265	22859	39770	36931	22715	3837	1727	33616	26851	1152	1158	774
1940	2107	2269	2299	4445	6158	49245	105999	88158	17790	746	0	1208
1939	8710	28431	31159	14997	23200	25776	14165	1511	1247	0	0	582
1938	5055	2352	68177	11648	35000	55998	145433	248635	142469	19396	1156	1899
1937	3944	3128	2479	3115	31726	37844	61414	42847	4065	0	0	0
1936	744	2231	2059	3154	5914	16923	64831	58669	23463	620	438	2582
1935	1822	2101	1760	1665	1596	1402	40887	54167	20746	0	0	0
1934	618	2823	2968	2382	2121	5340	2831	214	1182	0	0	222
1933	944	2051	2045	1899	1899	2224	1186	3606	16810	186	0	0
1932	0	1148	1208	2039	1946	6675	26092	49401	25597	386	0	0
1931	1701	1657	1597	1725	1018	224	174	46	0	0	111	0
1930	737	1226	5423	1523	1178	6690	19778	3546	550	0	0	131
1929	1897	1897	2570	8876	1695	1445	1045	1881	5103	0	0	0

OCTOBER 1928 - DECEMBER 1957 (CALENDAR YEARS), FLOWS WERE MEASURED AT THE PYRAMID DAM GAUGING SITE BY THE FEDERAL WATER MASTER, RENO, NEVADA. THESE RECORDS ARE ON FILE AT THAT OFFICE.

JANUARY 1958 TO PRESENT, FLOWS WERE MEASURED AT THE USGS GAUGING SITE APPROXIMATELY TWO MILES UP STREAM FROM THE OLD SITE. THESE RECORDS HAVE BEEN ADJUSTED TO THE OLD SITE BY REMOVING THE FLOW OF THE BUREAU OF INDIAN AFFAIRS-NIXON DITCH, WHICH LIES INBETWEEN.

THE 1955 RECORDS ARE INCOMPLETE SO THE DERBY DAM FLOWS ARE USED INSTEAD.

12.0 APPENDIX C

OBSERVED TRUCKEE CANAL FLOWS AT DERBY DAM HEAD GAUGE, 1917-1966. 1967-1972 FLOWS AT TUNNEL NUMBER 3, NEAR WADSWORTH, NEVADA. CUBIC FEET PER SECOND

APPENDIX C

OBSERVED TRUCKEE CANAL FLOWS AT DERBY DAM HEAD GAUGE, 1917-1966. 1967-1972 FLOWS AT TUNNEL NUMBER 3, NEAR WADSWORTH, NEVADA. CUBIC FEET PER SECOND.

DATE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1972	26710	26829	14710	2520	964	12170	35720	53680	29845	13498	14313	21109
1971	25450	29790	728	0	0	0	23770	45370	30260	28180	19350	16900
1970	14347	29020	23903	2960	1710	5550	8680	48980	48940	18000	15850	19530
1969	20640	31820	25100	3340	3340	1690	9930	13660	10340	20720	15450	20210
1968	15790	16590	12290	2400	1850	1960	19710	40000	21480	14340	16830	17380
1967	19455	28021	43118	31960	34560	19100	6300	18380	13030	23510	20850	18700
1966	31415	26223	26469	18774	3455	24364	30308	44596	14866	14414	16786	17119
1965	17998	21643	32246	15147	12898	11442	46429	16858	44392	20925	11092	20212
1964	17695	29849	27179	26360	23724	4512	25657	52818	30909	12739	12844	17089
1963	31199	32302	32173	22323	11817	19644	41469	35387	25338	16583	17008	19875
1962	4847	7223	9852	10539	18465	21815	54606	54135	36618	12969	13028	14200
1961	20875	18612	21732	16598	19572	19681	19551	19911	17052	11722	12022	6579
1960	21255	24058	25553	23473	30848	37227	34612	29808	22815	15798	16531	16186
1959	28937	31105	33596	32254	29593	34606	20196	21566	12707	13103	13834	18952
1958	29668	31396	33757	30446	30654	38452	17319	40933	47234	25138	19487	25312
1957	30631	37060	36381	30136	29217	40061	37582	47817	38618	16309	13874	18390
1956	19768	22134	30472	36725	9829	33496	32551	38747	26057	28154	15818	19665
1955	20702	27318	30840	32460	26395	30232	24219	29317	30785	13174	11301	16344
1954	31203	33899	32321	30515	28959	36641	36152	38176	16220	12266	13733	18041
1953	26250	32307	31210	29385	31038	34371	30957	38838	25508	36727	19574	24978
1952	26282	33226	41435	34505	12369	17160	24623	41255	44376	50003	21249	22271
1951	25213	30771	5930	2455	7444	14259	34469	60566	53343	13460	15309	19283
1950	14953	16816	20010	31452	31093	33909	51444	52103	46690	16574	14786	23514
1949	21323	23811	27775	23760	22770	25273	36400	48274	16089	11943	13333	10328
1948	25710	26663	27746	29517	22524	19326	23011	37422	41425	14543	13987	15899

APPENDIX C CONTINUED

DATE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1947	30021	29898	15850	10955	23984	32528	20544	25074	13613	11601	12674	16551
1946	24501	30223	18349	15990	3483	24019	33107	33575	23394	15030	13397	19549
1945	24629	31371	28989	28257	33830	37082	21558	17527	18099	14309	13056	17891
1944	20246	23711	29755	30108	27552	9393	17248	34448	23750	13096	13011	16042
1943	21958	29379	14707	10941	2804	3142	8763	23714	28029	18610	13579	17693
1942	25116	21671	4788	1477	1345	1883	25104	29801	16200	17010	12621	18366
1941	23447	11387	1594	2087	21774	41507	32527	50603	19356	15359	15866	18448
1940	29922	23558	24637	36741	33321	22010	12430	22477	23950	15507	12167	21451
1939	20986	4241	3041	20917	6269	10906	14658	19701	12258	12345	13876	21693
1938	5071	15529	16577	19535	4516	2746	5995	11183	12141	19786	13464	16361
1937	13296	12385	11987	12706	5429	2247	13506	51809	29975	13058	10031	6639
1936	1903	5562	7538	16622	21922	40913	43574	46298	31623	11850	11920	9169
1935	5453	8067	6795	8878	10745	12068	44867	51876	39087	6364	1671	1198
1934	1142	6956	10482	12724	13137	30217	20570	6294	3255	3764	8510	6823
1933	3748	4429	5326	7829	7932	11371	20917	26338	33432	5374	871	531
1932	1683	2988	8247	13442	14001	29761	46878	47514	43489	13480	6526	2701
1931	8878	11652	7970	9882	9116	19008	14795	14450	2164	240	0	461
1930	6637	9829	24778	15375	22386	32058	47847	47520	28013	7154	6368	7855
1929	16972	18042	15270	9005	12957	22439	23920	39194	15571	8371	4069	3756
1928	23653	28940	19659	4095	7950	7022	22636	41406	12806	11480	11621	14258
1927	2330	10304	19523	22762	25993	37266	36076	37253	35111	21675	12494	17759
1926	15818	15517	18347	14824	20881	30258	32632	27409	9239	6120	2932	1321
1925	10347	14628	9777	12937	27065	32134	35725	37383	28589	14361	14098	9765
1924	26457	26475	20579	16800	12621	17165	16606	11369	3782	1291	2705	5253
1923	23134	19853	14131	16674	14947	13288	18315	32937	34205	24087	21715	24091
1922	19888	20278	18987	15796	12642	11296	16133	32514	25031	19764	14844	16782
1921	11654	19844	23574	10205	11215	8773	32017	35290	33995	13900	11139	17984
1920	23612	26728	18800	18836	22469	28710	18422	31773	23582	11935	10896	9272
1919	16230	16000	15254	17954	18952	22362	26246	32712	19658	15378	16148	17260
1918	22630	26858	31334	9322	22268	26336	12402	32960	29948	22616	23348	23914
1917	10334	10922	12556	41774	40166	43372	47000	53000	50006	58364	26970	20908

13.0 APPENDIX D

PYRAMID LAKE ELEVATIONS IN FEET, INTERPOLATED TO THE 15TH OF THE MONTH

APPENDIX D

PYRAMID LAKE ELEVATIONS IN FEET, INTERPOLATED TO THE 15TH OF THE MONTH.

DATE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1972	3794.90	3794.85	3794.85	3794.95	3795.10	3795.30	3795.50	3795.45	3795.20	3794.90	3794.30	3793.85
1971	3793.50	3793.10	3793.00	3793.15	3793.75	3794.05	3794.25	3794.75	3795.65	3796.00	3795.80	3795.25
1970	3792.30	3792.05	3791.80	3792.15	3793.75	3794.70	3795.00	3795.00	3794.90	3794.90	3794.30	3793.75
1969	3786.70	3786.35	3786.10	3786.15	3787.10	3787.90	3789.50	3791.40	3793.10	3793.95	3793.45	3792.80
1968	3788.05	3787.75	3787.70	3787.75	3788.20	3788.70	3788.80	3788.80	3788.60	3788.10	3787.55	3787.10
1967	3784.70	3784.20	3784.05	3784.10	3783.90	3784.00	3784.60	3785.20	3787.60	3789.00	3788.80	3788.35
1966	3787.10	3787.10	3787.10	3787.10	3787.10	3787.20	3787.10	3786.80	3786.55	3786.35	3785.90	3785.10
1965	3786.40	3786.15	3786.25	3786.80	3787.60	3787.85	3787.90	3788.40	3788.75	3788.55	3788.15	3787.70
1964	3789.85	3789.55	3789.35	3788.90	3788.90	3788.65	3788.50	3788.70	3788.60	3788.30	3787.60	3786.95
1963	3790.10	3789.70	3789.75	3789.40	3790.20	3790.30	3790.50	3790.75	3791.75	3791.10	3790.50	3790.05
1962	3793.10	3792.65	3792.15	3791.90	3791.80	3791.80	3792.05	3792.15	3792.05	3791.30	3791.00	3790.45
1961	3795.95	3795.95	3795.75	3795.30	3795.00	3794.90	3794.70	3794.50	3794.50	3794.10	3793.65	3793.35
1960	3799.45	3799.10	3798.80	3798.60	3798.50	3798.50	3798.30	3797.95	3797.70	3796.90	3796.70	3796.65
1959	3803.10	3802.60	3802.40	3802.30	3802.05	3802.05	3801.95	3801.65	3801.45	3801.20	3800.40	3800.00
1958	3801.55	3801.35	3801.25	3801.05	3800.90	3800.85	3801.30	3803.35	3804.55	3804.60	3804.20	3803.70
1957	3804.15	3804.10	3804.20	3804.30	3804.10	3803.90	3803.60	3803.50	3803.50	3803.15	3802.55	3801.95
1956	3801.90	3802.00	3802.30	3802.80	3803.10	3803.55	3804.20	3804.90	3805.55	3805.65	3805.15	3804.55
1955	3805.60	3805.10	3804.60	3804.55	3804.39	3804.25	3803.95	3803.80	3803.85	3803.55	3802.85	3802.45
1954	3808.64	3808.20	3807.95	3807.64	3807.55	3807.60	3807.55	3807.35	3807.25	3807.05	3806.60	3806.10
1953	3809.45	3809.00	3808.80	3809.05	3809.20	3809.25	3809.25	3809.35	3809.80	3810.30	3809.60	3809.14
1952	3803.64	3803.14	3803.05	3803.05	3803.60	3804.45	3805.85	3808.10	3810.45	3810.45	3810.30	3809.80
1951	3802.05	3801.64	3803.60	3804.64	3805.35	3805.70	3805.64	3805.64	3805.60	3805.10	3804.60	3804.20
1950	3804.55	3804.25	3803.95	3803.75	3803.55	3803.45	3803.45	3803.55	3803.55	3803.39	3802.85	3802.50
1949	0.0	0.0	0.0	0.0	3805.70	3805.85	0.0	0.0	0.0	0.0	3805.60	3805.10
1948	3811.35	3811.14	3810.64	3810.14	3810.05	3809.80	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX D CONTINUED

DATE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1947	3813.55	3813.14	3812.89	3812.75	3812.60	3812.25	3812.10	3812.35	3812.80	3812.89	3812.14	3811.64
1946	3815.70	3815.15	3814.89	3815.85	3814.95	3815.00	3815.40	3815.60	3815.55	3815.20	3814.89	3814.39
1945	3817.50	3817.20	3816.80	3816.75	3816.75	3816.70	3816.75	3817.05	3817.20	3817.05	3816.55	3816.05
1944	3820.05	3819.80	3819.45	3819.35	3819.25	3819.14	0.0	0.0	3819.20	3819.00	3818.50	3817.95
1943	3817.14	3816.64	3816.75	3816.85	3818.14	3818.50	3820.30	3821.60	3821.95	3821.64	3821.05	3820.50
1942	3815.45	3815.35	3815.35	3815.45	3816.00	3816.50	3817.05	3817.55	3818.05	3818.60	3818.14	3817.60
1941	3817.00	3816.95	3817.14	3816.95	3817.25	3816.55	3816.14	3816.89	3817.25	3817.14	3816.64	3816.20
1940	3817.80	3817.45	3817.35	3817.20	3817.20	3816.95	3817.64	3818.85	3819.10	3818.64	3818.14	3817.50
1939	3820.20	3819.89	3819.85	3820.25	3820.05	3820.10	3820.14	3820.10	3819.80	3819.35	3818.95	3818.20
1938	3816.89	3816.85	3817.14	3817.14	3816.85	3816.85	3817.55	3818.85	3821.30	3821.64	3821.20	3820.64
1937	3818.70	3818.39	3818.10	3816.95	3817.00	3817.50	3818.10	3818.60	3818.60	3818.55	3818.14	3817.45
1936	3821.30	3820.80	3820.20	3820.14	3819.95	3819.80	3819.80	3820.00	3820.64	3820.20	3819.89	3819.25
1935	3823.39	3822.95	3822.85	3822.60	3822.45	3822.25	3822.05	3822.45	3822.80	3822.45	3821.95	3821.55
1934	3827.55	3827.25	3826.85	3825.95	3825.85	3825.75	3825.60	3825.30	3825.25	3824.89	3824.39	3823.85
1933	3830.39	3829.95	3829.75	3829.39	3829.30	3829.20	3829.14	3829.05	3829.35	3829.20	3828.00	3827.75
1932	3832.64	3832.25	3832.05	3831.85	3831.75	3831.64	3831.64	3831.75	3832.14	3831.89	3831.45	3830.95
1931	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3835.25[b]	0.0	0.0	0.0	0.0
1930	0.0	0.0	0.0	0.0	0.0	3838.85[b]	0.0	0.0	3838.25[b]	0.0	0.0	0.0
1929	3843.55[c]	0.0	0.0	0.0	0.0	0.0	0.0	3841.85[c]	3841.64[c]	3841.10[c]	3840.55[c]	3840.05[c]
1928	3843.55[c]	0.0	0.0	0.0	0.0	3844.95[c]	3845.39[c]	3845.55[c]	3845.14[c]	3844.75[c]	3844.35[c]	3843.95[c]
1927	0.0	0.0	0.0	3846.05[c]	3846.10[c]	3846.14[c]	3846.25[c]	3846.35[c]	3846.70[c]	3846.50[c]	3846.14[c]	3845.75[c]
1926	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3848.75	0.0	0.0	0.0
1925	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1924	0.0	0.0	0.0	0.0	0.0	3854.25	0.0	0.0	0.0	0.0	0.0	0.0
1923	3855.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1922	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3856.80	3855.85
1917	0.0	0.0	0.0	0.0	0.0	3861.65	0.0	0.0	0.0	0.0	0.0	0.0
1915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3861.85	0.0	0.0
1914	0.0	0.0	0.0	0.0	3864.45	0.0	0.0	0.0	0.0	3866.64	0.0	0.0

APPENDIX D CONTINUED

DATE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1913	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3864.70	0.0	0.0
1912	3868.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3866.85	0.0	0.0	0.0
1911	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3869.95	3869.95	3869.60	3868.75
1909	0.0	0.0	0.0	0.0	0.0	0.0	3869.45	0.0	0.0	0.0	0.0	0.0
1904	0.0	0.0	0.0	0.0	0.0	3862.07[a]	0.0	0.0	0.0	0.0	0.0	0.0
1890	0.0	0.0	0.0	0.0	0.0	3876.57[a]	0.0	0.0	0.0	0.0	0.0	0.0
1891	0.0	0.0	0.0	0.0	0.0	3878.15[a]	0.0	0.0	0.0	0.0	0.0	0.0
1889	0.0	0.0	0.0	0.0	0.0	3861.07[a]	0.0	0.0	0.0	0.0	0.0	0.0
1882	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3867.15
1871	0.0	0.0	0.0	0.0	0.0	3876.25[a]	0.0	0.0	0.0	0.0	0.0	0.0
1867	0.0	0.0	0.0	0.0	0.0	3867.25[a]	0.0	0.0	0.0	0.0	0.0	0.0
1856	0.0	0.0	0.0	0.0	0.0	3860.25[a]	0.0	0.0	0.0	0.0	0.0	0.0
1844	0.0	0.0	0.0	3860.75[b]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] DATA IS PLACED IN MID-YEAR BECAUSE ONLY THE YEAR OF THE OBSERVATION IS KNOWN.

[b] DATA IS PLACED IN MID-MONTH BECAUSE ONLY THE MONTH OF THE OBSERVATION IS KNOWN.

[c] DATA IS PLACED IN MID-MONTH BECAUSE ONLY THE MONTH OF THE OBSERVATION IS KNOWN. THIS DATA HAS BEEN INTERPOLATED TO THE 15TH OF THE MONTH TO FILL IN MISSING DATA BETWEEN CLOSELY SPACED POINTS.

14.0 APPENDIX E

14.1 PYRAMID LAKE ELEVATION MODEL DISCUSSION
14.2 PYRAMID LAKE ELEVATION MODEL FLOW CHART
14.3 PYRAMID LAKE ELEVATION MODEL USING TREE-RING GENERATED TRUCKEE RIVER FLOWS AS INPUT

14.0 APPENDIX E

14.1 THE PYRAMID LAKE ELEVATION MODEL DISCUSSION

The model is a straight forward monthly calculation of a new volume contained in the lake based upon the amount of inflow to the lake, less the evaporation and overflow (see the following flow chart, Appendix E). This final volume is used to calculate the surface area and lake elevation that correspond to that volume. The final volume, area, and elevation from one step become the initial values for the next step.

The only iterative loop within the program is for calculating the average area, AAREA, and Winnemucca Slough flows, WSFLO(J,M). At the beginning of each time step AAREA is set equal to the initial area, AREAI(J,M), for that step. The program then calculates the average elevation AEL(J,M), from AAREA. If AEL(J,M) is greater than 3863.25 feet the model chooses the appropriate equations for Manning's hydraulic radius, R, and cross-sectional area, XSECA. These values are then used in Manning's equation to calculate the volume of overflow through Winnemucca Slough, WSFLO(J,M). With this information on hand, the GAIN, final volume VOLF(J,M) and final area AREAF(J,M) are calculated. The average area, AAREA, can then be tested to see if it is less than 0.5 acre (an arbitrary cutoff for the test) from the true average of (AREAI(J,M) + AREAF(J,M)/2. If the test fails, the program loops back to perform the calculations again with AAREA set equal to the average it just calculated. This process rarely takes more than two iterations to close within the allowable error.

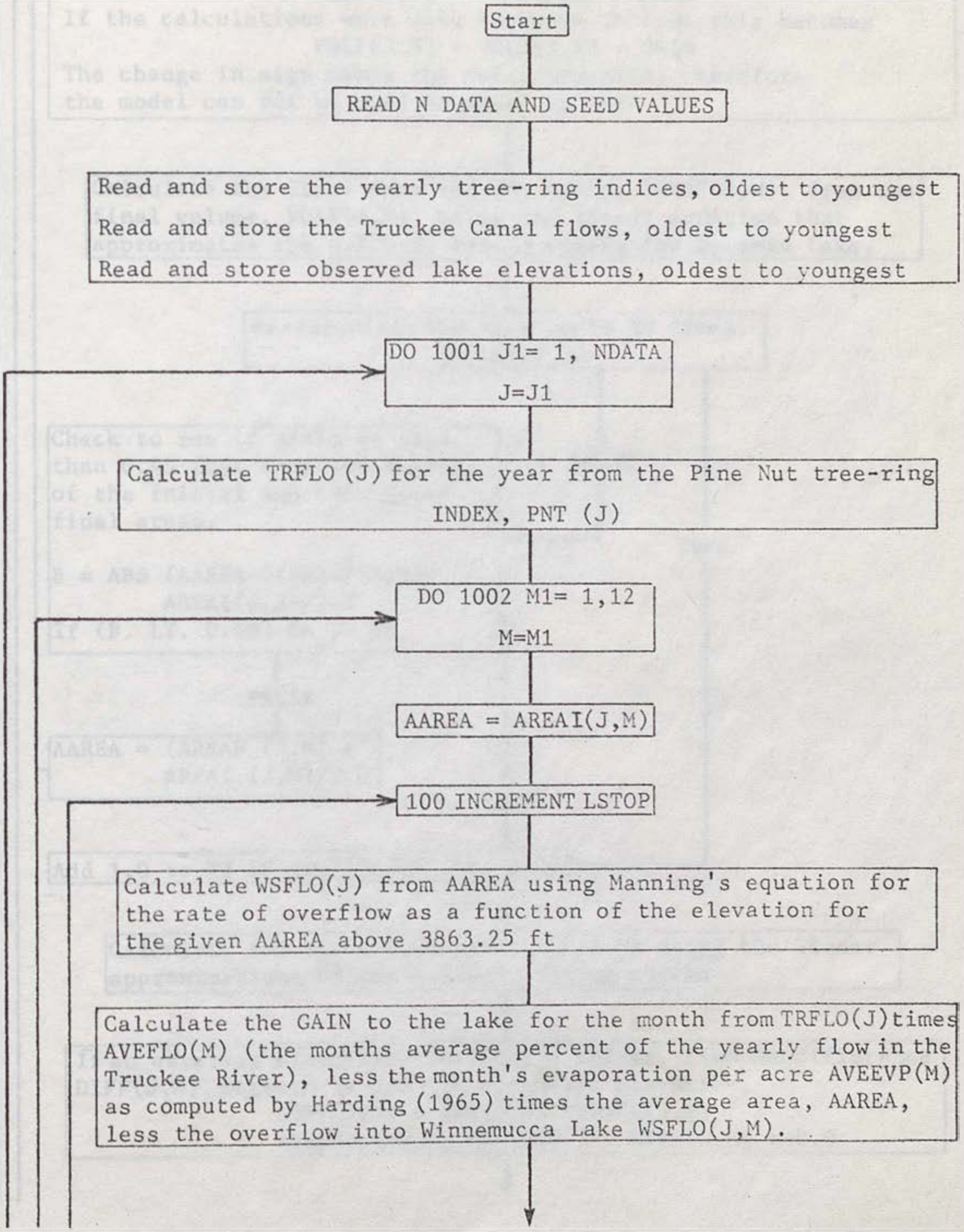
This procedure for calculating evaporation and overflow relative to the average area for the month makes the observed elevation on the middle of the month the most desirable for checking the synthetic elevations.

After all calculations have been made and stored, monthly and yearly summary tables are printed. The yearly values are the average of the twelve monthly calculations. The yearly averages are easier to interpret since the tree-ring data is on a yearly basis, and is the limiting factor of the accuracy of the calculations.

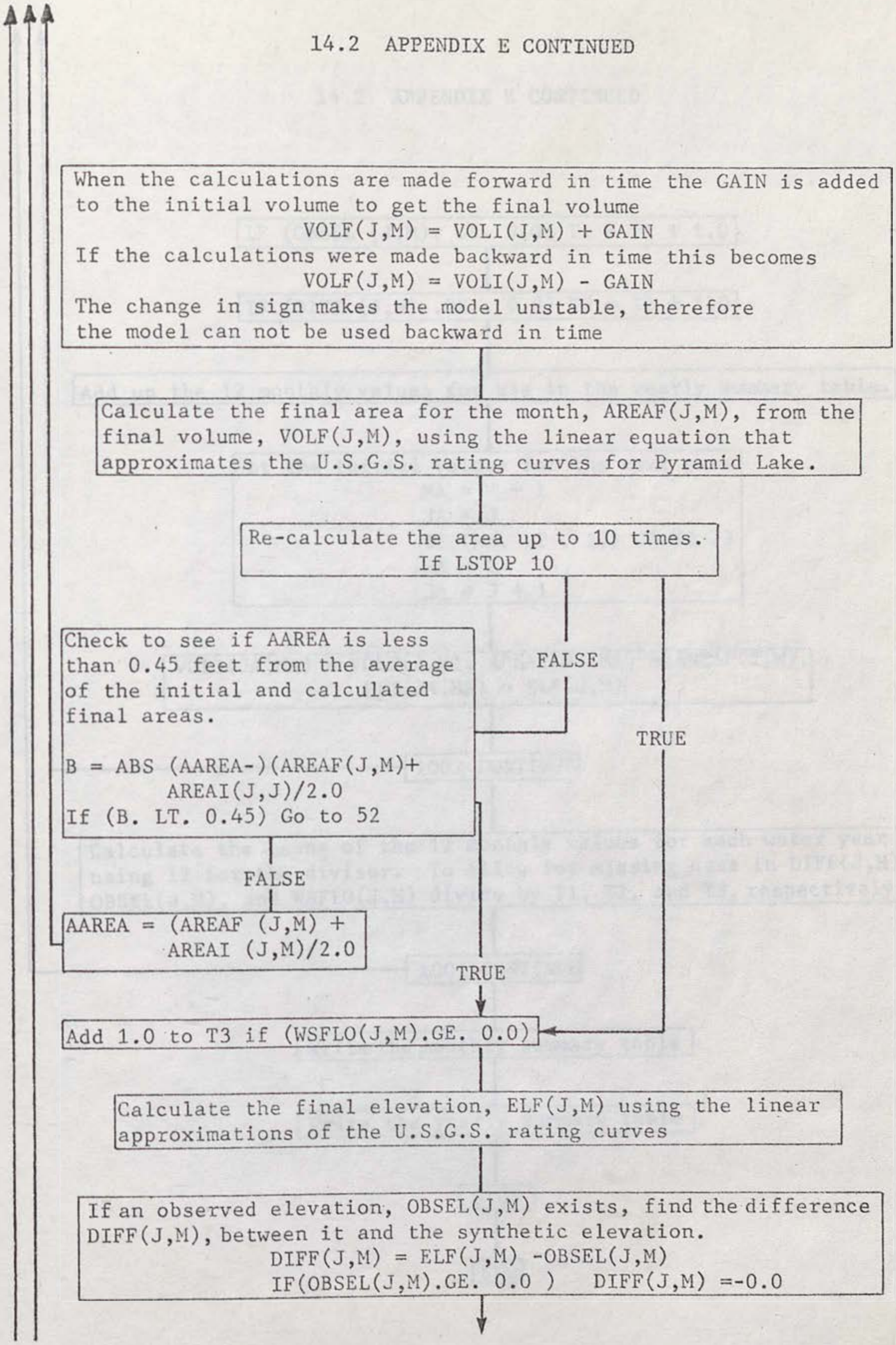
14.2 APPENDIX E

PYRAMID LAKE ELEVATION MODEL

FLOW CHART



14.2 APPENDIX E CONTINUED



When the calculations are made forward in time the GAIN is added to the initial volume to get the final volume

VOLF(J,M) = VOLI(J,M) + GAIN

If the calculations were made backward in time this becomes

VOLF(J,M) = VOLI(J,M) - GAIN

The change in sign makes the model unstable, therefore the model can not be used backward in time

Calculate the final area for the month, AREAF(J,M), from the final volume, VOLF(J,M), using the linear equation that approximates the U.S.G.S. rating curves for Pyramid Lake.

Re-calculate the area up to 10 times.
If LSTOP 10

Check to see if AAREA is less than 0.45 feet from the average of the initial and calculated final areas.

B = ABS (AAREA-)(AREAF(J,M)+
AREAI(J,J)/2.0
If (B. LT. 0.45) Go to 52

AAREA = (AREAF (J,M) +
AREAI (J,M)/2.0

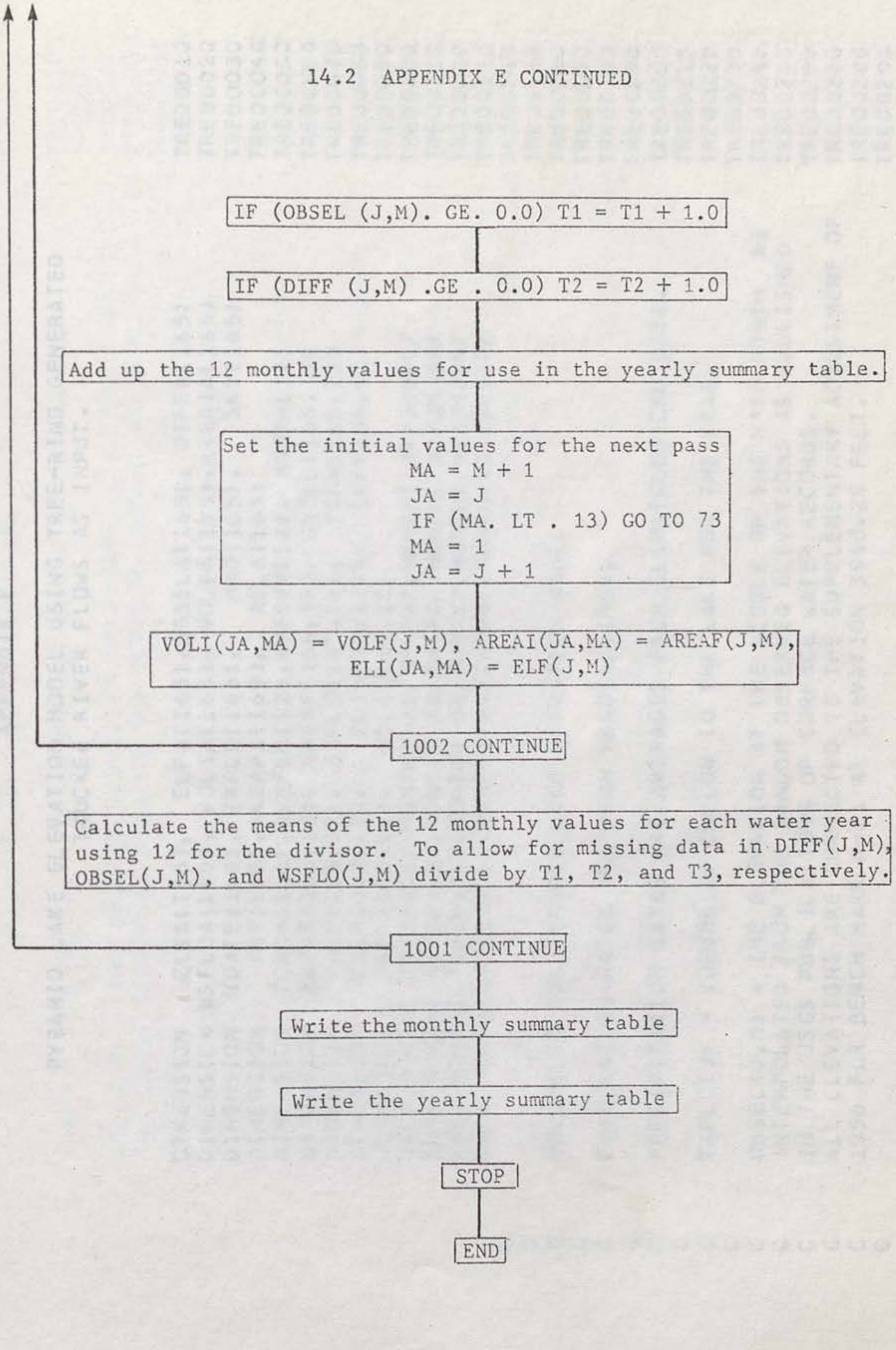
Add 1.0 to T3 if (WSFLO(J,M).GE. 0.0)

Calculate the final elevation, ELF(J,M) using the linear approximations of the U.S.G.S. rating curves

If an observed elevation, OBSEL(J,M) exists, find the difference DIFF(J,M), between it and the synthetic elevation.

DIFF(J,M) = ELF(J,M) -OBSEL(J,M)
IF(OBSEL(J,M).GE. 0.0)   DIFF(J,M) =-0.0

14.2 APPENDIX E CONTINUED



IF (OBSEL (J,M). GE. 0.0) T1 = T1 + 1.0

IF (DIFF (J,M) .GE . 0.0) T2 = T2 + 1.0

Add up the 12 monthly values for use in the yearly summary table.

Set the initial values for the next pass

```
MA = M + 1
JA = J
IF (MA. LT . 13) GO TO 73
MA = 1
JA = J + 1
```

VOLI(JA,MA) = VOLF(J,M), AREAI(JA,MA) = AREAF(J,M), ELI(JA,MA) = ELF(J,M)

1002 CONTINUE

Calculate the means of the 12 monthly values for each water year using 12 for the divisor. To allow for missing data in DIFF(J,M), OBSEL(J,M), and WSFLO(J,M) divide by T1, T2, and T3, respectively.

1001 CONTINUE

Write the monthly summary table

Write the yearly summary table

STOP

END

APPENDIX E

PYRAMID LAKE ELEVATION MODEL USING TREE-RING GENERATED TRUCKEE RIVER FLOWS AS INPUT.

```
      DIMENSION   ELIA(165),  ELFA(165),OBSELA(165), DIFFA(165)         TRE00010
      DIMENSION WSFLOA(165), VOLIA(165), VOLFA(165),AREAIA(165)         TRE00020
      DIMENSION  NDATE(165), TRFLO(165),   HHD(165),    SKY(165)        TRE00030
      DIMENSION    PNT(165),AREAFA(165),  AELA(165)                     TRE00040
      DIMENSION  TCANB(166),AVEFLO(12),AVEEVP(12), MONTH(12)            TRE00050
      DIMENSION  AREAI(165,12), AREAF(166,12), OBSEL(166,12)            TRE00060
      DIMENSION    AEL(165,12), WSFLO(165,12),  TCAN(165,12)            TRE00070
      DIMENSION   VOLF(165,12),     ELI(165,12),  ELF(166,12)           TRE00080
      DIMENSION   DIFF(165,12),   VCLI(165,12)                          TRE00090
      DATA MONTH( 1)/3HOCT/,MONTH( 2)/3HNOV/,MONTH( 3)/3HDEC/           TRE00100
      DATA MONTH( 4)/3HJAN/,MONTH( 5)/3HFEB/,MONTH( 6)/3HMAR/           TRE00110
      DATA MONTH( 7)/3HAPR/,MONTH( 8)/3HMAY/,MONTH( 9)/3HJUN/           TRE00120
      DATA MONTH(10)/3HJUL/,MONTH(11)/3HAUG/,MONTH(12)/3HSEP/           TRE00130
C                                                                       TRE00140
C                                                                       TRE00150
C     VARIABLES FOR PYRAMID LAKE ELEVATION MODEL                        TRE00160
C                                                                       TRE00170
C     EVAPORATION RATES ARE FROM HARDING,1965.                          TRE00180
C                                                                       TRE00190
C     PRECIPITATION RATES ARE AVERAGES FROM CLIMATOLOGICAL DATA.        TRE00200
C                                                                       TRE00210
C     TRFLO(J) = VOLUME OF INFLOW TO THE LAKE FOR THE YEAR.             TRE00220
C                                                                       TRE00230
C     OBSEL(J,M) = THE ELEVATION AT THE MIDDLE OF THE M'TH MONTH  AS     TRE00240
C     INTERPOLATED FROM THE RANDOM OBSERVED ELEVATIONS AS PUBLISHED     TRE00250
C     IN THE USGS PUBLICATIONS OF SURFACE WATER RECORDS.                TRE00260
C     ALL ELEVATIONS ARE CORRECTED TO THE SUPPLEMENTARY ADJUSTMENT OF   TRE00270
C     1956 FOR BENCH MARK N-21 AT ELEVATION 3940.29 FEET.               TRE00280
C                                                                       TRE00290
```

```
C     AAREA = AVERAGE AREA FOR COMPUTING VOLUME OF EVAPORATION.
C
C     AEL(J,M) = THE AVERAGE ELEVATION OF PYRAMID LAKE FOR COMPUTING
C     THE CROSS SECTIONAL AREA OF THE OUTFLOW CHANNEL AT WINNEMUCCA
C     SLOUGH.
C
C     XSECA = CROSS SECTIONAL AREA OF THE OUTFLOW CHANNEL AT
C     WINNEMUCCA SLOUGH.
C
C     R = HYDRAULIC RADIUS OF THE OUTFLOW CHANNEL AT WINNEMUCCA
C     SLOUGH.   THIS IS THE R OF MANNING'S EQUATION.
C
C     WSFLO(J,M) = THE RATE, ACRE FEET PER YEAR, OF OUTFLOW THROUGH
C     WINNEMUCCA SLOUGH.
C
C     GAIN = INFLOW VOLUME LESS THE AVERAGE AREA (AAREA) TIMES THE
C     MONTHS EPAPORATION LESS THE OVERFLOW, WSFLO(J,M).
C
C     AREAI(J,M), VOLI(J,M), AND ELI(J,M)=THE INITIAL AREA, VOLUME, AND
C     ELEVATION OF THE LAKE AT THE BEGINNING OF THE MONTH (THE
C     BEGINNING OF THE STEP).
C
C     AREAF(J,M), VOLF(J,M), AND ELF(J,M) = THE FINAL AREA, VOLUME, AND
C     ELEVATION AT THE MIDDLE OF THE NEXT MONTH.
C     THIS IS THE RESULT OF THE AVERAGING OF THE LAKE AREA, AAREA(J,M)
C     TO GET THE EVAPORATION AND THE AVERAGE ELEVATION, AEL(J,M), TO
C     CALCULATE THE OUTFLOW RATE.
C
      AVEFLO(1)=0.0436
      AVEFLO(2)=0.0605
      AVEFLO(3)=0.0768
      AVEFLO(4)=0.0784
      AVEFLO(5)=0.0867
      AVEFLO(6)=0.0924
```

```
      AVEFLO(7)=0.1494                                                  TRE00640
      AVEFLO(8)=0.1873                                                  TRE00650
      AVEFLO(9)=0.1181                                                  TRE00660
      AVEFLO(10)=0.0407                                                 TRE00670
      AVEFLO(11)=0.0304                                                 TRE00680
      AVEFLO(12)=0.0357                                                 TRE00690
      AVEEVP(1)=0.41                                                    TRE00700
      AVEEVP(2)=0.31                                                    TRE00710
      AVEEVP(3)=0.22                                                    TRE00720
      AVEEVP(4)=0.17                                                    TRE00730
      AVEEVP(5)=0.16                                                    TRE00740
      AVEEVP(6)=0.15                                                    TRE00750
      AVEEVP(7)=0.18                                                    TRE00760
      AVEEVP(8)=0.20                                                    TRE00770
      AVEEVP(9)=0.26                                                    TRE00780
      AVEEVP(10)=0.36                                                   TRE00790
      AVEEVP(11)=0.47                                                   TRE00800
      AVEEVP(12)=0.48                                                   TRE00810
C                                                                       TRE00820
C     READ THE NUMBER OF DATA POINTS.                                   TRE00830
C                                                                       TRE00840
      READ(5,3000) NDATA                                                TRE00850
 3000 FORMAT(I4)                                                        TRE00860
C                                                                       TRE00870
C     READ THE TREE-RING DATA FOR ALL YEARS THEN THE OBSERVED           TRE00880
C     PYRAMID LAKE ELEVATIONS FOR ALL YEARS.                            TRE00890
C                                                                       TRE00900
      READ(5,4)(NDATE(J),HHD(J),SKY(J),PNT(J),J=1,NDATA)                TRE00910
    4 FORMAT(I4,3F7.0/)                                                 TRE00920
      READ(5,6)((OBSEL(J,M),M=1,12),J=1,NDATA)                          TRE00930
    6 FORMAT(4X,12F6.2)                                                 TRE00940
C                                                                       TRE00950
C     READ THE TRUCKEE CANAL FLOWS (TCAN(J,M)) IF APPLICABLE.           TRE00960
C     REMOVE THE C IN THE NEXT TWO CARDS AND PUT A C IN FRONT OF,       TRE00970
```

```
C     THE TCAN(J,M) = -0.0 BELOW.
C      READ(5,7) ((TCAN(J,M),M=1,12),J=1,NDATA)
C    7 FORMAT(4X,12F6.0)
C
C
C
C     READ AND WRITE THE CODE NUMBER AND SIGN THAT INDICATES THE
C     THE DIRECTION THE COMPUTATIONS TAKE PLACE.   A NEGATIVE 1
C     MEANS THE COMPUTATIONS ARE BACKWARD WITH RESPECT TO TIME.
C     A POSITIVE 1 MEANS THEY ARE FORWARD WITH RESPECT TO TIME.
C
      READ(5,5) KNOCK
    5 FORMAT(I2)
C
C
      WRITE(6,3001) KNOCK
 3001 FORMAT(1H1,I2,4X,102H -1 INDICATES THE DIRECTION OF COMPUTATION IS
     1 BACKWARD WITH RESPECT TO TIME.  A +1 IS FORWARD IN TIME.)
C
C
C     READ THE YEAR, MONTH, NUMBER OF DATA POINTS, AND THREE SEED
C     VALUES (ELEVATION, AREA, AND VOLUME).
C
C
      WRITE(6,1)
    1 FORMAT(1H0,46HDATE MONTH NDATA   SEED EL SEED AREA  SEED VOL)
C
      IF (KNOCK.EQ.-1) GO TO 3040
      IF (KNOCK.EQ.+1) GO TO 3041
C
 3040 READ(5,2)MDATE,MMCNTH,NDATA,ELI(NDATA,12),AREAI(NDATA,12),
     1VOLI(NDATA,12)
    2 FORMAT(I4,1X,A3,I4,1X,F7.2,1X,F7.0,3X,F9.0)
      WRITE(6,3)MDATE,MMONTH,NDATA,ELI(NDATA,12),AREAI(NDATA,12),
```

APPENDIX E CONTINUED

```
     1VOLI(NDATA,12)                                                    TRE01320
    3 FORMAT(1H ,I4,3X,A3,1X,I4,3X,F7.2,3X,F7.0,1X,F9.0)                TRE01330
      GO TO 3042                                                        TRE01340
 3041 READ(5,2)MDATE,MMONTH,NDATA,ELI(1,1),AREAI(1,1),VOLI(1,1)         TRE01350
      WRITE(6,3)MDATE,MMONTH,NDATA,ELI(1,1),AREAI(1,1),VOLI(1,1)        TRE01360
 3042 CONTINUE                                                          TRE01370
C                                                                       TRE01380
      IDATA = NDATA + 1                                                 TRE01390
      DO 1001 J1=1,NDATA                                                TRE01400
      IF(KNOCK.EQ.-1) J = IDATA - J1                                    TRE01410
      IF(KNOCK.EQ.+1) J = J1                                            TRE01420
      T1=0.0                                                            TRE01430
      T2= 0.0                                                           TRE01440
      T3=0.0                                                            TRE01450
C                                                                       TRE01460
      AREAFA(J) = -0.0                                                  TRE01470
      AREAIA(J) =-0.0                                                   TRE01480
      VOLFA(J) = -0.0                                                   TRE01490
      VOLIA(J) = -0.0                                                   TRE01500
      WSFLOA(J)= -0.0                                                   TRE01510
      AELA(J) =-0.0                                                     TRE01520
      DIFFA(J) =-0.0                                                    TRE01530
      OBSELA(J) =-0.0                                                   TRE01540
      ELFA(J) =-0.0                                                     TRE01550
      ELIA(J)=-0.0                                                      TRE01560
     ITCANB(J) =-0.0                                                    TRE01570
C                                                                       TRE01580
C                                                                       TRE01590
C     IF NOTYPE =+1  ALL OF THE WRITE STATEMENTS BETWEEN HERE AND THE   TRE01600
C     MONTHLY SUMMARY TABLE ARE DELEATED.  IF ANYTHING ELSE ALL OF      TRE01610
C     THE TABLES WILL PRINT.                                            TRE01620
C                                                                       TRE01630
C                                                                       TRE01640
      READ(5,9) NOTYPE                                                  TRE01650
```

```
   9 FORMAT(I2)
C
     WRITE(6,11) NCTYPE
  11 FORMAT(1X,I4,2X,'A POSITIVE ONE MEANS ALL INTERNAL PRINTS
    *FOR CHECKING FOR PERFORMANCE OF THE MODEL ARE DELETED.',/,
    *7X,'IF ANYTHING ELSE ALL WILL PRINT.')
C
C    TRFLO(J), EQUATICN BELOW, CALCULATES THE SYNTHETIC FLOW OF THE
C    TRUCKEE RIVER USINT TREE-RINGS FOR INPUT.
C
C
  10 TRFLO(J)=(((PNT(J)*(   .92550))+ 10.62960)/100.)*506570.
C
     LSTOP = 0
C
C
     IF(NUTYPE.NE.+1) GO TO 400
C
C
     WRITE(6,20)
  20 FORMAT(1H0,44HDATE     HHD(J)     SKY(J)     PNT(J)  TRFLO(J))
     WRITE(6,21)NDATE(J),HHD(J),SKY(J),PNT(J),TRFLO(J)
  21 FORMAT(1H ,I4,4F10.0)
     WRITE(6,22)
  22 FORMAT(1H ,124HDATE       OCT        NOV        DEC        JAN
    1FEB       MAR       APR       MAY       JUN       JUL       AUG
    2  SEP)
     WRITE(6,23)NDATE(J),(OBSEL(J,M),M=1,12)
  23 FORMAT(1H ,I4,12F10.2)
C
C
C
 400 CONTINUE
C
```

APPENDIX E CONTINUED

```
      DO 1002 M1 = 1,12                                                 TRE02000
      IF(KNOCK.EQ.-1) M = 13 - M1                                       TRE02010
      IF(KNOCK.EQ.+1) M = M1                                            TRE02020
C                                                                       TRE02030
 2002 AAREA=AREAI(J,M)                                                  TRE02040
C                                                                       TRE02050
C     PUT A C IN FRONT OF THE NEXT CARD IF TCAN FLOWS ARE PRESENT       TRE02060
C                                                                       TRE02070
      TCAN(J,M)= -0.0                                                   TRE02080
C                                                                       TRE02090
C                                                                       TRE02100
      IF(NOTYPE.NE.+1) GO TO 401                                        TRE02110
C                                                                       TRE02120
      WRITE(6,24)                                                       TRE02130
   24 FORMAT(1H0,117H    GAIN=  (TRFLO* %FLO)  -TCAN -(AAREA* %E)   -WSFTRE02140
     1LO  INIT VOL    FIN VOL    I AREA     F AREA   AVE EL      XSECA RTRE02150
     2)                                                                 TRE02160
C                                                                       TRE02170
  401 CONTINUE                                                          TRE02180
C                                                                       TRE02190
C                                                                       TRE02200
C                                                                       TRE02210
C     ASSUME AVERAGE AREA IS EQUAL TO AREAI(J,M) TO START, THEN ITTERATETRE02220
C     TO MINIMIZE THE DIFFERENCE BETWEEN AAREA AND THE TRUE AVERAGE     TRE02230
C     AAREA.                                                            TRE02240
C     FROM THE AVERAGE AREA FOR EACH PASS CALCULATE THE AVERAGE         TRE02250
C     ELEVATION ,AEL(J,M), SO THAT THE OVERFLOW RATE CAN BE CALCULATED  TRE02260
C     USING MANNING'S EQUATION.                                         TRE02270
C                                                                       TRE02280
C                                                                       TRE02290
  100 LSTOP = LSTOP + 1                                                 TRE02300
C                                                                       TRE02310
C                                                                       TRE02320
      IF(AAREA.GT.     0..AND.AAREA.LE. 11800.) GO TO 101               TRE02330
```

```
      IF(AAREA.GT. 11800..AND.AAREA.LE. 23000.) GO TO 102               TRE02340
      IF(AAREA.GT. 23000..AND.AAREA.LE. 35100.) GO TO 103               TRE02350
      IF(AAREA.GT. 35100..AND.AAREA.LE. 44200.) GO TO 104               TRE02360
      IF(AAREA.GT. 44200..AND.AAREA.LE. 62100.) GO TO 105               TRE02370
      IF(AAREA.GT. 62100..AND.AAREA.LE. 76600.) GO TO 106               TRE02380
      IF(AAREA.GT. 76600..AND.AAREA.LE. 87800.) GO TO 107               TRE02390
      IF(AAREA.GT. 87800..AND.AAREA.LE. 94900.) GO TO 108               TRE02400
      IF(AAREA.GT. 94900..AND.AAREA.LE.103700.) GO TO 109               TRE02410
      IF(AAREA.GT.103700..AND.AAREA.LE.111300.) GO TO 110               TRE02420
      IF(AAREA.GT.111300..AND.AAREA.LE.118600.) GO TO 111               TRE02430
      IF(AAREA.GT.118600..AND.AAREA.LE.129100.) GO TO 112               TRE02440
      IF(AAREA.GT.129100..AND.AAREA.LE.139000.) GO TO 113               TRE02450
      IF(AAREA.GT.139000..AND.AAREA.LE.142400.) GO TO 114               TRE02460
      IF(AAREA.GT.142400..AND.AAREA.LE.144300.) GO TO 115               TRE02470
      IF(AAREA.GT.144300.) GO TO 116                                    TRE02480
  101 AEL(J,M)= .00177966*AAREA+3459.00                                 TRE02490
      GO TO 199                                                         TRE02500
  102 AEL(J,M)= .00178571*AAREA+3458.93                                 TRE02510
      GO TO 199                                                         TRE02520
  103 AEL(J,M)= .00247934*AAREA+3442.98                                 TRE02530
      GO TO 199                                                         TRE02540
  104 AEL(J,M)= .00329670*AAREA+3414.29                                 TRE02550
      GO TO 199                                                         TRE02560
  105 AEL(J,M)= .00335196*AAREA+3411.84                                 TRE02570
      GO TO 199                                                         TRE02580
  106 AEL(J,M)= .00275862*AAREA+3448.69                                 TRE02590
      GO TO 199                                                         TRE02600
  107 AEL(J,M)= .00357143*AAREA+3386.43                                 TRE02610
      GO TO 199                                                         TRE02620
  108 AEL(J,M)= .00422535*AAREA+3329.01                                 TRE02630
      GO TO 199                                                         TRE02640
  109 AEL(J,M)= .00454545*AAREA+3298.64                                 TRE02650
      GO TO 199                                                         TRE02660
  110 AEL(J,M)= .00394737*AAREA+3360.66                                 TRE02670
```

APPENDIX E CONTINUED

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      GO TO 199                                                         TRE02680
  111 AEL(J,M)= .00273973*AAREA+3495.07                                 TRE02690
      GO TO 199                                                         TRE02700
  112 AEL(J,M)= .00190476*AAREA+3594.10                                 TRE02710
      GO TO 199                                                         TRE02720
  113 AEL(J,M)= .00202020*AAREA+3579.19                                 TRE02730
      GO TO 199                                                         TRE02740
  114 AEL(J,M)= .00294118*AAREA+3451.18                                 TRE02750
      GO TO 199                                                         TRE02760
  115 AEL(J,M)= .00526316*AAREA+3120.53                                 TRE02770
      GO TO 199                                                         TRE02780
  116 AEL(J,M)= .00202020*AAREA+3588.49                                 TRE02790
  199 WSFLO(J,M)=-0.0                                                   TRE02800
      XSECA=-0.0                                                        TRE02810
      R=-0.0                                                            TRE02820
      IF(NDATE(J).EQ.1891.OR.NDATE(J).EQ.1890) GO TO 34                 TRE02830
      A10 = 3863.25                                                     TRE02840
      A11 = 3868.25                                                     TRE02850
      A12 = 3873.25                                                     TRE02860
      IF(AEL(J,M).LE. A10   ) GO TO 34                                  TRE02870
      IF(AEL(J,M).GT. A10   .AND.AEL(J,M).LE. A11   ) GO TO 30          TRE02880
      IF(AEL(J,M).GT. A11   .AND.AEL(J,M).LE. A12   ) GO TO 31          TRE02890
      IF(AEL(J,M).GT. A12   ) GO TO 32                                  TRE02900
   30 XSECA=(AEL(J,M)- A10   )*60.                                      TRE02910
      R=2.*(AEL(J,M)- A10   )+60.                                       TRE02920
      GO TO 33                                                          TRE02930
   31 XSECA=(AEL(J,M)- A10   )*60.+.5*((AEL(J,M)- A11   )**2)/0.035714  TRE02940
      R=70.+(AEL(J,M)- A11   )+SQRT(((AEL(J,M)- A11   )**2)+((AEL(J,M)  TRE02950
     1- A11   )/0.035714)**2)                                           TRE02960
      GO TO 33                                                          TRE02970
   32 XSECA=(AEL(J,M)- A10   )*(60.+140.)+350.00+600.00+(.5*((AEL(J,M)- TRE02980
     1A12   )**2)/0.035714)+(.5*((AEL(J,M)- A12   )**2)/0.22727)        TRE02990
      R=215.09+SQRT(((AEL(J,M)- A12   )**2)+((AEL(J,M)- A12   )/0.22727)TRE03000
     1**2)+SQRT(((AEL(J,M)- A12   )**2)+((AEL(J,M)- A12   )/0.035714)**2TRE03010
```

```
     1)                                                                 TRE03020
C                                                                       TRE03030
   33 WSFLO(J,M)=(1.98)*(XSECA)*(1.49)*(0.7)*(SQRT(0.0003367))*         TRE03040
     1(R**0.6666666667)*(30.)                                           TRE03050
C                                                                       TRE03060
C                                                                       TRE03070
C     CALCULATE THE GAIN TO THE LAKE, FROM THE TRUCKEE FLOW TIMES       TRE03080
C     THE AVERAGE PERCENT INFLOW FOR THE MONTH, LESS THE AMOUNT         TRE03090
C     OF EXPORTED WATER, TCAN(J,M) (IF ANY), LESS THE AVERAGE AREA      TRE03100
C     (AAREA), TIMES THE AVERAGE RATE OF EVAPORATION PER ACRE, LESS THE TRE03110
C     CALCULATED OVERFLOW INTO WINNEMUCCA LAKE, IF ANY.                 TRE03120
C                                                                       TRE03130
   34 GAIN=TRFLO(J)*AVEFLO(M)-TCAN(J,M)-AAREA*AVEEVP(M)-WSFLO(J,M)      TRE03140
C                                                                       TRE03150
      IF (KNOCK.EQ.-1) GO TO 35                                         TRE03160
      IF (KNOCK.EQ.+1) GO TO 36                                         TRE03170
   35 CONTINUE                                                          TRE03180
   36 CONTINUE                                                          TRE03190
   37 CONTINUE                                                          TRE03200
C                                                                       TRE03210
C                                                                       TRE03220
      IF (KNOCK.EQ.-1) GO TO 2010                                       TRE03230
      IF (KNOCK.EQ.+1) GO TO 2011                                       TRE03240
 2010 VOLF(J,M) = VOLI(J,M) - GAIN                                      TRE03250
      GO TO 2012                                                        TRE03260
 2011 VOLF(J,M) = VOLI(J,M) + GAIN                                      TRE03270
C                                                                       TRE03280
C                                                                       TRE03290
C     COMPUTE AREA AFTER INFLOW USING THE LINEAR EQUATIONS THAT         TRE03300
C     APPROXIMATE THE AREA-CAPITITY CURVE.                              TRE03310
C                                                                       TRE03320
C                                                                       TRE03330
 2012 IF(VOLF(J,M).GT.      0..AND.VOLF(J,M).LE.  121000.) GO TO 201    TRE03340
      IF(VOLF(J,M).GT.  121000..AND.VOLF(J,M).LE.  470000.) GO TO 202   TRE03350
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      IF(VOLF(J,M).GT.  470000..AND.VOLF(J,M).LE. 1350000.) GO TO 203   TRE03360
      IF(VOLF(J,M).GT. 1350000..AND.VOLF(J,M).LE. 2550000.) GO TO 204   TRE03370
      IF(VOLF(J,M).GT. 2550000..AND.VOLF(J,M).LE. 5720000.) GO TO 205   TRE03380
      IF(VOLF(J,M).GT. 5720000..AND.VOLF(J,M).LE. 8490000.) GO TO 206   TRE03390
      IF(VOLF(J,M).GT. 8490000..AND.VOLF(J,M).LE.11790000.) GO TO 207   TRE03400
      IF(VOLF(J,M).GT.11790000..AND.VOLF(J,M).LE.14530000.) GO TO 208   TRE03410
      IF(VOLF(J,M).GT.14530000..AND.VOLF(J,M).LE.18500000.) GO TO 209   TRE03420
      IF(VOLF(J,M).GT.18500000..AND.VOLF(J,M).LE.21720000.) GO TO 210   TRE03430
      IF(VOLF(J,M).GT.21720000..AND.VOLF(J,M).LE.24020000.) GO TO 211   TRE03440
      IF(VOLF(J,M).GT.24020000..AND.VOLF(J,M).LE.26490000.) GO TO 212   TRE03450
      IF(VOLF(J,M).GT.26490000..AND.VOLF(J,M).LE.29180000.) GO TO 213   TRE03460
      IF(VOLF(J,M).GT.29180000..AND.VOLF(J,M).LE.30580000.) GO TO 214   TRE03470
      IF(VOLF(J,M).GT.30580000..AND.VOLF(J,M).LE.32020000.) GO TO 215   TRE03480
      IF(VOLF(J,M).GT.32020000.) GO TO 216                              TRE03490
  201 AREAF(J,M)=(( .00017355372*VOLF(J,M))+3459.00-3459.00)/ .00177966 TRE03500
      GO TO 299                                                         TRE03510
  202 AREAF(J,M)=(( .0000573O659*VOLF(J,M))+3473.07-3458.93)/ .00178571 TRE03520
      GO TO 299                                                         TRE03530
  203 AREAF(J,M)=(( .00003409091*VOLF(J,M))+3483.98-3442.98)/ .00247934 TRE03540
      GO TO 299                                                         TRE03550
  204 AREAF(J,M)=(( .00002500000*VOLF(J,M))+3496.25-3414.29)/ .00329670 TRE03560
      GO TO 299                                                         TRE03570
  205 AREAF(J,M)=(( .00001892744*VOLF(J,M))+3511.74-3411.84)/ .00335196 TRE03580
      GO TO 299                                                         TRE03590
  206 AREAF(J,M)=(( .00001444043*VOLF(J,M))+3537.40-3448.69)/ .00275862 TRE03600
      GO TO 299                                                         TRE03610
  207 AREAF(J,M)=(( .00001212121*VOLF(J,M))+3557.09-3386.43)/ .00357143 TRE03620
      GO TO 299                                                         TRE03630
  208 AREAF(J,M)=(( .00001094891*VOLF(J,M))+3570.91-3329.01)/ .00422535 TRE03640
      GO TO 299                                                         TRE03650
  209 AREAF(J,M)=(( .00001007557*VOLF(J,M))+3583.60-3298.64)/ .00454545 TRE03660
      GO TO 299                                                         TRE03670
  210 AREAF(J,M)=(( .00000931677*VOLF(J,M))+3597.64-3360.66)/ .00394737 TRE03680
      GO TO 299                                                         TRE03690
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  211 AREAF(J,M)=(( .00000869565*VOLF(J,M))+3611.13-3495.07)/ .00273973
      GO TO 299
  212 AREAF(J,M)=(( .00000809717*VOLF(J,M))+3625.51-3594.10)/ .00190476
      GO TO 299
  213 AREAF(J,M)=(( .00000743494*VOLF(J,M))+3643.05-3579.19)/ .00202020
      GO TO 299
  214 AREAF(J,M)=(( .00000714286*VOLF(J,M))+3651.57-3451.18)/ .00294118
      GO TO 299
  215 AREAF(J,M)=(( .00000694444*VOLF(J,M))+3657.64-3120.53)/ .00526316
      GO TO 299
  216 AREAF(J,M)=(( .00000743494* VOLF( J,M))+3641.93-3588.49)/ .00202020
  299 CONTINUE
C
C
C
      IF(NOTYPE.NE.+1) GO TO 402
C
      WRITE(6,51)GAIN,TRFLO(J),AVEFLO(M),TCAN(J,M),AAREA,AVEEVP(M),WSFLC
     1(J,M),VOLI(J,M),VOLF(J,M),AREAI(J,M),AREAF(J,M),AEL(J,M),XSECA,R
   51 FORMAT(1H ,2F9.0,F6.4,F7.0,F9.0,F4.2,F9.0,2F10.0,2F9.0,F8.2,2F9.2)
C
  402 CONTINUE
C
C
C
C     CHECK TO SEE IF THE AVERAGE AREA, AAREA, FROM THE LAST PASS
C     IS NEARLY EQUAL TO THE AVERAGE AREA, AAREA, FOR THE NEW PASS.
C     IF NOT, ADJUST THE AVERAGE AREA, AAREA, TO THE TRUE MEAN,
C     THEN GO BACK TO 100 AND CALCULATE THE EVAPORATION LOSS AND THE
C     WINNEMUCCA SLOUGH OUTFLOW AGAIN.
C     WHEN IT IS NEARLY EQUAL TO ITSELF PROCEED.
C
C
      IF (LSTOP.GE.10) GO TO 52
```

```
C                                                                       TRE04040
C                                                                       TRE04050
      B = ABS(AAREA-((AREAF(J,M)+AREAI(J,M))/2.))                       TRE04060
      IF(B.LT.0.45) GO TO 52                                            TRE04070
      AAREA=(AREAF(J,M)+AREAI(J,M))/2.                                  TRE04080
      GO TO 100                                                         TRE04090
   52 CONTINUE                                                          TRE04100
C                                                                       TRE04110
      IF(WSFLO(J,M).EQ.-0.0) GO TO 55                                   TRE04120
      T3=T3+1.0                                                         TRE04130
   55 CONTINUE                                                          TRE04140
C                                                                       TRE04150
C                                                                       TRE04160
C                                                                       TRE04170
      IF(NOTYPE.NE.+1) GO TO 403                                        TRE04180
C                                                                       TRE04190
      WRITE(6,53)                                                       TRE04200
   53 FORMAT(1H ,50H FIN AAREA  F AVE EL FIN XSECA   FINAL R FIN WSFLO) TRE04210
      WRITE(6,54)AAREA,AEL(J,M),XSECA,R,WSFLO(J,M)                      TRE04220
   54 FORMAT(1H ,F10.0,3F10.2,F10.0)                                    TRE04230
C                                                                       TRE04240
  403 CONTINUE                                                          TRE04250
C                                                                       TRE04260
C                                                                       TRE04270
C                                                                       TRE04280
C     AFTER CORRECT "AAREA" IS DETERMINED, COMPUTE ELEVATION FROM       TRE04290
C     THE EQUATIONS THAT APPROXIMATE THE ELEVATION -VOLUME CURVE.       TRE04300
C                                                                       TRE04310
      IF(VOLF(J,M).GT.       0..AND.VOLF(J,M).LE.  121000.) GO TO 301   TRE04320
      IF(VOLF(J,M).GT.  121000..AND.VOLF(J,M).LE.  470000.) GO TO 302   TRE04330
      IF(VOLF(J,M).GT.  470000..AND.VOLF(J,M).LE. 1350000.) GO TO 303   TRE04340
      IF(VCLF(J,M).GT. 1350000..AND.VOLF(J,M).LE. 2550000.) GO TO 304   TRE04350
      IF(VOLF(J,M).GT. 2550000..AND.VOLF(J,M).LE. 5720000.) GO TO 305   TRE04360
      IF(VOLF(J,M).GT. 5720000..AND.VOLF(J,M).LE. 8490000.) GO TO 306   TRE04370
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      IF(VOLF(J,M).GT. 8490000..AND.VOLF(J,M).LE.11790000.) GO TO 307    TRE04380
      IF(VOLF(J,M).GT.11790000..AND.VOLF(J,M).LE.14530000.) GO TO 308    TRE04390
      IF(VOLF(J,M).GT.14530000..AND.VOLF(J,M).LE.18500000.) GO TO 309    TRE04400
      IF(VOLF(J,M).GT.18500000..AND.VOLF(J,M).LE.21720000.) GO TO 310    TRE04410
      IF(VOLF(J,M).GT.21720000..AND.VOLF(J,M).LE.24020000.) GO TO 311    TRE04420
      IF(VOLF(J,M).GT.24020000..AND.VOLF(J,M).LE.26490000.) GO TO 312    TRE04430
      IF(VOLF(J,M).GT.26490000..AND.VOLF(J,M).LE.29180000.) GO TO 313    TRE04440
      IF(VOLF(J,M).GT.29180000..AND.VOLF(J,M).LE.30580000.) GO TO 314    TRE04450
      IF(VOLF(J,M).GT.30580000..AND.VOLF(J,M).LE.32020000.) GO TO 315    TRE04460
      IF(VOLF(J,M).GT.32020000.) GO TO 316                               TRE04470
  301 ELF(J,M)= .00017355372*VOLF(J,M)+3459.00                           TRE04480
      GO TO 399                                                          TRE04490
  302 ELF(J,M)= .00005730659*VOLF(J,M)+3473.07                           TRE04500
      GO TO 399                                                          TRE04510
  303 ELF(J,M)= .00003409091*VOLF(J,M)+3483.98                           TRE04520
      GO TO 399                                                          TRE04530
  304 ELF(J,M)= .00002500000*VOLF(J,M)+3496.25                           TRE04540
      GO TO 399                                                          TRE04550
  305 ELF(J,M)= .00001892744*VOLF(J,M)+3511.74                           TRE04560
      GO TO 399                                                          TRE04570
  306 ELF(J,M)= .00001444043*VOLF(J,M)+3537.40                           TRE04580
      GO TO 399                                                          TRE04590
  307 ELF(J,M)= .00001212121*VOLF(J,M)+3557.09                           TRE04600
      GO TO 399                                                          TRE04610
  308 ELF(J,M)= .00001094891*VOLF(J,M)+3570.91                           TRE04620
      GO TO 399                                                          TRE04630
  309 ELF(J,M)= .00001007557*VOLF(J,M)+3583.60                           TRE04640
      GO TO 399                                                          TRE04650
  310 ELF(J,M)= .00000931677*VOLF(J,M)+3597.64                           TRE04660
      GO TO 399                                                          TRE04670
  311 ELF(J,M)= .00000869565*VOLF(J,M)+3611.13                           TRE04680
      GO TO 399                                                          TRE04690
  312 ELF(J,M)= .00000809717*VOLF(J,M)+3625.51                           TRE04700
      GO TO 399                                                          TRE04710
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  313 ELF(J,M)= .00000743494*VOLF(J,M)+3643.05
      GO TO 399
  314 ELF(J,M)= .00000714286*VOLF(J,M)+3651.57
      GO TO 399
  315 ELF(J,M)= .00000694444*VOLF(J,M)+3657.64
      GO TO 399
  316 ELF(J,M)= .00000743494*VOLF(J,M)+3641.93
  399 CONTINUE
C
C
C     CALCULATE THE DIFFERENCE IN THE OBSERVED AND CALCULATED ELEVATION
C
      DIFF(J,M)= -0.0
      IF (OBSEL(J,M).LE.0.) GO TO 70
      DIFF(J,M)=ELF(J,M)-OBSEL(J,M)
      T1=T1+1.0
   70 CONTINUE
C
      IF(DIFF(J,M).EQ.-0.0) GO TO 60
      T2=T2+1.0
   60 CONTINUE
C
C     ADD UP THE 12 MONTHLY VALUES FOR USE IN THE YEARLY SUMMARY TABLE.
C
      ELIA(J)=ELIA(J)+ELI(J,M)
      ELFA(J)=ELFA(J)+ELF(J,M)
      OBSELA(J)=OBSELA(J)+OBSEL(J,M)
      DIFFA(J)=DIFFA(J)+DIFF(J,M)
      AELA(J)=AELA(J)+AEL(J,M)
      TCANB(J)=TCANB(J)+TCAN(J,M)
      WSFLOA(J)=WSFLOA(J)+WSFLO(J,M)
      VOLIA(J)=VOLIA(J)+VOLI(J,M)
      VOLFA(J)=VOLFA(J)+VOLF(J,M)
      AREAIA(J)=AREAIA(J)+AREAI(J,M)
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      AREAFA(J)=AREAFA(J)+AREAF(J,M)                                    TRE05060
C                                                                       TRE05070
C                                                                       TRE05080
      IF(NOTYPE.NE.+1) GO TO 404                                        TRE05090
C                                                                       TRE05100
      WRITE(6,71)                                                       TRE05110
   71 FORMAT(1H ,124HDATE MON  INIT EL (FIN EL-OBS EL)=DIFF EL  AVE EL  TRE05120
     1 TRFLO    TCAN    WSFLO  HHD  SKY  PNT  INIT VOL    FIN VOL  I AREA TRE05130
     2 F AREA)                                                          TRE05140
      WRITE(6,72)NDATE(J),MONTH(M),ELI(J,M),ELF(J,M),OBSEL(J,M),DIFF(J,MTRE05150
     1),   AEL(J,M),TRFLO(J),TCAN(J,M),WSFLO(J,M),HHD(J),SKY(J),PNT(J),VOTRE05160
     2LI(J,M),VOLF(J,M),AREAI(J,M),AREAF(J,M)                           TRE05170
   72 FORMAT(1H ,I4,1X,A3,1X,5F8.2,3F8.0,3F5.0,2F10.0,2F8.0)            TRE05180
C                                                                       TRE05190
  404 CONTINUE                                                          TRE05200
C                                                                       TRE05210
C                                                                       TRE05220
C                                                                       TRE05230
C     SET INITIAL VALUES FOR THE NEXT PASS                              TRE05240
C                                                                       TRE05250
      IF (KNOCK.EQ.-1) GO TO 2030                                       TRE05260
      IF (KNOCK.EQ.+1) GO TO  2031                                      TRE05270
 2030 IF(J.EQ.1.AND.M.EQ.1) GO TO 73                                    TRE05280
      MA = M -1                                                         TRE05290
      JA = J                                                            TRE05300
      IF (MA.EQ.0) GO TO 500                                            TRE05310
      GO TO 73                                                          TRE05320
  500 MA = 12                                                           TRE05330
      JA = J -1                                                         TRE05340
      GO TO 73                                                          TRE05350
 2031 IF(J.EQ.NDATA.AND.M.EQ.12) GO TO 73                               TRE05360
      MA = M + 1                                                        TRE05370
      JA = J                                                            TRE05380
      IF(MA.LT.13) GO TO 73                                             TRE05390
```

APPENDIX E CONTINUED

```
      MA = 1                                                            TRE05400
      JA = J + 1                                                        TRE05410
   73 VOLI(JA,MA)=VOLF(J,M)                                             TRE05420
      AREAI(JA,MA)=AREAF(J,M)                                           TRE05430
      ELI(JA,MA)=ELF(J,M)                                               TRE05440
 1002 CONTINUE                                                          TRE05450
C                                                                       TRE05460
C     CALCULATE THE MEANS OF THE 12 MONTHLY VALUES FOR THE YEARLY       TRE05470
C     SUMMARY TABLE.                                                    TRE05480
C                                                                       TRE05490
      IF(T1.GT.0.0) GO TO 600                                           TRE05500
      OBSELA(J)=-0.0                                                    TRE05510
      GO TO 601                                                         TRE05520
  600 OBSELA(J)=OBSELA(J)/T1                                            TRE05530
  601 IF(T2.GT.0.0) GO TO 602                                           TRE05540
      DIFFA(J)=-0.0                                                     TRE05550
      GO TO 603                                                         TRE05560
  602 DIFFA(J)=DIFFA(J)/T2                                              TRE05570
  603 IF(T3.GT.0.0) GO TO 604                                           TRE05580
      WSFLOA(J)=-0.0                                                    TRE05590
      GO TO 605                                                         TRE05600
  604 WSFLOA(J)=WSFLOA(J)/T3                                            TRE05610
  605 ELIA(J)=ELIA(J)/12.                                               TRE05620
      ELFA(J)=ELFA(J)/12.                                               TRE05630
      AELA(J)=AELA(J)/12.                                               TRE05640
      VOLIA(J)=VOLIA(J)/12.                                             TRE05650
      VOLFA(J)=VOLFA(J)/12.                                             TRE05660
      AREAIA(J)=AREAIA(J)/12.                                           TRE05670
      AREAFA(J)=AREAFA(J)/12.                                           TRE05680
 1001 CONTINUE                                                          TRE05690
C                                                                       TRE05700
C                                                                       TRE05710
C     WRITE THE MONTHLY SUMMARY TABLE.                                  TRE05720
C                                                                       TRE05730
```

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C                                                                       TRE05740
      WRITE(6,78)                                                       TRE05750
   78 FORMAT(1HS)                                                       TRE05760
      WRITE(6,74)                                                       TRE05770
   74 FORMAT (1H1,35HSUMMARY TABLE GIVING MONTHLY VALUES)               TRE05780
      WRITE(6,75)                                                       TRE05790
   75 FORMAT(1H0,124HDATE MON  INIT EL  (FIN EL-OBS EL)=DIFF EL   AVE EL  TRE05800
     1 TRFLO    TCAN    WSFLO   HHD   SKY   PNT   INIT VOL   FIN VOL   I AREA TRE05810
     2 F AREA)                                                          TRE05820
C                                                                       TRE05830
      T5=0.0                                                            TRE05840
      SDIFF= -0.0                                                       TRE05850
C                                                                       TRE05860
C                                                                       TRE05870
      DO 1003 J1=1,NDATA                                                TRE05880
      IF(KNOCK.EQ.-1) J = IDATA - J1                                    TRE05890
      IF(KNOCK.EQ.+1) J = J1                                            TRE05900
      DO 1003 M1 = 1,12                                                 TRE05910
      IF(KNOCK.EQ.-1) M = 13 - M1                                       TRE05920
      IF(KNOCK.EQ.+1) M = M1                                            TRE05930
C                                                                       TRE05940
      SDIFF=DIFF(J,M)+SDIFF                                             TRE05950
      IF(DIFF(J,M).EQ.-0.0) GO TO 79                                    TRE05960
      T5=T5+1.0                                                         TRE05970
   79 CONTINUE                                                          TRE05980
C                                                                       TRE05990
      WRITE(6,72)NDATE(J),MONTH(M),ELI(J,M),ELF(J,M),OBSEL(J,M),DIFF(J,MTRE06000
     1),  AEL(J,M),TRFLO(J),TCAN(J,M),WSFLO(J,M),HHD(J),SKY(J),PNT(J),VOTRE06010
     2LI(J,M),VOLF(J,M),AREAI(J,M),AREAF(J,M)                           TRE06020
 1003 CONTINUE                                                          TRE06030
C                                                                       TRE06040
      IF(T5.GT.0.0) GO TO 650                                           TRE06050
      ADIFF=-0.0                                                        TRE06060
      GO TO 651                                                         TRE06070
```

```
  650 ADIFF=SDIFF/T5                                                    TRE06080
  651 CONTINUE                                                          TRE06090
C                                                                       TRE06100
      WRITE(6,76)SDIFF                                                  TRE06110
   76 FORMAT(1H0,10X,21HSUM OF THE DIFFERENCE,3X,F8.2)                  TRE06120
      WRITE(6,77)ADIFF                                                  TRE06130
   77 FORMAT(1H ,10X,22HMEAN OF THE DIFFERENCE,2X,F8.2)                 TRE06140
C                                                                       TRE06150
C                                                                       TRE06160
C     WRITE THE YEARLY SUMMARY TABLE.                                   TRE06170
C                                                                       TRE06180
C                                                                       TRE06190
      WRITE(6,80)                                                       TRE06200
   80 FORMAT(1H1,53HSUMMARY TABLE GIVING YEARLY AVERAGES OF THE 12 MONTHTRE06210
     1S)                                                                TRE06220
      WRITE(6,81)                                                       TRE06230
   81 FORMAT(1H ,119HDATE INIT EL (FIN EL-OBS EL)=DIFF EL   AVE EL   TRFLTRE06240
     1O   TCAN   WSFLO  HHD  SKY  PNT  INIT VOL   FIN VOL  I AREA  F ARTRE06250
     2EA)                                                               TRE06260
C                                                                       TRE06270
C                                                                       TRE06280
      SDIFFA= -0.0                                                      TRE06290
      T4=0.0                                                            TRE06300
C                                                                       TRE06310
      DO 1004 J1=1,NDATA                                                TRE06320
      IF(KNOCK.EQ.-1) J = IDATA - J1                                    TRE06330
      IF(KNOCK.EQ.+1) J = J1                                            TRE06340
C                                                                       TRE06350
      SDIFFA=DIFFA(J)+SDIFFA                                            TRE06360
      IF(DIFFA(J).EQ.-0.0) GO TO 85                                     TRE06370
      T4=T4+1.0                                                         TRE06380
   85 CONTINUE                                                          TRE06390
C                                                                       TRE06400
      WRITE(6,82)NDATE(J),ELIA(J),ELFA(J),OBSELA(J),DIFFA(J),AELA(J),TRFTRE06410
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```
     1LO(J)  ,TCANB(J),WSFLOA(J),HHD(J),SKY(J),PNT(J),VOLIA(J),VOLFA(J),ATRE06420
     1REAIA(J),AREAFA(J)                                                TRE06430
   82 FORMAT(1H ,I4,5F8.2,3F8.0,3F5.0,2F10.0,2F8.0)                     TRE06440
C                                                                       TRE06450
 1004 CONTINUE                                                          TRE06460
C                                                                       TRE06470
C                                                                       TRE06480
      IF(T4.GT.0.0) GO TO 670                                           TRE06490
      ADIFFA= -0.0                                                      TRE06500
      GO TO 671                                                         TRE06510
  670 ADIFFA=SDIFFA/T4                                                  TRE06520
  671 CONTINUE                                                          TRE06530
C                                                                       TRE06540
      WRITE(6,83)SDIFFA                                                 TRE06550
   83 FORMAT(1H0,4X,21HSUM OF THE DIFFERENCE,3X,F8.2)                   TRE06560
      WRITE(6,84)ADIFFA                                                 TRE06570
   84 FORMAT(1H ,4X,22HMEAN OF THE DIFFERENCE,2X,F8.2)                  TRE06580
10000 CONTINUE                                                          TRE06590
      STOP                                                              TRE06600
      END                                                               TRE06610
                                                                        TRE06620
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PLEASE NOTE:

Plate I., "Topographic Map of Truckee & Carson River Drainages", not microfilmed because it will not reproduce well in xerographic copies. Available for consultation at the University of Nevada Library.

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