PREDICTION OF THE EFFECTS OF MINE DEWATERING ON FOUR LAKES NEAR CRANDON, WISCONSIN, BY USE OF A WATER-BUDGET MODEL

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The following factors may be used to convert the inch-pound units used in this report to metric (International System) units.

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
acre	4,047	square meter (m^2)
inch per year (in/yr)	25.40	millimeter per year (mm/yr)
foot per year (ft/yr)	0.3048	meter per year (m/yr)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

PREDICTION OF THE EFFECTS OF MINE DEWATERING ON FOUR LAKES

NEAR CRANDON, WISCONSIN, BY USE OF A WATER-BUDGET MODEL

by William R. Krug, Nile A. Ostenso, and James T. Krohelski

ABSTRACT

The effects of dewatering a proposed zinc and copper mine on water levels of four lakes near Crandon, Wisconsin, were predicted by use of a digital water-budget model of the lakes.

The average lake-stage reduction predicted by the model for expected ground-water levels after mine dewatering ranged from 0.21 feet for Duck Lake to 6.9 feet for Little Sand Lake. These stage reductions assume that no water is pumped into the lakes and that no changes are made to the outlet structures. The predicted flow augmentation to the lakes to offset lowering of ground-water levels by mine dewatering range from 8 gallons per minute for Duck Lake to 580 gallons per minute for Little Sand Lake.

Because of uncertainty in variables used in the model and in the data used to calibrate the model, the predictions of the model are subject to an undetermined degree of uncertainty.

INTRODUCTION

Background

A mining company has proposed opening an underground mine 6 mi south of Crandon in northeastern Wisconsin (fig. 1); the operation plan proposes dewatering the mine (Exxon Minerals Company, 1985). The pumping necessary to dewater the mine will create a cone of depression in the surrounding water table and this may affect nearby lakes (fig. 2). The U.S. Geological Survey, in cooperation with the Wisconsin Department of Natural Resources, developed a water-budget model for the lakes most likely to be affected by the mine operations. Duck, Deephole, Little Sand, and Skunk Lakes are most likely to be affected. The calibrated model was used to predict the effects of mine pumping on lake levels and lake outflows.

The area near the proposed mine is predominantly forested, with numerous lakes and wetlands. Some of the lakes are surrounded by cottages and full-time residences. The topography is of glacial origin with poorly developed drainage.

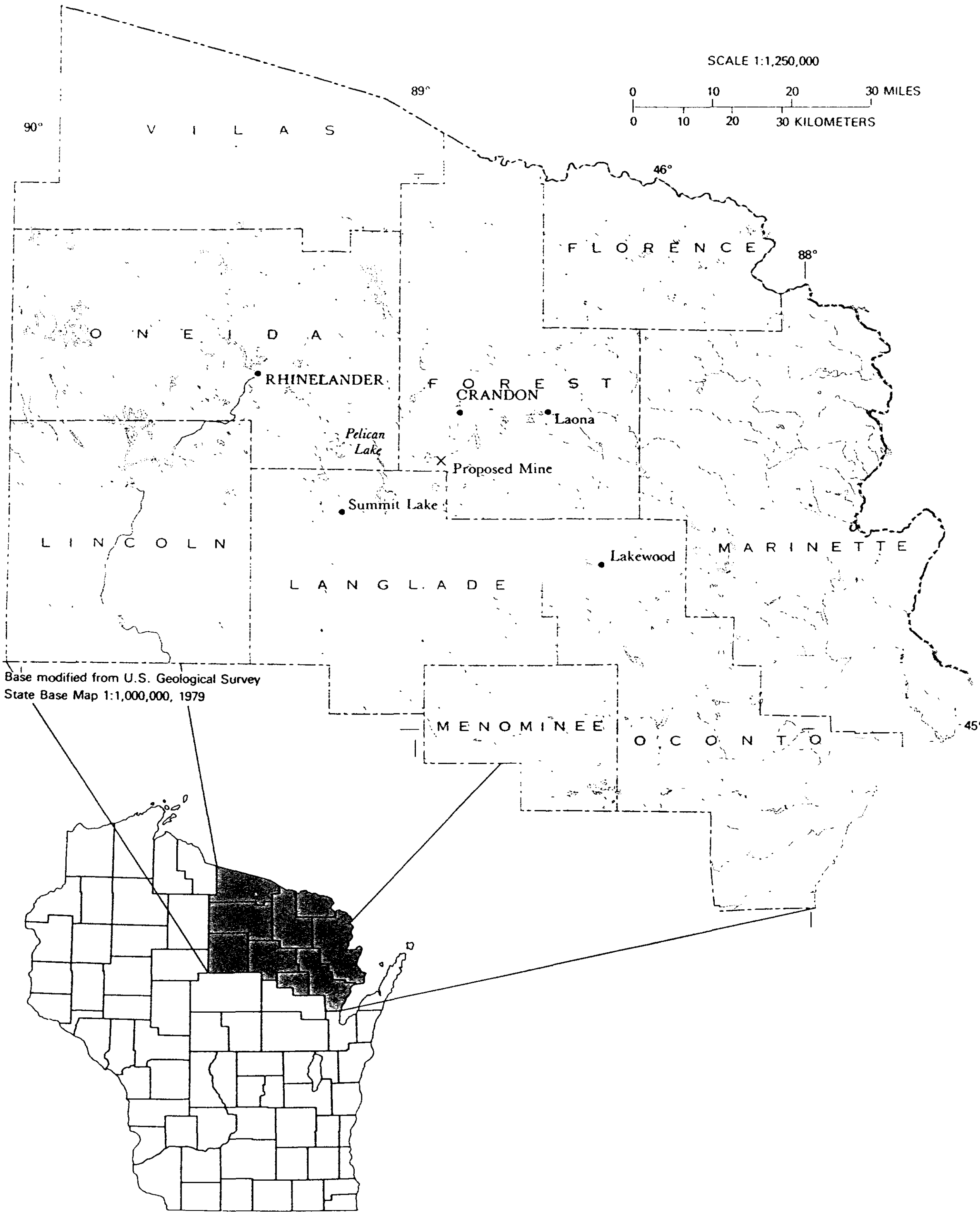

Figure 1. Map of the study area and its location in Wisconsin.

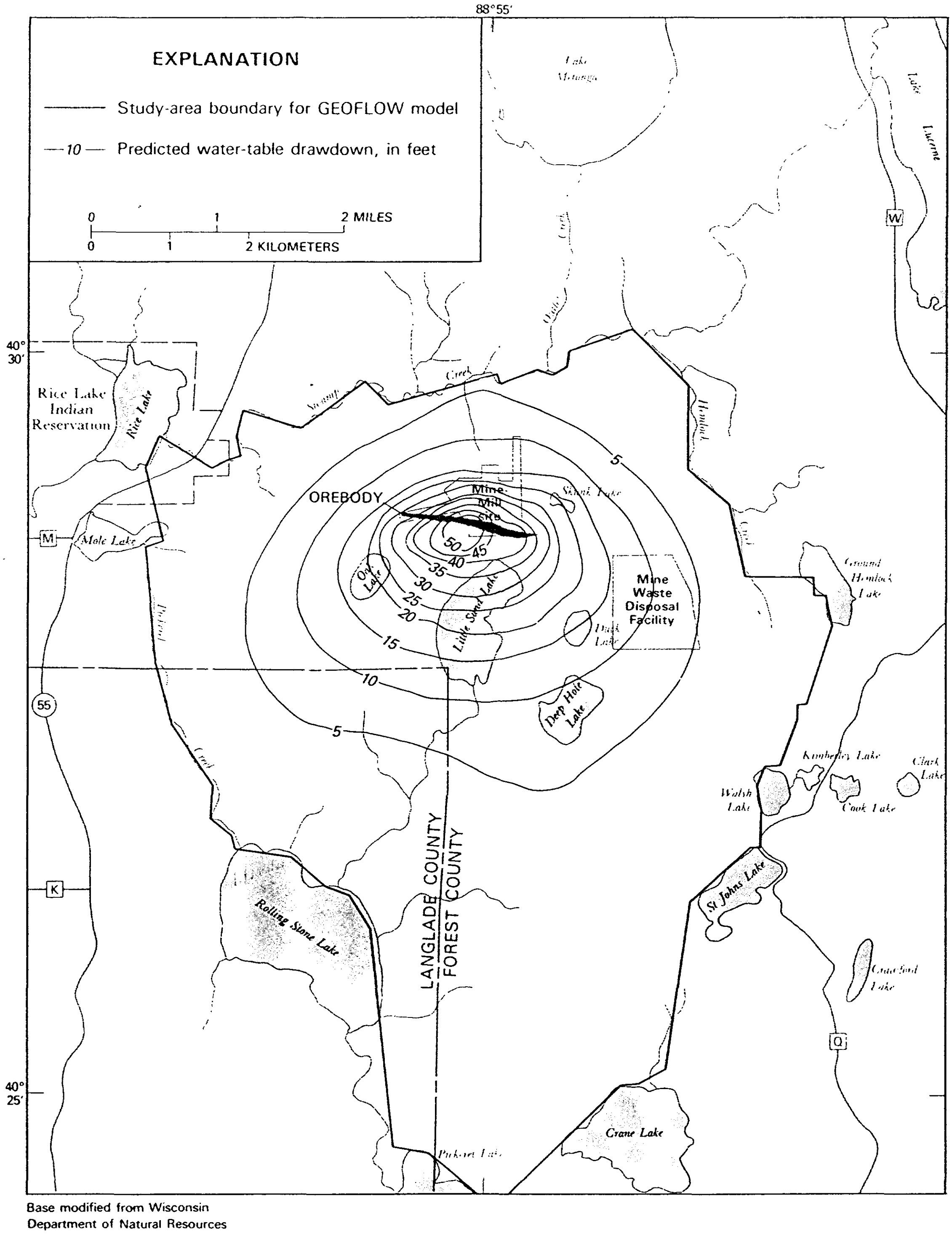

Figure 2. Estimated reduction of ground-water levels near the proposed mine and the lakes studied.

The lakes are in pitted outwash and hummocky till of the Copper Falls Formation (Simpkins and others, Wisconsin Geological and Natural History Survey, written commun., 1985). Drumlins form the upland areas around the lakes and they are set in deep iceblock depressions that have been lined with silt and clay lacustrine sediment. Till and outwash underlie the lacustrine sediment. One hundred to 300 ft of drift overlies Precambrian crystalline bedrock.

The lakes are near a surface-water divide. The drainage patterns of the lakes range from poorly developed to developed. Lakes with outlets intermittently drain south 1.8 to 2.6 mi to Rolling Stone Lake.

The lakes included in this study are all ground-water recharge lakes---that is, water seeps from the lake bottom into the ground-water reservoir. The water surfaces of the lakes are above the altitude of the water table, but the lakebeds are below the altitude of the water table, keeping the sediments of the lakebed saturated.

The mining company has made extensive studies of the geology and water resources of the project area to prepare an Environmental Impact Report (Exxon Minerals Company, 1985). Lake-level data collected over several years and streamflow measurements made on some of the streams flowing out of the lakes are included in the Environmental Impact Report. Wells have been drilled to define the glacial geology and the water table in the area.

A contractor for the mining company used the GEOFLOW ground-water flow model (Haji-Djafari, S., 1983) to simulate the aquifer in the study area. That model was used to simulate the water table in the study area for baseline conditions and to predict the mine inflow and cone of depression for the conditions of pumping to dewater the mine.

Purpose and Scope

The purpose of this report is to present a method for predicting the effects of dewatering a proposed zinc and copper mine on levels of four lakes (Little Sand, Deephole, Duck, and Skunk Lakes) near Crandon by use of a digital water-budget model of the lakes. The model is documented, calibration with field data is described, and the results of model simulations of the four lakes most likely to be affected by the proposed dewatering are summarized. An estimate is made of the amount of water that would have to be added to the lakes to prevent their water levels from being drawn down by the lowering of ground-water levels. The water budgets for the lakes were simulated using 31 years of precipitation and evaporation data collected by the National Weather Service at stations near the study site. The water budgets were calculated for current ground-water levels and for expected ground-water levels after mine dewatering, based on GEOFLOW model calculations. The computer code and documentation for the water-budget model are in the appendix.

PREDICTION OF EFFECTS OF MINE DEWATERING

Water-Budget Model

A water-budget model was constructed and used to simulate the water levels of four lakes in the Crandon area, under current (1984) conditions and after mine dewatering. The lakes simulated are Duck Lake, Deephole Lake, Little Sand Lake, and Skunk Lake.

Model Components

The model includes all of the major components of the water budget. The gains to the lakes include precipitation onto the lake itself (PI), surface-water runoff into the lake from the surrounding drainage area (RI), and (in the case of Little Sand Lake) outflow from upstream lakes (SI). The losses include evaporation from the lake surface (EO), seepage to ground water (SEEP), and surface-water outflow (SO) (except for Skunk Lake, which has no surface outlet). If gains and losses are not equal, there is a change in storage in the lake (STOR). The water budget can be expressed as:

$$\text{Change in storage} = \text{Gains} - \text{Losses}$$

or

$$STOR = PI + RI + SI - EO - SO - SEEP$$

The computer program and a list and description of the variables and how they are used in the model are in the appendix.

Lake-Surface Area

For each lake, the total surface area of the lake and adjoining wetlands was computed by using equations furnished by the mining company. These are the same equations used in a simple, monthly, water-budget model developed by contractors for the mining company (Dames & Moore, 1985). Similar equations were developed for the open-water areas of each lake. These were determined from tables relating area to depth for the lakes (Exxon Minerals Company, written commun., 1985). The wetland areas are the difference between the areas computed from these two sets of equations. The lake-area equations are summarized in table 1.

Precipitation on Water Surface

Direct precipitation on the water surface (PI) adds a volume of water equal to the precipitation times the lake area. Precipitation data used for simulation were collected at Laona, Wis., 7.29 mi from the proposed mine (fig. 1). The station at Laona is the nearest site for which long-term precipitation records are available.

Monthly total precipitation data were used in the model. The expense of preparing daily data for the model was not justified, because monthly changes in the lake stage are sufficient to show the effects of ground-water drawdowns on the lake stages. The model divided the monthly precipitation uniformly

Table 1.—*Equations used to compute area of lakes and wetlands*

[Data from Exxon Minerals Company, written commun., 1985]

Range of lake level (LL) (feet above sea level)	Area of lake proper (acres)	Area of lake and wetlands (acres)
	Duck Lake	
Below 1602.00	0.0	0.0
1602.00 - 1606.44	3.5 x (LL -1602.0)	3.5 x (LL -1602.0)
1606.44 - 1607.97	3.5 x (LL -1602.0)	31.7 x (LL -1605.95)
1607.97 - 1608.04	3.5 x (LL -1602.0)	9.79 x (LL -1601.43)
Above 1608.04	1.13 x (LL -1589.33)	9.79 x (LL -1601.43)
	Deephole Lake	
Below 1590.83	0.0	0.0
1590.83 - 1595.83	4.82 x (LL -1590.83)	4.82 x (LL -1590.83)
1595.83 - 1602.92	9.58 x (LL -1593.31)	9.58 x (LL -1593.31)
Above 1602.92	2.6 x (LL -1567.52)	9.99 x (LL -1593.71)
	Little Sand Lake	
Below 1581.96	10.8 x (LL -1575.66)	
1581.96 - 1586.96	24.8 x (LL -1579.22)	No wetlands
1586.96 - 1589.80	10.64 x (LL -1568.77)	
Above 1589.80	9.90 x (LL -1567.24)	
	Skunk Lake	
Below 1592.80	0.0	0.0
1592.80 - 1595.09	0.35 x (LL -1592.8)	0.35 x (LL -1592.8)
1595.09 - 1597.09	1.0 x (LL -1594.29)	1.82 x (LL -1594.65)
Above 1597.09	3.6 x (LL -1596.31)	10.9 x (LL -1596.68)

over the days of the month; this allowed smoother transitions in the computed inflows and outflows, because the lake stage could be adjusted every day.

Daily precipitation was required for short-term calibration of the model. Precipitation data from four stations nearest the site were averaged to estimate daily precipitation at the site. The daily precipitation recorded at each station was weighted by the square of the reciprocal of its distance from the site to emphasize the station nearest the site (U.S. National Weather Service, 1972). The four stations and their weighting factors were: Laona (0.62), South Pelican (0.18) (at Pelican Lake), Lakewood (0.06), and Summit Lake (0.14) (fig. 1).

Evaporation

Evaporation from the water surface (EO) was calculated from recorded pan evaporation times a pan coefficient times the lake area. Evaporation data for this study were recorded at the nearest National Weather Service evaporation pan at Rainbow Reservoir, near Rhinelander, Wis. (fig. 1). The total monthly evaporation was used in the model.

The recorded pan evaporation for the months of May through October was adjusted to lake evaporation with a pan coefficient of 0.81 (Farnsworth and others, 1982). The data for some months were missing for some years. The average evaporation over the period of record for that month was used for the missing data. In each year monthly evaporation for each of the other 6 months was set to 0.0498 times the total evaporation for May to October. This value was computed from average published coefficients (Farnsworth and others, 1982) (Dames & Moore, 1985).

Surface Runoff

Surface runoff (RI) to the lakes was estimated by a monthly runoff coefficient multiplied by the monthly precipitation and the effective drainage area. These runoff coefficients were computed from streamflow measurements on area streams (Dames & Moore, 1985). The same runoff coefficient was used for each day of the month as follows:

October	0.15
November-April	.45
May	.16
June	.12
July	.13
August	.09
September	.12

The effective drainage area for surface runoff is the effective drainage area of the lake minus the computed surface area of the lake for a given day. The drainage area used in the model to compute the surface runoff was changed daily to adjust for daily changes in the area of the lakes.

The effective drainage area of Little Sand Lake is the drainage area of the lake minus the drainage areas for Duck and Deephole Lakes. The surface runoff from the drainage areas of these two upstream lakes was included in the water budgets for those lakes. Any of this water that would ultimately reach Little Sand Lake was included in the computed outflow for the two upstream lakes.

Seepage to Ground Water

Seepage to ground water (SEEP) was calculated using Darcy's law:

$$SEEP = \frac{K * A * H}{THK}$$

Where

SEEP is the volume of seepage (cubic feet per day) per unit time (day),
K is the hydraulic conductivity (feet per day),
A is the area of the lake bed (square feet),
H is the hydraulic head (feet), and
THK is the thickness of the confining sediments (feet).

Hydraulic head is the difference between the lake-water-surface elevation and the potential head at the base of the sediments. (In all cases, the potential head is lower than the lake levels; all seepage is outward). The thickness is the thickness of the relatively impermeable sediments under the lakes and the adjoining wetlands. The hydraulic conductivity (K) was the major variable adjusted in calibrating the model.

The area available for seepage was computed separately for the lakes and their adjoining wetlands. The hydraulic conductivity was assumed to be the same for the wetlands as it was in the adjoining lake, although the thickness of the sediments was different in the lakes and wetlands. Sediment thickness was based on field measurements.

The maximum possible head on any of the sediments was limited by the difference between the lake level and the elevation of the bottom of the confining sediments. If the water table drops below the bottom of lake sediments, any continued increase in drawdown would not increase seepage.

Surface-Water Outflow

Surface-water outflow (SO) was computed with a stage-discharge rating curve based on measurements of lake stage and streamflow. Little Sand, Duck, and Deephole Lakes have intermittent surface outlets. Measurements of streamflow and concurrent lake stage at the outlets of Little Sand and Duck Lake allowed the computation of stage-discharge relations for these outlets. The equation for the Deephole Lake outlet was assumed to be similar to the equations for the other two lakes, based on the outlet configuration and the elevation of the outlet channel. The rating equations are listed in table 2.

Table 2.—*Rating equations used for lake outflow*

[Q = discharge, in ft^3/s; LL = lake level, in feet above sea level]

	From 1977 measurements	From 1985 calibration
Duck Lake	$Q = (0.579 \times (LL - 1610.00))^{7.69}$	$Q = (0.579 \times (LL - 1611.46))^{7.69}$
Deephole Lake	$Q = (0.65 \times (LL - 1604.50))^{5.76}$	$Q = (0.65 \times (LL - 1605.31))^{5.76}$
Little Sand Lake	$Q = (0.58 \times (LL - 1590.30))^{4.76}$	$Q = (0.58 \times (LL - 1590.76))^{4.76}$

Most of the measurements of streamflow used to define the outflow ratings were made in 1978. These ratings could change with time, especially because beavers are active in the outlet channels. Beaver dams currently control the lake outlets. There is no guarantee that these structures have been stable over time or that they will remain so. Therefore, the results of this model (as far as they are affected by the computed outflow), are strictly applicable only for the outlet conditions described by the rating curves.

Computation Procedures

The water-budget model works on a daily time step, using monthly precipitation and evaporation data. A monthly time step would have introduced errors by not properly changing outflow and seepage with changing lake stage.

All of the model calculations are performed in units of feet and days. All variables that have units of length, area, and volume are converted to units of feet, feet squared, and cubic feet, respectively. All variables with time units are converted to days.

The main body of the program reads all of the precipitation and evaporation data, then calls subroutines to calculate the water budget for each lake. The water budget for the entire 31-year period is calculated, summarized, and printed for each lake before going on the the next lake. The order of calculation is: Duck Lake, Deephole Lake, Little Sand Lake, then Skunk Lake.

The computation procedure is the same for all of the lakes for each day. First, the surface areas of the lake and the adjoining flooded wetlands are calculated for the lake stage from the previous day. All of the inflows and outflows are then calculated for this lake stage and area. The net inflow (with outflow being negative) is converted to a change in lake stage by dividing by the area of the lake. The new lake stage for the next day is calculated from the previous day's stage and the change in stage. The sum of the outflows for each day from Duck Lake and Deephole Lake were saved and used as inflows to Little Sand Lake.

A modification of the procedure for calculating the new lake stage was required for Skunk Lake. The area of Skunk Lake can approach zero so it is inadvisable to divide by area. The total volume of water in Skunk Lake is computed from the previous day's volume and the change in volume. The new lake level is then computed using lake level-volume equations derived from the lake level-area equations.

Versions of the Model

A version of the model that used daily precipitation data to simulate a period of several months to a few years was developed for calibration. It was used with data from 1977 to calibrate the hydraulic conductivity (K) for each lake. It was also used with data from 1985 to adjust the outflow rating curves for apparent changes in the outflow structures.

A version of the model that used only monthly precipitation data was used for calibration of the winter runoff coefficients and for longer term simulations.

Model Calibration

There is uncertainty in nearly all of the components of the model. Except for information obtained by analyses of samples collected at widely separated points, there is no practical way to measure the overall hydraulic conductivity and thickness of the lakebeds. The ground-water altitudes were measured only at scattered wells and only at certain times. Overland runoff was estimated from limited streamflow measurements at other streams in the area, not at the lakes themselves. Precipitation was measured more than 7 mi away. Evaporation was measured at an evaporation pan about 40 mi away and adjusted to lake evaporation by a monthly average coefficient. Lake outflow was measured on a few occasions, and the rating curves were developed from those measurements; the relation of lake level to outflow may have changed over time.

The most uncertain component of the model is the hydraulic conductivity (K). The next most uncertain component is the thickness of the sediments (THK). An increase in K has the same effect on the water budget as a proportional decrease in THK, because these two variables appear together in Darcy's Law as K/THK. For convenience, only the value of K was adjusted in the model, and the value of THK was held fixed. The same result could have been obtained by holding K constant and adjusting THK.

The model was calibrated in three stages. First, the best value of K was determined for each lake using data from 1977 in the daily version of the model. Second, the surface-outflow rating curves were adjusted for current conditions using data from 1985 in the daily version. Third, the runoff coefficients were adjusted using 31 years of data in the monthly model.

Daily Calibration

The period having the most lake-level data (1977) was used for accurate calibration. The daily version of the model was used for calibration. The values of K were adjusted until the computed lake levels were in the best possible agreement with the observed lake levels during the open-water period of 1977. Figures 3-6 show the comparisons of simulated daily lake stage with observed lake stage. The root mean square error varied from 0.06 ft for Little Sand Lake to 0.28 ft for Skunk Lake. The errors in simulated lake stage on days when lake stage was observed are shown in table 3. The values of K determined with this calibration are the best approximation of the average lake-sediment hydraulic conductivity.

When the calibration was tested with data from 1985, the simulated stages were significantly lower than the observed stages. There were not sufficient discharge measurements to recompute the rating curves at the outlet, but a few field observations indicated that there was less discharge from the outlets than indicated by the rating curves. It was assumed that beaver dam construction had raised the outlet controls. The model was adjusted by raising the

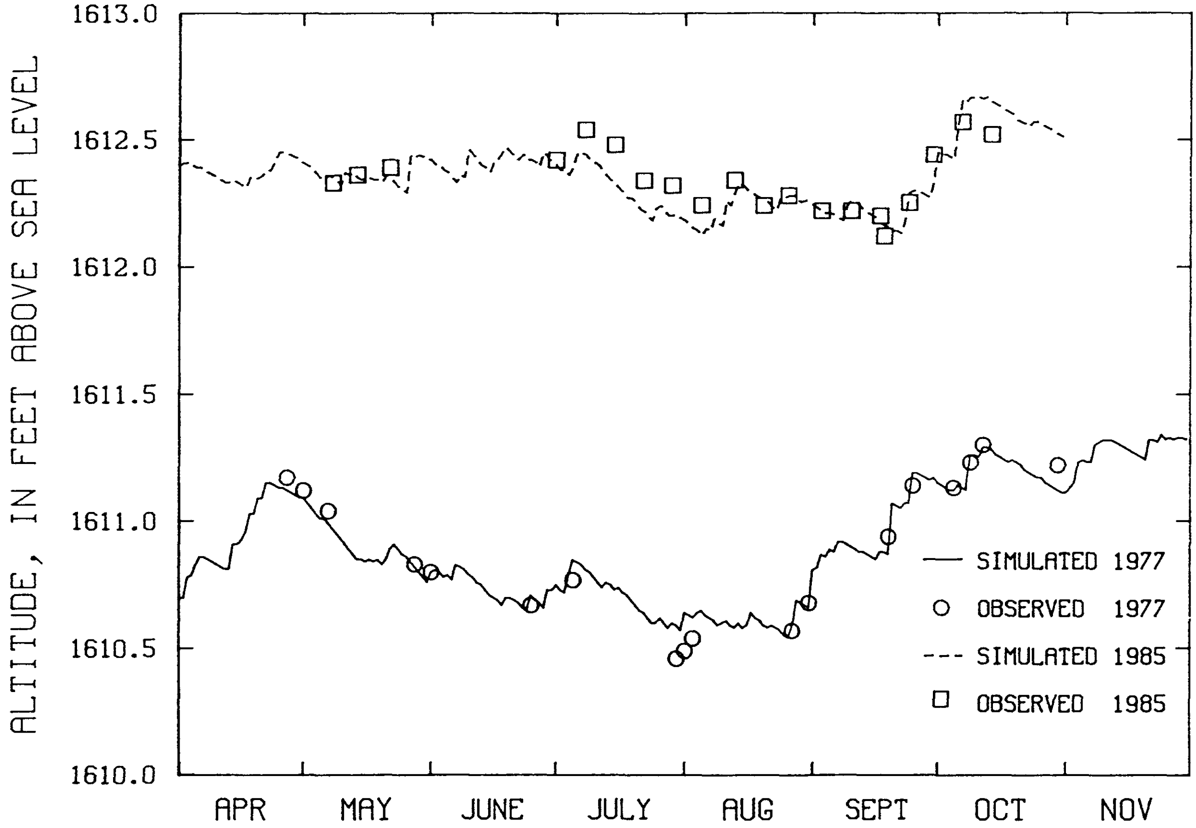

Figure 3. Observed and simulated daily lake levels for Duck Lake

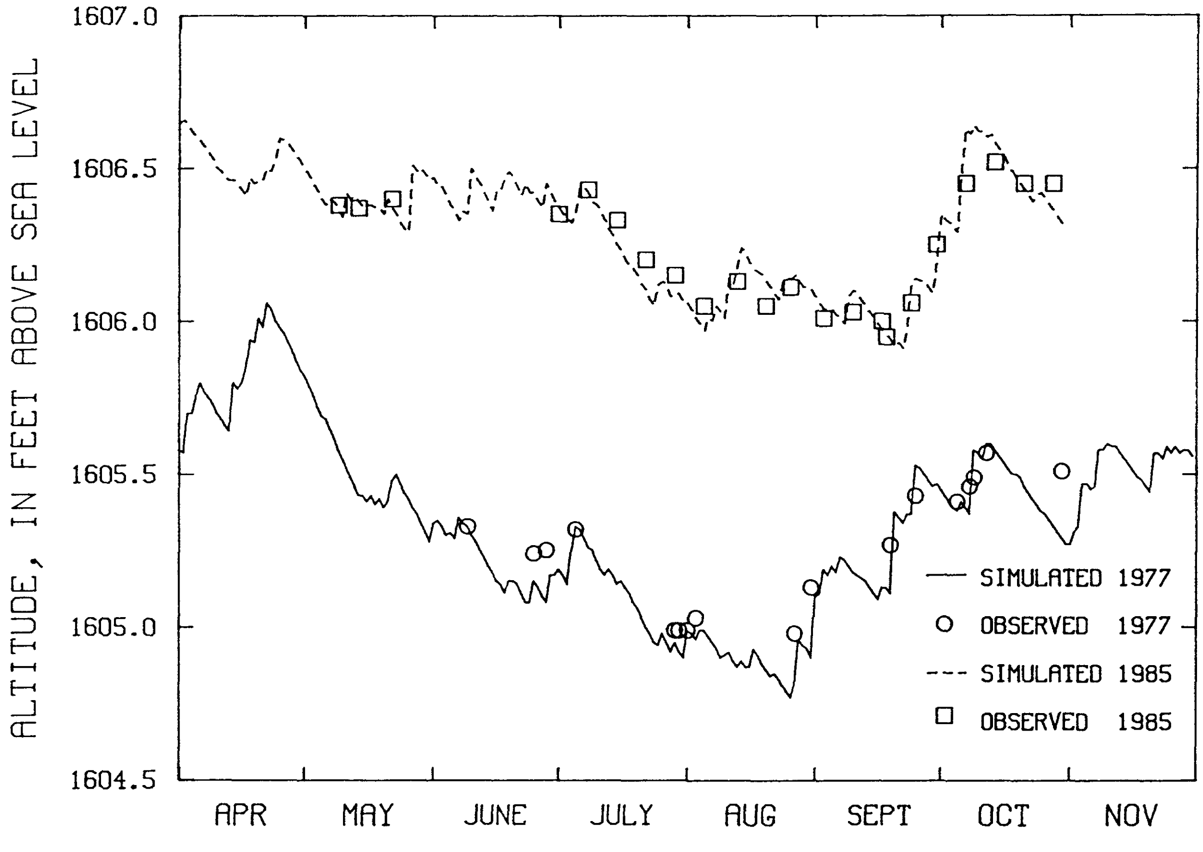

Figure 4. Observed and simulated daily lake levels for Deephole Lake.

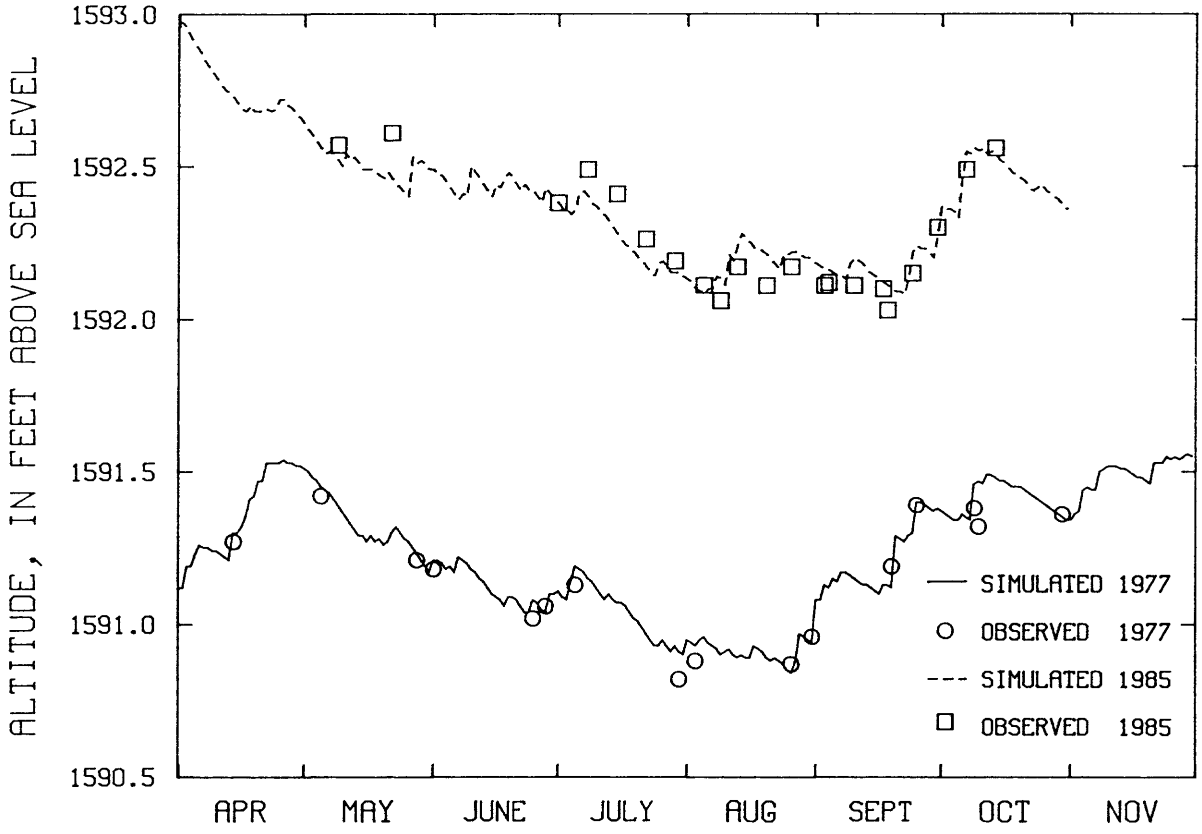

Figure 5. Observed and simulated daily lake levels for Little Sand Lake.

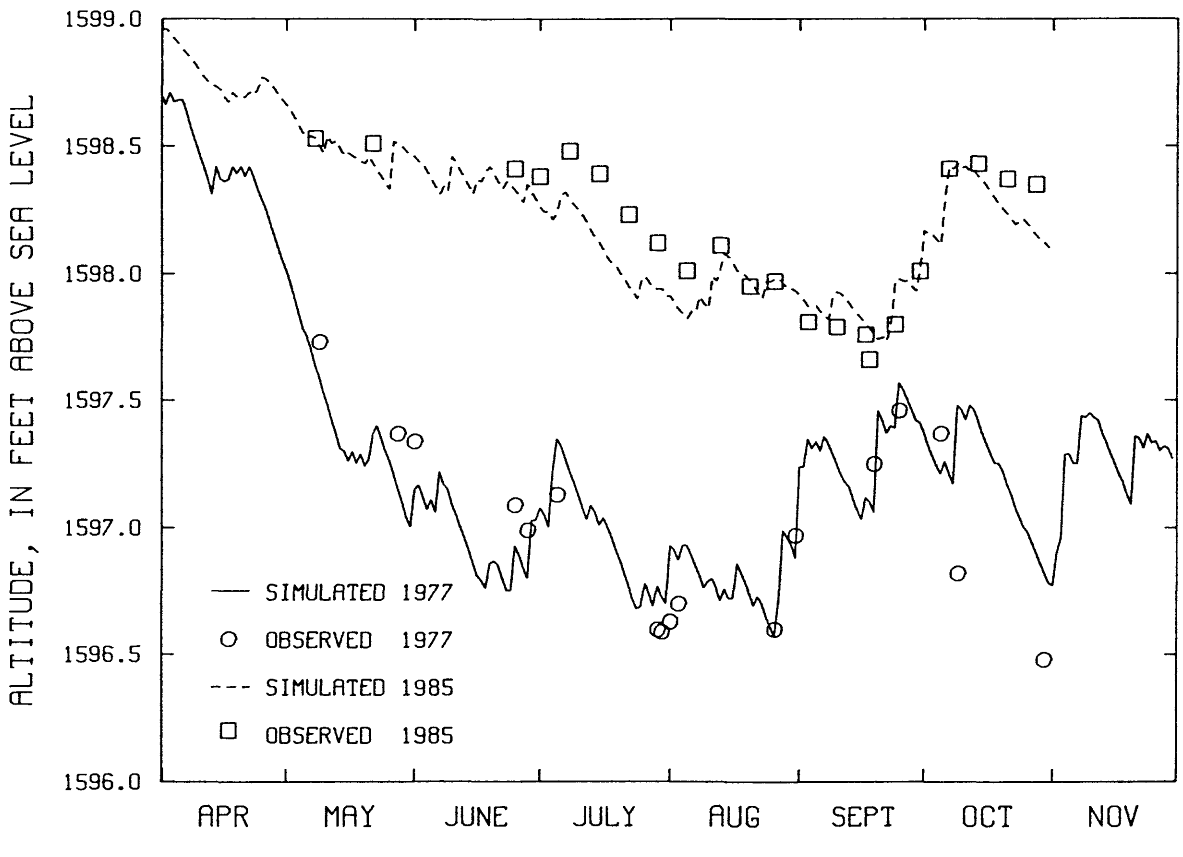

Figure 6. Observed and simulated daily lake levels for Skunk Lake.

Table 3.—*Comparison of measured and calculated lake levels for calibration with 1977 data*

[ft, feet; ft/yr, feet per year; K, hydraulic conductivity]

DUCK LAKE

Lake K = 1.48 ft/yr Thickness = 37.50 ft
Wetland K = 1.48 ft/yr Thickness = 10.00 ft

Date Month	Day	Lake level Measured (ft)	Lake level Calculated (ft)	Difference (ft)
4	27	1,611.17	1,611.12	-0.05
5	1	1,611.12	1,611.09	-.03
5	7	1,611.04	1,610.99	-.05
5	28	1,610.83	1,610.82	-.01
6	1	1,610.80	1,610.80	.00
6	25	1,610.67	1,610.71	.04
6	28	1,611.13	1,610.66	-.47
7	5	1,610.77	1,610.85	.08
7	29	1,610.23	1,610.60	.37
7	30	1,610.46	1,610.59	.13
8	1	1,610.49	1,610.64	.15
8	3	1,610.54	1,610.62	.08
8	27	1,610.57	1,610.59	.02
8	31	1,610.68	1,610.66	-.02
9	19	1,610.94	1,610.87	-.07
9	25	1,611.14	1,611.19	.05
10	5	1,611.13	1,611.12	-.01
10	9	1,611.23	1,611.26	.03
10	12	1,611.30	1,611.29	-.01
10	30	1,611.22	1,611.12	-.10
Root mean square =				.15
Maximum departure from measured lake level =				-.47

LITTLE SAND LAKE

Lake K = 2.62 ft/yr Thickness = 15.00 ft

Date Month	Day	Lake level Measured (ft)	Lake level Calculated (ft)	Difference (ft)
4	14	1,591.27	1,591.30	0.03
5	5	1,591.42	1,591.45	.03
5	28	1,591.21	1,591.23	.02
6	1	1,591.18	1,591.21	.03
6	25	1,591.02	1,591.08	.06
6	28	1,591.06	1,591.04	-.02
7	5	1,591.13	1,591.19	.06
7	30	1,590.82	1,590.91	.09
8	3	1,590.88	1,590.93	.05
8	26	1,590.87	1,590.84	-.03
8	31	1,590.96	1,590.94	-.02
9	19	1,591.19	1,591.12	-.07
9	25	1,591.39	1,591.40	.01
10	9	1,591.38	1,591.46	.08
10	10	1,591.32	1,591.47	.15
10	30	1,591.36	1,591.35	-.01
Root mean square =				.06
Maximum departure from measured lake level =				.15

DEEP HOLE LAKE

Lake K = 4.19 ft/yr Thickness = 17.40 ft
Wetland K = 4.19 ft/yr Thickness = 1.50 ft

Date Month	Day	Lake level Measured (ft)	Lake level Calculated (ft)	Difference (ft)
6	9	1,605.33	1,605.33	0.00
6	25	1,605.24	1,605.15	-.09
6	28	1,605.25	1,605.08	-.17
7	5	1,605.32	1,605.33	.01
7	29	1,604.99	1,604.95	-.04
7	30	1,604.96	1,604.92	-.04
8	1	1,604.99	1,604.99	.00
8	3	1,605.03	1,604.96	-.07
8	27	1,604.98	1,604.82	-.16
8	31	1,605.13	1,604.90	-.23
9	19	1,605.27	1,605.11	-.16
9	25	1,605.43	1,605.53	.10
10	5	1,605.41	1,605.38	-.03
10	8	1,605.46	1,605.37	-.09
10	9	1,605.49	1,605.58	.09
10	12	1,605.57	1,605.60	.03
10	30	1,605.51	1,605.29	-.22
Root mean square =				.11
Maximum departure from measured lake level =				-.23

SKUNK LAKE

Lake K = 36.0 ft/yr Thickness = 10.00 ft
Wetland K = 36.0 ft/yr Thickness = 10.00 ft

Date Month	Day	Lake level Measured (ft)	Lake level Calculated (ft)	Difference (ft)
5	9	1,597.73	1,597.36	-0.37
5	28	1,597.37	1,597.00	-.37
6	1	1,597.34	1,597.01	-.33
6	25	1,597.09	1,596.79	-.30
6	28	1,596.99	1,596.65	-.34
7	5	1,597.13	1,597.25	.12
7	29	1,596.60	1,596.62	.02
7	30	1,596.59	1,596.57	-.02
8	1	1,596.63	1,596.79	.16
8	3	1,596.70	1,596.72	.02
8	26	1,596.60	1,596.39	-.21
8	31	1,596.97	1,596.72	-.25
9	19	1,597.25	1,596.93	-.32
9	25	1,597.46	1,597.50	.04
10	5	1,597.37	1,597.08	-.29
10	9	1,596.82	1,597.40	.58
10	30	1,596.48	1,596.66	.18
Root mean square =				.28
Maximum departure from measured lake level =				.58

Table 4.—*Comparison of measured and calculated lake levels for calibration with 1985 data*

[ft. feet: ft/yr. feet per year: K. hydraulic conductivity]

DUCK LAKE

Lake K = 1.48 ft/yr Thickness = 37.50 ft
Wetland K = 1.48 ft/yr Thickness = 10.00 ft

Date Month	Date Day	Lake level Measured (ft)	Lake level Calculated (ft)	Difference (ft)
5	8	1,612.33	1,612.35	0.02
5	14	1,612.36	1,612.35	-.01
5	22	1,612.39	1,612.35	-.04
7	1	1,612.42	1,612.40	-.02
7	8	1,612.54	1,612.44	-.10
7	15	1,612.48	1,612.33	-.15
7	22	1,612.34	1,612.22	-.12
7	29	1,612.32	1,612.20	-.12
8	5	1,612.24	1,612.12	-.12
8	13	1,612.34	1,612.29	-.05
8	20	1,612.24	1,612.26	.02
8	26	1,612.28	1,612.28	.00
9	3	1,612.22	1,612.21	-.01
9	10	1,612.22	1,612.26	.04
9	17	1,612.20	1,612.17	-.03
9	18	1,612.12	1,612.16	.04
9	24	1,612.25	1,612.29	.04
9	30	1,612.44	1,612.33	-.11
10	7	1,612.57	1,612.66	.09
10	14	1,612.52	1,612.65	.13

Root mean square = .08

Maximum departure from measured lake level = -.15

LITTLE SAND LAKE

Lake K = 2.62 ft/yr Thickness = 15.00 ft

Date Month	Date Day	Lake level Measured (ft)	Lake level Calculated (ft)	Difference (ft)
5	9	1,592.57	1,592.52	-0.05
5	22	1,592.61	1,592.46	-.15
7	1	1,592.38	1,592.38	.00
7	8	1,592.49	1,592.40	-.09
7	15	1,592.41	1,592.28	-.13
7	22	1,592.26	1,592.17	-.09
7	29	1,592.19	1,592.15	-.04
8	5	1,592.11	1,592.08	-.03
8	9	1,592.06	1,592.13	.07
8	13	1,592.17	1,592.24	.07
8	20	1,592.11	1,592.21	.10
8	26	1,592.17	1,592.22	.05
9	3	1,592.11	1,592.16	.05
9	4	1,592.12	1,592.16	.04
9	10	1,592.11	1,592.20	.09
9	17	1,592.10	1,592.12	.02
9	18	1,592.03	1,592.11	.08
9	24	1,592.15	1,592.22	.07
9	30	1,592.30	1,592.27	-.03
10	7	1,592.49	1,592.55	.06
10	14	1,592.56	1,592.54	-.02

Root mean square = .07

Maximum departure from measured lake level = -.15

DEEP HOLE LAKE

Lake K = 4.19 ft/yr Thickness = 17.40 ft
Wetland K = 4.19 ft/yr Thickness = 1.50 ft

Date Month	Date Day	Lake level Measured (ft)	Lake level Calculated (ft)	Difference (ft)
5	9	1,606.38	1,606.37	-0.01
5	14	1,606.37	1,606.39	.02
5	22	1,606.40	1,606.37	-.03
7	1	1,606.35	1,606.37	.02
7	8	1,606.43	1,606.42	-.01
7	15	1,606.33	1,606.25	-.08
7	22	1,606.20	1,606.10	-.10
7	29	1,606.15	1,606.09	-.06
8	5	1,606.05	1,605.97	-.08
8	13	1,606.13	1,606.18	.05
8	20	1,606.05	1,606.13	.08
8	26	1,606.11	1,606.14	.03
9	3	1,606.01	1,606.04	.03
9	10	1,606.03	1,606.10	.07
9	17	1,606.00	1,605.97	-.03
9	18	1,605.95	1,605.96	.01
9	24	1,606.06	1,606.13	.07
9	30	1,606.25	1,606.19	-.06
10	7	1,606.45	1,606.63	.18
10	14	1,606.52	1,606.58	.06
10	21	1,606.45	1,606.43	-.02
10	28	1,606.45	1,606.36	-.09

Root mean square = .07

Maximum departure from measured lake level = .18

SKUNK LAKE

Lake K = 22.0 ft/yr Thickness = 1 .00 ft
Wetland K = 22.0 ft/yr Thickness = 10.00 ft

Date Month	Date Day	Lake level Measured (ft)	Lake level Calculated (ft)	Difference (ft)
5	8	1,598.53	1,598.53	0.00
5	22	1,598.51	1,598.43	-.08
6	25	1,598.41	1,598.33	-.08
7	1	1,598.38	1,598.26	-.12
7	8	1,598.48	1,598.29	-.19
7	15	1,598.39	1,598.12	-.27
7	22	1,598.23	1,597.95	-.28
7	29	1,598.12	1,597.94	-.18
8	5	1,598.01	1,597.82	-.19
8	13	1,598.11	1,598.03	-.08
8	20	1,597.95	1,597.97	.02
8	26	1,597.97	1,597.98	.01
9	3	1,597.81	1,597.87	.06
9	10	1,597.79	1,597.93	.14
9	17	1,597.76	1,597.80	.04
9	18	1,597.66	1,597.78	.12
9	24	1,597.80	1,597.97	.17
9	30	1,598.01	1,598.02	.01
10	7	1,598.41	1,598.42	.01
10	14	1,598.43	1,598.38	-.05
10	21	1,598.37	1,598.23	-.14
10	28	1,598.35	1,598.15	-.20

Root mean square = .14

Maximum departure from measured lake level = -.28

base elevation of the rating curves to correct the calibration for the 1985 data. Comparisons of simulated and observed lake stages for 1985 also are shown in figures 3-6. Errors in simulated daily lake levels are shown in table 4. The rating curves estimated for this calibration are the best approximation of current conditions and are used in the long-term model.

Long-Term Recalibration

Values of winter runoff coefficients were readjusted using 31 years of monthly data to produce the best agreement between simulated monthly lake stages and observed daily lake stages for 1985. Comparisons of observed and simulated lake levels for 1985 are shown in figures 7-10 and summarized in table 5.

Long-Term Simulation

The values of K and winter runoff coefficients and rating curves determined during calibration were used in the model to simulate 31 years of monthly data for each of the lakes. The 31 years of data comprise a representative sample of real weather conditions that include wet and dry periods. The simulated values included lake level, area, seepage, runoff, and outflow.

The model was run for two conditions: current ground-water levels (represented by ground-water levels beneath the lakes measured in recent years) and expected ground-water levels after dewatering (represented by ground-water levels beneath the lakes predicted by the GEOFLOW model). In both cases, an areally weighted average ground-water elevation was used for each lake. The effect of mine dewatering on the lakes was represented by the difference between the lake level simulated for current conditions and that simulated after mine dewatering.

Current ground-water levels were derived from a water-table map that was based on measured water levels during 1984 (Exxon Minerals Company, written commun., April 1984). The model was run using 31 years of monthly data to simulate the monthly lake-stage variation that would be expected under the prevailing conditions, without the mine. A reasonable starting elevation was assumed for each lake, and the model run was started with 2 years of average precipitation and evaporation to obtain stable average starting elevations.

The model was rerun using lowered ground-water levels to simulate the effect of mine dewatering. Ground-water levels were determined from results from the GEOFLOW model (IT Corporation, written commun., 1986). The ground-water levels were determined with the GEOFLOW model using the K values for the lakebed sediments that were estimated by the calibration of this model.

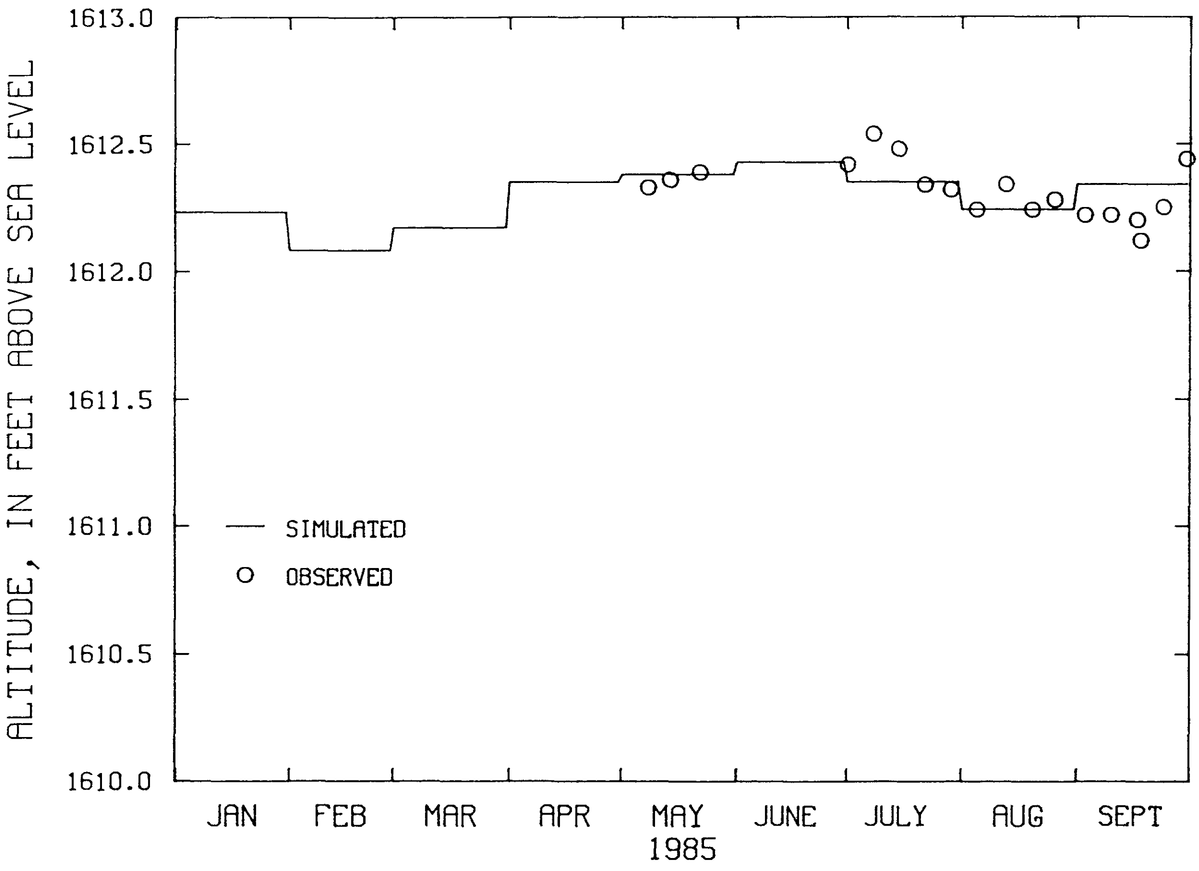

Figure 7. Observed and simulated monthly lake levels using long-term model for Duck Lake.

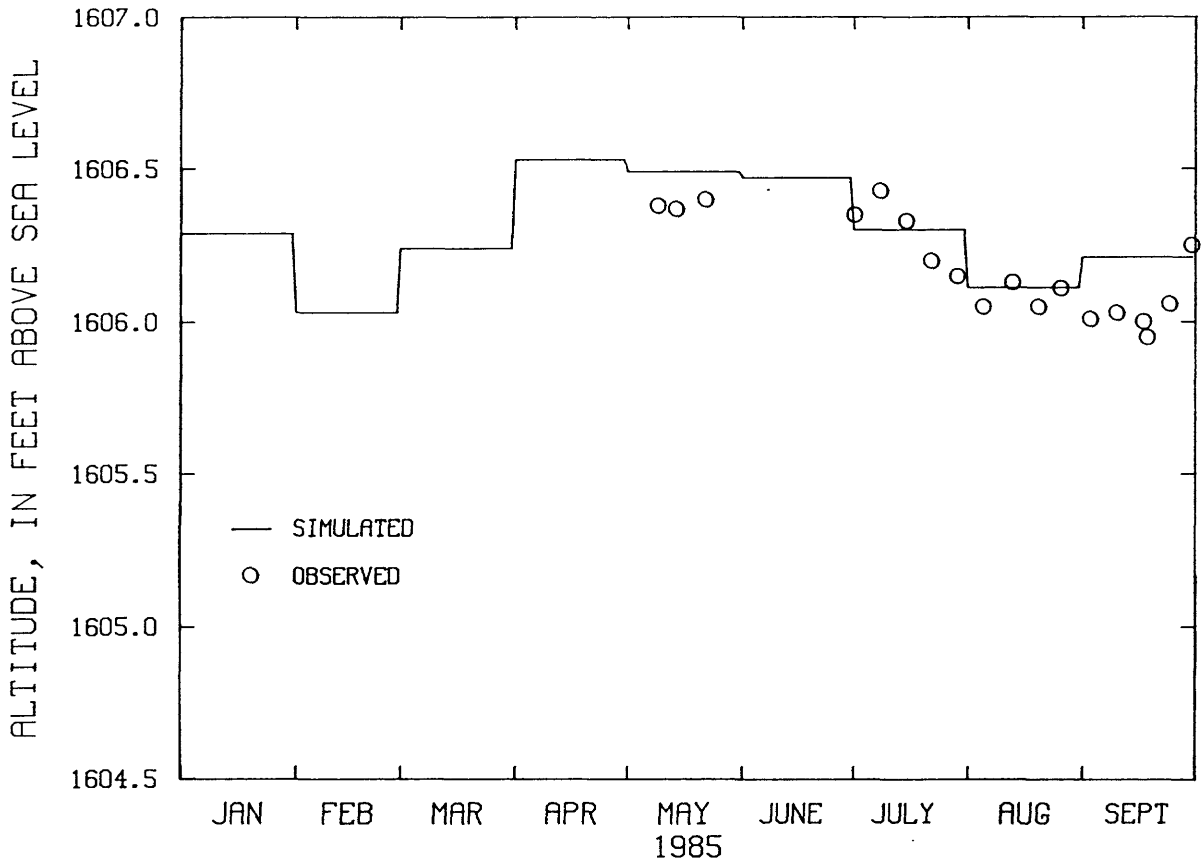

Figure 8. Observed and simulated monthly lake levels using long-term model for Deephole Lake.

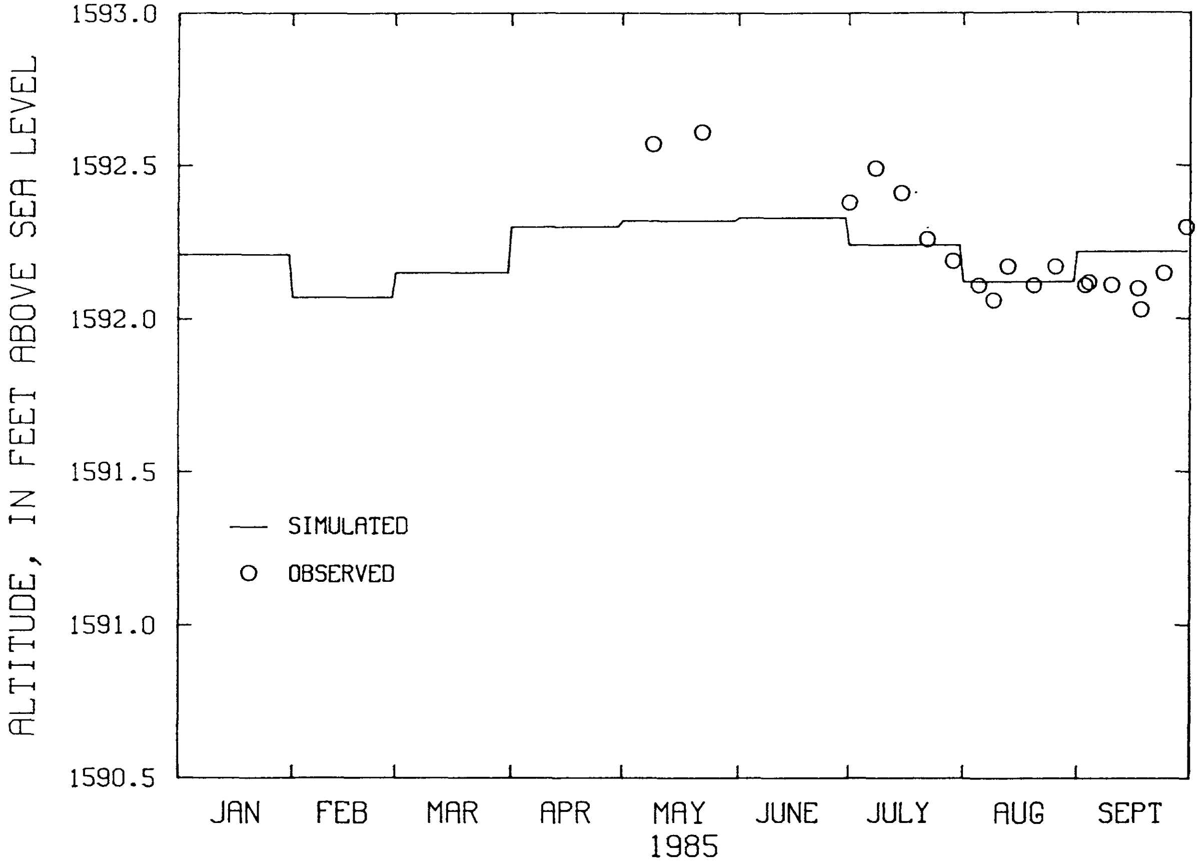

Figure 9. Observed and simulated monthly lake levels using long-term model for Sand Lake.

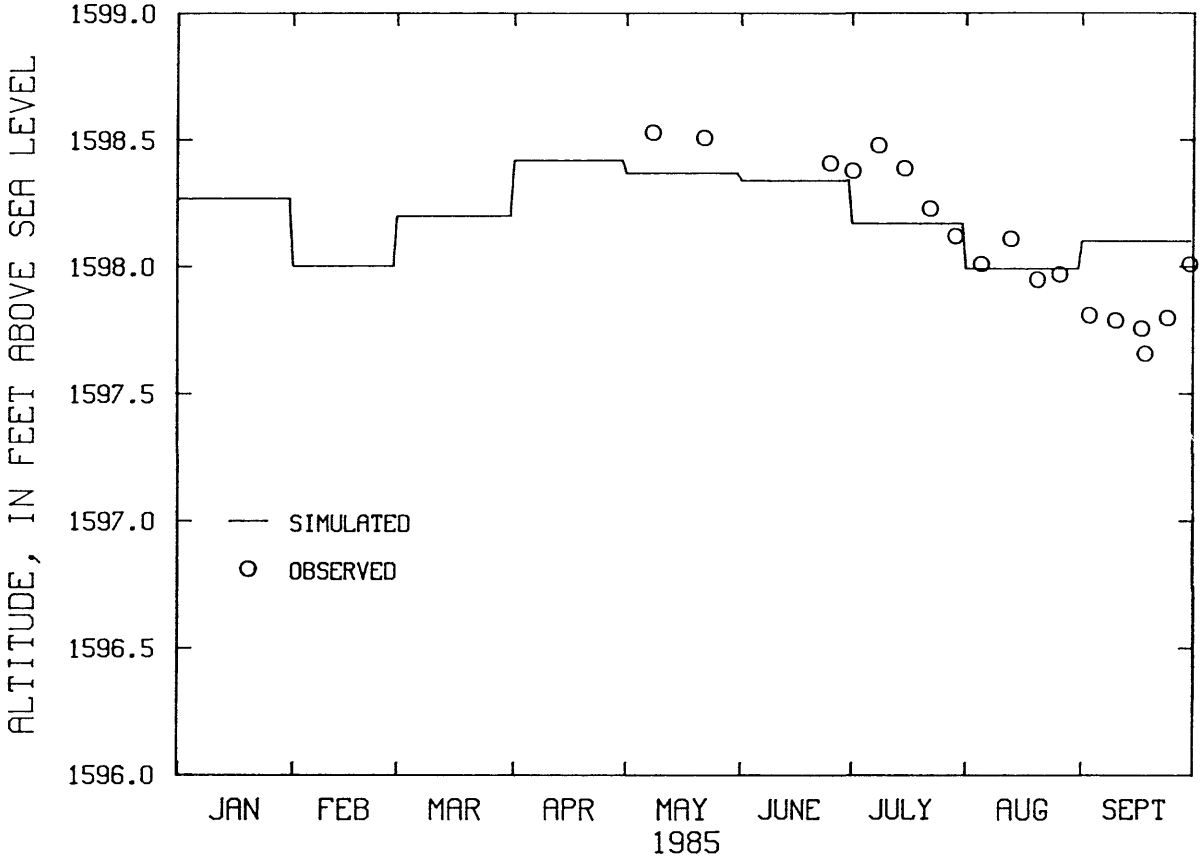

Figure 10. Observed and simulated monthly lake levels using long-term model for Skunk Lake.

Table 5.—*Summary of errors in calculated mean monthly lake levels during 1985 after long-term calibration*

	July (feet)	August (feet)	September (feet)	Mean (feet)	Root mean square (feet)
		Duck Lake			
Observed	1,612.42	1,612.28	1,612.27		
Calculated	1,612.35	1,612.24	1,612.34		
Error	-.07	-.04	.07	-0.01	0.06
		Deephole Lake			
Observed	1,606.29	1,606.09	1,606.07		
Calculated	1,606.30	1,606.11	1,606.21		
Error	.01	.02	.14	.06	.08
		Little Sand Lake			
Observed	1,592.34	1,592.14	1,592.15		
Calculated	1,592.24	1,592.12	1,592.22		
Error	-.10	-.02	.07	-.02	.07
		Skunk Lake			
Observed	1,598.32	1,598.01	1,597.81		
Calculated	1,598.17	1,597.99	1,598.10		
Error	-.15	-.02	.29	.04	.19

Analysis of Model Results

Comparison of Drawdown Conditions to Baseline

The 31 years of simulated monthly lake-level data were analyzed further to determine the frequency of various lake stages. A duration table was calculated for each lake for each month. The duration tables are summarized in tables 6-9, which indicate lake stages that would be exceeded 90, 50, and 10 percent of the time during a dry period, a normal period, and a wet period, respectively; the tables also give the mean for each month.

The effect of the mine dewatering on lake levels during dry, normal, and wet periods was determined by taking the difference between the corresponding values on the duration tables for current conditions and for conditions after mine dewatering. These are included in tables 6-9. The simulation predicts that the effects of water-table drawdown would range from slight to very significant and would vary with each lake and the amount of drawdown affecting it. The greatest predicted effect is on Little Sand Lake, where the drawdown during average conditions would be 6.9 ft for the expected water-table altitudes. The simulated effects on the other lakes were not as extreme. The average drawdown of Duck Lake is 0.21 ft, of Deephole Lake is 0.63 ft, and of Skunk Lake is 1.9 ft.

Estimation of Mitigation Inflows

One possible mitigation tactic for preventing drawdown of the lake levels is to pump water into the lakes. Tables 10-13 were prepared to show the rate of pumping required to maintain lake levels at specified elevations for various amounts of water-table drawdown and for various values of hydraulic conductivity. A range of ground-water levels and hydraulic conductivities is shown because neither of these values is certain. In addition, water-table drawdown will gradually increase as pumping is started to dewater the mine. There is a significant, but undetermined, possible error in the models used to predict ground-water levels and hydraulic conductivity. The tables allow estimation of the pumping required under various possible conditions, including the transition period when mine dewatering begins.

Table 14 summarizes the average water-table drawdown and pumpage required to maintain levels of each lake.

The actual effect of mine dewatering on lake stage could be less than or greater than that predicted by the model. Other aspects of the overall hydrologic budget of the area subject to ground-water drawdown must be considered in forming a final judgment on possible effects on lake levels. These other aspects include the ability of the underlying aquifer to transmit water from the area below the lakes to the mine, and the total amount of water to be pumped from the mine. The total seepage from the lakes must be less than the water pumped from the mine, and cannot exceed the capacity of the aquifer to transmit water from the lakes.

Table 6.—*Stage-duration table for current and expected ground-water levels after mine dewatering for Duck Lake*

Month	Mean	Percentage of time stage exceeded		
		90	50	10
		Lake level at current ground-water level		
October	1,611.28	1,610.13	1,611.10	1,612.45
November	1,611.34	1,610.15	1,611.10	1,612.44
December	1,611.40	1,610.25	1,611.15	1,612.49
January	1,611.38	1,610.12	1,611.13	1,612.48
February	1,611.31	1,610.00	1,611.01	1,612.37
March	1,611.31	1,609.87	1,611.23	1,612.38
April	1,611.46	1,610.05	1,611.65	1,612.60
May	1,611.55	1,610.22	1,611.54	1,612.61
June	1,611.45	1,610.03	1,611.62	1,612.47
July	1,611.32	1,609.91	1,611.54	1,612.48
August	1,611.23	1,609.93	1,611.41	1,612.47
September	1,611.26	1,610.02	1,611.13	1,612.45
		Lake level at expected ground-water level after mine dewatering		
October	1,611.07	1,609.84	1,610.84	1,612.40
November	1,611.12	1,609.87	1,610.84	1,612.39
December	1,611.19	1,609.98	1,610.89	1,612.41
January	1,611.17	1,609.83	1,610.86	1,612.35
February	1,611.10	1,609.72	1,610.74	1,612.22
March	1,611.09	1,609.59	1,610.96	1,612.31
April	1,611.25	1,609.77	1,611.38	1,612.48
May	1,611.34	1,609.95	1,611.27	1,612.50
June	1,611.25	1,609.76	1,611.35	1,612.36
July	1,611.11	1,609.63	1,611.31	1,612.37
August	1,611.02	1,609.66	1,611.13	1,612.44
September	1,611.05	1,609.75	1,610.85	1,612.37
		Difference due to mine dewatering		
October	-.21	-.28	-.26	-.06
November	-.21	-.29	-.26	-.05
December	-.21	-.27	-.26	-.08
January	-.22	-.29	-.27	-.12
February	-.21	-.28	-.27	-.15
March	-.22	-.29	-.27	-.07
April	-.21	-.28	-.27	-.12
May	-.21	-.27	-.27	-.11
June	-.21	-.27	-.27	-.11
July	-.21	-.27	-.23	-.11
August	-.21	-.27	-.28	-.03
September	-.21	-.27	-.28	-.08
Average	-.21	-.28	-.27	-.09

Table 7.—*Stage-duration table for current and expected ground-water levels after mine dewatering for Deephole Lake*

Month	Mean	Percentage of time stage exceeded		
		90	50	10
		Lake level at current ground-water level		
October	1,605.66	1,604.87	1,605.77	1,606.34
November	1,605.75	1,604.97	1,605.78	1,606.34
December	1,605.87	1,605.11	1,606.02	1,606.58
January	1,605.83	1,605.04	1,605.89	1,606.54
February	1,605.70	1,604.83	1,605.87	1,606.38
March	1,605.71	1,604.75	1,605.78	1,606.61
April	1,605.97	1,605.06	1,605.99	1,606.72
May	1,606.09	1,605.22	1,606.22	1,606.58
June	1,605.94	1,605.11	1,606.09	1,606.51
July	1,605.76	1,604.86	1,605.80	1,606.37
August	1,605.63	1,604.79	1,605.73	1,606.18
September	1,605.64	1,604.93	1,605.63	1,606.29
		Lake level at expected ground-water level after mine dewatering		
October	1,604.99	1,603.87	1,605.04	1,605.92
November	1,605.07	1,604.06	1,605.02	1,606.06
December	1,605.21	1,604.14	1,605.10	1,606.25
January	1,605.17	1,603.97	1,605.37	1,606.15
February	1,605.04	1,603.73	1,605.27	1,606.08
March	1,605.05	1,603.68	1,604.96	1,606.23
April	1,605.35	1,603.96	1,605.39	1,606.56
May	1,605.51	1,604.17	1,605.67	1,606.36
June	1,605.36	1,604.00	1,605.58	1,606.17
July	1,605.17	1,603.79	1,605.45	1,606.09
August	1,605.01	1,603.84	1,605.10	1,605.92
September	1,605.00	1,603.88	1,605.05	1,605.86
		Difference due to mine dewatering		
October	-.67	-1.00	-.73	-.43
November	-.68	-.91	-.76	-.29
December	-.66	-.97	-.92	-.33
January	-.65	-1.07	-.52	-.39
February	-.66	-1.10	-.60	-.30
March	-.66	-1.06	-.82	-.38
April	-.63	-1.09	-.60	-.16
May	-.59	-1.05	-.55	-.22
June	-.58	-1.11	-.51	-.34
July	-.59	-1.07	-.35	-.29
August	-.61	-.95	-.63	-.26
September	-.64	-1.05	-.58	-.43
Average	-.63	-1.04	-.63	-.32

Table 8.—*Stage-duration table for current and expected ground-water levels after mine dewatering for Little Sand Lake*

Month	Mean	Percentage of time stage exceeded		
		90	50	10
	Lake level at current ground-water level			
October	1,591.94	1,591.49	1,592.01	1,592.33
November	1,591.98	1,591.54	1,592.02	1,592.33
December	1,592.03	1,591.59	1,592.06	1,592.42
January	1,592.00	1,591.57	1,592.04	1,592.40
February	1,591.94	1,591.50	1,592.03	1,592.31
March	1,591.94	1,591.44	1,591.96	1,592.42
April	1,592.07	1,591.61	1,592.03	1,592.54
May	1,592.13	1,591.67	1,592.13	1,592.47
June	1,592.03	1,591.53	1,592.04	1,592.39
July	1,591.90	1,591.39	1,591.91	1,592.32
August	1,591.83	1,591.38	1,591.85	1,592.23
September	1,591.89	1,591.45	1,591.85	1,592.26
	Lake level at expected ground-water level after mine dewatering			
October	1,585.01	1,583.75	1,584.87	1,586.60
November	1,585.06	1,583.86	1,584.78	1,586.52
December	1,585.13	1,584.00	1,584.77	1,586.51
January	1,585.10	1,583.92	1,584.85	1,586.49
February	1,585.01	1,583.69	1,584.75	1,586.47
March	1,584.99	1,583.55	1,585.00	1,586.48
April	1,585.20	1,583.75	1,585.26	1,586.89
May	1,585.34	1,583.90	1,585.13	1,587.03
June	1,585.24	1,583.73	1,585.17	1,586.85
July	1,585.09	1,583.61	1,585.01	1,586.58
August	1,584.98	1,583.70	1,584.84	1,586.53
September	1,585.00	1,583.71	1,584.83	1,586.62
	Difference due to mine dewatering			
October	-6.93	-7.74	-7.14	-5.73
November	-6.93	-7.68	-7.24	-5.81
December	-6.90	-7.58	-7.29	-5.90
January	-6.90	-7.66	-7.19	-5.90
February	-6.93	-7.82	-7.28	-5.83
March	-6.95	-7.89	-6.96	-5.93
April	-6.88	-7.86	-6.77	-5.65
May	-6.79	-7.77	-7.00	-5.44
June	-6.78	-7.80	-6.87	-5.54
July	-6.81	-7.78	-6.90	-5.74
August	-6.85	-7.68	-7.01	-5.70
September	-6.89	-7.74	-7.02	-5.64
Average	-6.88	-7.75	-7.06	-5.74

Table 9.—*Stage-duration table for current and expected ground-water levels after mine dewatering for Skunk Lake*

Month	Mean	Percentage of time stage exceeded		
		90	50	10
	Lake level at current ground-water level			
October	1,597.93	1,597.61	1,597.96	1,598.35
November	1,598.01	1,597.70	1,598.05	1,598.34
December	1,598.10	1,597.71	1,598.11	1,598.51
January	1,598.04	1,597.55	1,598.01	1,598.50
February	1,597.92	1,597.52	1,597.95	1,598.28
March	1,597.96	1,597.52	1,597.91	1,598.47
April	1,598.22	1,597.81	1,598.17	1,598.69
May	1,598.29	1,597.91	1,598.29	1,598.58
June	1,598.11	1,597.78	1,598.06	1,598.46
July	1,597.93	1,597.60	1,597.89	1,598.29
August	1,597.84	1,597.53	1,597.85	1,598.17
September	1,597.89	1,597.52	1,597.89	1,598.31
	Lake level at expected ground-water level after mine dewatering			
October	1,595.88	1,595.53	1,595.84	1,596.37
November	1,596.25	1,595.52	1,596.24	1,596.98
December	1,596.41	1,595.52	1,596.52	1,597.14
January	1,596.09	1,595.28	1,596.05	1,596.96
February	1,595.82	1,595.10	1,595.76	1,596.53
March	1,596.12	1,595.38	1,596.05	1,597.09
April	1,596.78	1,596.11	1,596.85	1,597.27
May	1,596.61	1,596.10	1,596.65	1,597.11
June	1,596.10	1,595.50	1,596.11	1,596.66
July	1,595.89	1,595.47	1,595.88	1,596.33
August	1,595.78	1,595.17	1,595.84	1,596.21
September	1,595.92	1,595.29	1,595.90	1,596.50
	Difference due to mine dewatering			
October	-2.05	-2.08	-2.12	-1.98
November	-1.77	-2.18	-1.81	-1.37
December	-1.69	-2.20	-1.59	-1.38
January	-1.95	-2.26	-1.96	-1.54
February	-2.10	-2.41	-2.19	-1.74
March	-1.84	-2.14	-1.86	-1.39
April	-1.44	-1.70	-1.32	-1.42
May	-1.68	-1.82	-1.64	-1.48
June	-2.01	-2.28	-1.95	-1.80
July	-2.04	-2.13	-2.01	-1.95
August	-2.07	-2.36	-2.01	-1.96
September	-1.97	-2.23	-1.99	-1.81
Average	-1.88	-2.15	-1.87	-1.65

Table 10.—*Change in seepage for various ground-water levels and various values of hydraulic conductivity for Duck Lake*

[Datum is sea level]

Lake level = 1,611.36 — Lake area = 24.89 acres; Wetland area = 72.32 acres — Sediment thickness = 37.50 feet; Sediment thickness = 10.00 feet

	Ground-water level (feet)													
K (feet per year)		0.10	0.52	0.86	0.90	1.00	1.15	1.35	1.40	1.45	1.48	2.43	4.97	6.
		Average seepage at the current ground-water level (gallons per minute)												
Lake	1,594.88	0.68	3.52	5.83	6.10	6.78	7.79	9.15	9.49	9.83	10.0	16.5	33.7	40
Wetland		7.33	38.1	63.0	66.0	73.3	84.3	99.0	103	106	108	178	364	4
Total (inches per year)		1.60	8.30	13.7	14.4	16.0	18.4	21.5	22.3	23.1	23.6	38.8	79.3	95
		Increase in seepage at the indicated ground-water levels (gallons per minute)												
	1,594.00	0.04	0.19	0.31	0.33	0.36	0.42	0.49	0.51	0.52	0.54	0.88	1.80	2.
	1,593.00	.08	.40	.66	.70	.77	.89	1.04	1.08	1.12	1.14	1.88	3.84	4.
	1,592.00	.12	.62	1.02	1.07	1.18	1.36	1.60	1.66	1.72	1.75	2.88	5.89	7.
	1,591.00	.16	.83	1.37	1.44	1.60	1.83	2.15	2.23	2.31	2.36	3.88	7.93	9.
	1,590.00	.20	1.04	1.73	1.81	2.01	2.31	2.71	2.81	2.91	2.97	4.88	9.97	12
	1,588.00	.28	1.47	2.43	2.55	2.83	3.25	3.82	3.96	4.10	4.19	6.88	14.1	17
	1,586.00	.37	1.90	3.14	3.29	3.65	4.20	4.93	5.11	5.30	5.40	8.87	18.1	21
	1,584.00	.45	2.33	3.85	4.03	4.47	5.15	6.04	6.26	6.49	6.62	10.9	22.2	26
	1,582.00	.53	2.75	4.56	4.77	5.30	6.09	7.15	7.42	7.68	7.84	12.9	26.3	31
	[1]1,581.27	.56	2.91	4.81	5.04	5.60	6.44	7.56	7.84	8.12	[2]8.28	13.6	27.8	33
	1,580.00	.61	3.18	5.26	5.51	6.12	7.04	8.26	8.57	8.87	9.06	14.9	30.4	36
	1,578.00	.69	3.61	5.97	6.25	6.94	7.98	9.37	9.72	10.1	10.3	16.9	34.5	41
	1,576.00	.78	4.04	6.68	6.99	7.76	8.93	10.5	10.9	11.3	11.5	18.9	38.6	46
	1,574.00	.86	4.47	7.38	7.73	8.59	9.87	11.6	12.0	12.5	12.7	20.9	42.7	51
	1,572.00	.94	4.89	8.09	8.47	9.41	10.8	12.7	13.2	13.6	13.9	22.9	46.8	56
Bottom of sediment	1,557.30	1.55	8.04	13.3	13.9	15.5	17.8	20.9	21.6	22.4	22.9	37.6	76.8	92

[1]Expected ground-water level after mine dewatering.
[2]Expected increase in seepage.

Table 11.—*Change in seepage for various ground-water levels and various levels of hydraulic conductivity (K) for Deephole Lake*

[Datum is sea level]

Lake level = 1,605.80 | Lake area = 99.53 acres | Sediment thickness = 17.40 feet
Wetland area = 21.25 acres | Sediment thickness = 1.50 feet

K (feet per year)		0.07	0.13	0.52	0.70	0.77	3.20	3.30	3.55	3.86	4.00	4.19	5.32	6.00
	Ground-water level (feet)	Average seepage at the curreng ground-water level (gallons per minute)												
Lake	1,590.70	3.75	6.96	27.8	37.5	41.2	171	177	190	207	214	224	285	321
Wetland		1.41	2.62	10.5	14.1	15.5	64.6	66.6	71.7	77.9	80.8	84.6	107	121
Total (inches per year)		0.83	1.54	6.15	8.27	9.10	37.8	39.0	42.0	45.6	47.3	49.5	62.9	70.9
		Increase in seepage at the indicated ground-water elevation (gal/min)												
	1,590.00	0.17	0.32	1.29	1.74	1.91	7.94	8.19	8.81	9.58	9.92	10.4	13.2	14.9
	1,589.00	.42	.78	3.13	4.22	4.64	19.3	19.9	21.4	23.3	24.1	25.2	32.1	36.1
	1,588.00	.67	1.24	4.98	6.70	7.37	30.6	31.6	34.0	36.9	38.3	40.1	50.9	57.4
	1,587.00	.92	1.70	6.82	9.18	10.1	42.0	43.3	46.6	50.6	52.5	54.9	69.8	78.7
	1,586.00	1.17	2.17	8.66	11.7	12.8	53.3	55.0	59.1	64.3	66.6	69.8	88.6	99.9
	1,585.00	1.41	2.63	10.5	14.1	15.6	64.6	66.7	71.7	78.0	80.8	84.6	107	121
	[1]1,584.79	1.47	2.72	10.9	14.7	16.1	67.0	69.1	74.4	80.8	83.8	[2]87.8	111	126
	1,584.00	1.66	3.09	12.3	16.6	18.3	76.0	78.4	84.3	91.7	95.0	99.5	126	142
	1,583.00	1.91	3.55	14.2	19.1	21.0	87.3	90.1	96.9	105	109	114	145	164
	1,582.00	2.16	4.01	16.0	21.6	23.7	98.7	102	109	119	123	129	164	185
	1,581.00	2.41	4.47	17.9	24.1	26.5	110	113	122	133	138	144	183	206
	1,580.00	2.65	4.93	19.7	26.5	29.2	121	125	135	146	152	159	202	228
	1,579.00	2.90	5.39	21.6	29.0	31.9	133	137	147	160	166	174	221	249
	1,578.00	3.15	5.85	23.4	31.5	34.7	144	149	160	174	180	189	239	270
	1,577.00	3.40	6.31	25.2	34.0	37.4	155	160	172	187	194	203	258	291
Bottom of sediment	1,570.00	5.14	9.54	38.1	51.4	56.5	235	242	260	283	293	307	390	440

[1]Expected ground-water level after mine dewatering.
[2]Expected increase in seepage.

Table 12.—*Change in seepage for various ground-water levels and various values of hydraulic conductivity (K for Little Sand Lake*

[Datum is sea level]

Lake level = 1,591.97 Lake area = 244.85 acres Sediment thickness = 15.00 feet

K (feet per year)		0.11	0.52	0.60	1.10	1.66	1.75	1.80	2.07	2.20	2.50	2.62	3.81	6.0C
	Ground-water level (feet)	Average seepage at the current ground-water level (gallons per minute)												
Lake	1,587.59	4.87	23.0	26.6	48.7	73.5	77.5	79.7	91.7	97.4	111	116	169	266
Total (in/yr)		.39	1.82	2.10	3.85	5.82	6.13	6.31	7.25	7.71	8.76	9.18	13.4	21.0
		Increase in seepage at the indicated ground-water level (gallons per minute)												
	1,585.00	2.88	13.6	15.7	28.8	43.5	45.8	47.1	54.2	57.6	65.5	68.6	99.8	15
	1,584.00	3.99	18.9	21.8	39.9	60.3	63.5	65.4	75.2	79.9	90.8	95.1	138	21
	1,582.00	6.22	29.4	33.9	62.2	93.8	98.9	102	117	124	141	148	215	33
	1,580.00	8.44	39.9	46.1	84.4	127	134	138	159	169	192	201	292	46
	1,578.00	10.7	50.4	58.2	107	161	170	175	201	213	242	254	370	58
	1,576.00	12.9	61.0	70.3	129	195	205	211	243	258	293	307	447	70
	1,574.00	15.1	71.5	82.5	151	228	241	247	285	302	344	360	524	82
	1,572.00	17.3	82.0	94.6	173	262	276	284	326	347	394	413	601	94
	1,570.00	19.6	92.5	107	196	295	311	320	368	391	445	466	678	1,06
	1,568.00	21.8	103	119	218	329	347	357	410	436	495	519	755	1,18
	1,566.00	24.0	114	131	240	362	382	393	452	480	546	572	832	1,31
	[1]1,565.87	24.2	114	132	242	365	384	395	455	483	549	[2]576	837	1,31
	1,564.00	26.2	124	143	262	396	418	429	494	525	596	625	909	1,43
	1,562.00	28.5	135	155	285	430	453	466	536	569	647	678	986	1,55
	1,560.00	30.7	145	167	307	463	488	502	578	614	698	731	1063	1,67
Bottom of sediment	1,552.91	38.6	182	210	386	582	614	631	726	772	877	919	1336	2,10

[1]Expected ground-water level after mine dewatering.
[2]Expected increase in seepage.

Table 13.—*Change in seepage for various ground-water levels and various values of hydraulic conductivity (K) for Skunk Lake*

[Datum is sea level]

Lake level = 1598.02 — Lake area = 6.16 acres — Sediment thickness = 10.00 feet
Wetland area = 8.45 acres — Sediment thickness = 10.00 feet

K (feet per year)		0.04	0.47	0.52	2.22	5.38	20.00	21.00	22.00	30.00	36.00	43.20	45.00	60.00
	Ground-water level (feet)	Average seepage at the current ground-water level (gallons per minute)												
Lake	1,595.98	0.03	0.37	0.40	1.73	4.19	15.6	16.4	17.1	23.4	28.0	33.6	35.0	46.7
Wetland		.04	.50	.56	2.37	5.75	21.4	22.4	23.5	32.0	38.4	46.1	48.1	64.1
Total (inches per year)		.10	1.15	1.27	5.43	13.2	49.0	51.4	53.9	73.4	88.1	106	110	147
		Increase in seepage at the indicated ground-water level (gallons per minute)												
	1,595.00	0.04	0.42	0.46	1.97	4.77	17.7	18.6	19.5	26.6	31.9	38.3	39.9	53.2
	1,594.00	.07	.84	.93	3.98	9.64	35.8	37.6	39.4	53.8	64.5	77.4	80.7	108
	1,593.00	.11	1.27	1.40	5.99	14.5	54.0	56.6	59.3	80.9	97.1	117	121	162
	1,592.00	.14	1.69	1.87	8.00	19.4	72.1	75.7	79.3	108	130	156	162	216
	1,591.00	.18	2.12	2.34	10.0	24.3	90.2	94.7	99.2	135	162	195	203	270
	1,590.00	.22	2.54	2.81	12.0	29.1	108	114	119	162	195	234	244	325
	1,589.00	.25	2.97	3.29	14.0	34.0	126	133	139	190	227	273	284	379
	1,588.00	.29	3.40	3.76	16.0	38.9	144	152	159	217	260	312	325	433
	1,587.00	.33	3.82	4.23	18.0	43.7	163	171	179	244	293	351	366	488
	1,586.00	.36	4.25	4.70	20.1	48.6	181	190	199	271	325	390	407	542
	1,585.00	.40	4.67	5.17	22.1	53.5	199	209	219	298	358	429	447	596
	1,584.00	.43	5.10	5.64	24.1	58.3	217	228	239	325	390	468	488	651
	1,583.00	.47	5.52	6.11	26.1	63.2	235	247	258	352	423	508	529	705
Bottom of sediment	1,582.80	.48	5.61	6.20	26.5	64.2	239	251	262	358	[1]430	515	537	716

[1]Expected increase in seepage.

Table 14.—*Summary of average decrease in lake levels without pumpage and pumpage required to maintain lake levels*

Lake	Average drawdown (feet)	Pumpage required (gallons per minute)
Duck	0.21	8
Deephole	.63	88
Little Sand	6.88	576
Skunk	1.88	430

SUMMARY AND CONCLUSIONS

The effects of dewatering a proposed mine on levels of four lakes near Crandon, Wis., were predicted by use of a digital water-budget model of the lakes. The model included all of the major components of the water budget. Gains to the lakes included precipitation, surface-water runoff, and streamflow from upstream lakes. Losses included evaporation, surface-water outflow, and seepage to ground water. Changes in lake levels were computed from changes in storage resulting from the combination of gains and losses.

This model was calibrated with available data collected at or near the site. Root mean square error in the calibration for the four lakes ranged from 0.06 to 0.28 ft for 1977, and from 0.07 to 0.14 ft for 1985.

The model was used to predict the effect on lake levels of the proposed ground-water drawdown in the area. Monthly lake levels were simulated for 31 years with ground-water levels based on a water-table map prepared from data collected during 1984. These were compared to monthly lake levels simulated for 31 years with ground-water levels based on predicted ground-water drawdowns simulated by the GEOFLOW model.

On the basis of these two simulations, the estimated effect of mine dewatering on lake levels was determined to range from slight to very significant. The predicted reduction in average lake levels was 6.9 ft for Little Sand Lake, 1.9 ft for Skunk Lake, 0.63 ft for Deephole Lake, and 0.21 ft for Duck Lake.

Water could be pumped into the lakes to prevent lake levels from falling in response to water-table drawdown by compensating for the increased seepage from the lakes caused by lower ground-water levels. The pumping required was estimated to be 576 gal/min for Little Sand Lake, 430 gal/min for Skunk Lake, 88 gal/min for Deephole Lake, and 8 gal/min for Duck Lake.

The water-budget model provides a reasonable method for evaluating the possible effects of water-table drawdown on Duck, Deephole, Little Sand, and Skunk Lakes. The daily model simulations agree very well with the observed lake levels in 1977 and 1985 (root mean square errors of 0.06 to 0.28 ft). The monthly model simulations for baseline conditions are in close agreement with observed 1985 lake levels (root mean square errors of 0.06 to 0.19 ft).

Uncertainties in all of the model components add potential error to the model and to its predictions. The uncertainty in each component can be estimated only crudely. The cumulative effect of these uncertainties on the accuracy of model predictions cannot be determined.

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APPENDIX

OUTLINE OF THE MODEL WITH A LIST OF VARIABLES USED IN THE MODEL AND THE FORTRAN CODE

Description of the Crandon Lakes Model

The Crandon Lakes water-budget model is run by a driver routine that does little except call subroutines in the proper sequence. The program first prompts for the number of years to be computed, then reads the files of monthly precipitation and evaporation, which are the same for all lakes. The water budget for each of the lakes is computed for all of the years requested before going on to the next lake. All output for each lake is also made before going on to the next lake. Thus most of the variables are reused for all of the lakes, reducing the amount of storage required.

The lakes are computed in the following order:

Duck Lake
Deephole Lake
Little Sand Lake
Skunk Lake
Oak Lake

Within the computations for each lake, the following subroutines are called in order:

GETVAR (or GETVARS for Skunk Lake)
the routine with the lake name (e.g. DUCK, etc.)

TOTMON
TABMON

GETVAR (or GETVARS) is the interactive prompting routine to read in the various variables (like hydraulic conductivity, sediment thickness, ground-water elevation, starting lake level, outflow rating curves, etc.). The difference in GETVARS is that it also computes the starting lake volume from the starting lake level. It was necessary to have the volume computed for Skunk Lake because that lake sometimes would have such a small area that the routine used to compute change in lake level from the lake area did not work properly.

The lake name routines (e.g. DUCK, DEEPHOLE, etc.), are all in the same basic pattern. There is an outer loop to step through all of the months to be simulated, and an inner loop to go through the 30 days of the month. The volumes of all lake-budget components are computed in cubic feet for each day. The computations proceed as follows:

Area of lake proper computed from previous day's lake level.
Area of lake + wetlands computed similarly (not used on Little Sand Lake).
Area of wetland computed as difference in the preceding.
Precipitation falling on lake times (lake + wetland) area.
Runoff from upland area computed by runoff coefficient method.
Lake evaporation times (lake + wetland) area.
Surface outflow computed from lake level and outflow rating curve (not used for Skunk Lake).

Seepage to ground water from lake and wetlands computed by Darcy's Law.
Total inflow is sum of precipitation and upland runoff (plus the outflow from Duck and Deephole Lakes for Little Sand Lake).
Total outflow is sum of evaporation, seepage, and surface outflow (except no surface outflow for Skunk Lake).
Change in storage is total inflow - total outflow.
Change in lake level is change in storage divided by total area (except that on Skunk Lake the change in storage is added to the lake volume and lake level is computed from the volume).
New lake level is old lake level plus change in lake level.

This completes calculation for 1 day. For the next day go back to recomputing lake area.

The surface outflows from Duck and Deephole Lakes are accumulated and used as surface inflows to Little Sand Lake.

TOTMON computes the monthly and annual totals and averages of all of the variables in the lake budgets. Monthly average lake level, seepage, and outflow are written to separate files for later use and computations of duration curves. The overall averages are output as a summary.

TABMON uses the monthly averages computed in TOTMON to print a table of all of the monthly averages since 1970.

SUMMARY OF VARIABLE USED IN MONTHLY LAKE BUDGET MODEL

MONTHLY INPUT VARIABLES

PRECIP(500)	Monthly precipitation, in inches
EVAP(500)	Monthly lake evaporation, in inches

CONSTANTS FOR EACH LAKE OR EACH RUN

GW	Elevation of potentiometric surface under lake, in ft above mean sea level
GWB	Elevation of potentiometric surface under wetland, in ft above mean sea level
K	Hydraulic conductivity under lake, read in ft/yr, converted and used in ft/day
KB	Hydraulic conductivity under wetland, read in ft/yr, converted and used in ft/day
RC(12)	Monthly overland runoff coefficients
THK	Thickness of confining sediments under lake, in ft
THKB	Thickness of confining sediments under wetland, in ft

Constants for outflow rating equations:

BASE	Base elevation
COEF	Coefficient
EXP	Exponent

WATER BUDGET VARIABLES (all of these variables are in ft^3/day)

PI(500,31)	Direct precipitation on lake and wetland
RI(500,31)	Runoff from drainage area
INFLOW(500,31)	Inflow from upstream lakes
X(500,31)	Used to accumulate OUTFLOW from Duck and Deephole Lakes for later use as INFLOW for Little Sand Lake
IN(500,31)	Total inflow to lake (Sum of PI, RI, and INFLOW)
EO(500,31)	Evaporation for lake and wetland
OUTFLOW(500,31)	Discharge from outflow channel
SEEP(500,31)	Seepage to ground water
OUT(500,31)	Total outflow (Sum of EO, OUTFLOW, and SEEP)
STOR(500,31)	Net inflow (IN - OUT)

VARIABLES CHANGING DAILY & USED TO COMPUTE WATER BALANCE

AREA(500,31)	Total area of lake and wetland, in ft^2
AREAB(500,31)	Area of wetland, in ft^2
AREAL(500,31)	Area of lake, in ft^2
CLL(500,31)	Daily change in lake level, in ft
LL(500,31)	Daily lake level, in ft above mean sea level
S(500,31)	An intermediate variable used to compute lake level from volume for Skunk Lake
V(500,31)	Daily volume of lake in ft^3

VARIABLES FOR MONTHLY SUMMARIES (used to total daily values and determine the monthly means. The units for printed output are ft^3/sec, except as indicated)

MOTOTAR(35,12)	Total area of lake and wetland, in acres
MOTOTPI(35,12)	Average inflow rate of direct precipitation
MOTOTRI(35,12)	Average inflow from overland runoff
MOTOTINFLOW(35,12)	Average inflow from upstream lakes
MOTOTIN(35,12)	Average total inflow
MOTOTEO(35,12)	Average evaporation
MOTOTOUTFLOW(35,12)	Average outflow in stream channels
MOTOTSEEP(35,12)	Average outflow from seepage to ground water
MOTOTOUT(35,12)	Average total outflow
MOTOTLL(35,12)	Average monthly mean lake level, in ft above mean sea level

VARIABLES FOR ANNUAL SUMMARIES (used to compute averages of the entire period simulated. The units are in/yr over the average lake area except as indicated)

ANNAR	Average total area of lake and wetland, in acres
ANNPI	Average inflow of direct precipitation
ANNRI	Average inflow of overland runoff
ANNINFLOW	Average inflow from upstream lakes
ANNIN	Average total inflow
ANNEO	Average evaporation
ANNOUTFLOW	Average outflow in stream channels
ANNSEEP	Average seepage to ground water
ANNOUT	Average total outflow
ANNLL	Average monthly mean lake level, in ft above mean sea level
FACT	Used to convert units and average the variables

OTHER VARIABLES

ANSW	A character variable used to read YES/NO input
LAKE	Used for different purposes in different subroutines In data input routines it is a character variable used to display the lake name when prompting for input In data summary routines it is an integer variable which is used to signal which lake name to print in the output
MON(12)	A character variable containing abbreviations for month names, used in labeling printout.
NM	Total number of months being simulated
NY	Total number of years being simulated

```
      PROGRAM LAKES
      PARAMETER ND=31
      REAL PRECIP,EVAP,THK,K,LL,PI,
     &RI,EO,OF,SEEP,IN,STOR,OUTFLOW,GW,
     &OUT,CLL,AREA,INFLOW,RC(12)
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON X(500,31)
C X IS THE SUM OF INFLOW TO LITTLE SAND LAKE
      DATA (RC(I),I=1,12)/.15,.45,.45,.45,.45,.45,.45,.16,
     &.12,.13,.09,.12/
      PRINT 5
    5 FORMAT('ENTER NUMBER OF YEARS FOR RUN')
      READ(*,*)NY
      NM=12*NY
      READ(11,20)(PRECIP(I),I=1,NM)
      READ(12,20)(EVAP(I),I=1,NM)
   20 FORMAT(10X,12F10.2)
      CALL GETVAR('DUCK LAKE            ')
      CALL DUCK(NM,RC)
      CALL TOTMON(NY,NM)
      CALL TABMON(NY,1,RC)
      DO 25 I=1,NM
      DO 25 J=1,30
      X(I,J)=OUTFLOW(I,J)
   25 CONTINUE
      CALL GETVAR('DEEPHOLE LAKE        ')
      CALL DEEPHOLE(NM,RC)
      CALL TOTMON(NY,NM)
      CALL TABMON(NY,3,RC)
      DO 50 I=1,NM
      DO 50 J=1,30
      X(I,J)=X(I,J)+OUTFLOW(I,J)
   50 CONTINUE
      DO 60 I=1,NM
      DO 60 J=1,30
      INFLOW(I,J)=X(I,J)
   60 CONTINUE
      CALL GETVAR('LITTLE SAND LAKE     ')
      CALL SAND(NM,RC)
      CALL TOTMON(NY,NM)
      CALL TABMON(NY,2,RC)
      DO 55 I=1,NM
      DO 55 J=1,30
      INFLOW(I,J)=0.0
   55 CONTINUE
      CALL GETVARS(' SKUNK LAKE          ')
      CALL SKUNK(NM,RC)
```

```
      CALL TOTMON(NY,NM)
      CALL TABMON(NY,4,RC)
      DO 66 I=1,NM
      DO 66 J=1,30
      INFLOW(I,J)=0.0
   66 CONTINUE
      CALL GETVAR(' OAK LAKE            ')
      CALL OAK(NM,RC)
      CALL TOTMON(NY,NM)
      CALL TABMON(NY,5,RC)
      PRINT 10
   10 FORMAT('RUN COMPLETED!!!!!!!!!!')
      STOP
      END
```

```
      SUBROUTINE DUCK(NM,RC)
      PARAMETER ND=31
      REAL PRECIP,EVAP,THK,K,LL,PI,KB,GWB,THKB,
     &RI,EO,OF,SEEP,IN,STOR,OUTFLOW,
     &OUT,CLL,AREA,INFLOW,RC(12),GW,AREAL,AREAB
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON/COMBLK3/ AREAL(500,ND), AREAB(500,ND),GWB,KB,THKB
      K=(K/12.)/30.
      KB=(KB/12.)/30.
      L=0
      N=0
      DO 3 I=1,NM
      L=1+L
      IF(L.EQ.13) THEN
       L=1
      END IF
      DO 3 J=1,30
      N=N+1
C INITIALIZE ALL CALCULATED VARIABLES
      PI(I,J)=0.0
      RI(I,J)=0.0
      EO(I,J)=0.0
      SEEP(I,J)=0.0
      IN(I,J)=0.0
      STOR(I,J)=0.0
      OUTFLOW(I,J)=0.0
      INFLOW(I,J)=0.0
      OUT(I,J)=0.0
      AREA(I,J)=0.0
      AREAL(I,J)=0.0
      AREAB(I,J)=0.0
C CHECK STAGES OF LAKE LEVEL AND COMPUTE AREA OF LAKE
C
C  **  AREAL IS LAKE AREA AS PREVIOUSLY COMPUTED
C  **  NOW REVISED BASED ON HIPSOGRAPHS
C
      IF (LL(I,J).LT.1602.0)THEN
      WRITE (6,1201)
         AREAL(I,J) = 0.0
      ELSE IF (LL(I,J).GE.1602.0.AND.LL(I,J).LE.1608.04) THEN
         AREAL(I,J)=(3.5*(LL(I,J)-1602.0))*43560.0
      ELSE
        AREAL(I,J)=(1.13*(LL(I,J)-1589.33))*43560.0
      END IF
C
C  **  AREA IS NOW TOTAL AREA (BOG + LAKE)
C
```

```
      IF (LL(I,J).LT.1602.0)THEN
         AREA(I,J) = 0.0
      ELSE IF (LL(I,J).GE.1602.0.AND.LL(I,J).LT.1606.44)THEN
         AREA(I,J)=(3.5*(LL(I,J)-1602.0))*43560.0
      ELSE  IF (LL(I,J).GE.1606.44.AND.LL(I,J).LT.1607.97)THEN
         AREA(I,J)=(31.7*(LL(I,J)-1605.95))*43560.0
      ELSE
         AREA(I,J)=(9.79*(LL(I,J)-1601.43))*43560.0
      END IF
C
C  **  AREAB IS BOG AREA
C
      AREAB(I,J)=AREA(I,J)-AREAL(I,J)
      IF (AREAB(I,J).LT.0.0)AREAB(I,J)=0.0
 1201 FORMAT('WARNING DUCK LAKE IS DRY')
C CALC PRECIP INPUT- PI
      PI(I,J)=((PRECIP(I)/12)/30)*AREA(I,J)
C CALC RUNOFF INPUT- RI
      RI(I,J)=((PRECIP(I)/12)/30)*RC(L)*(384.6*43560.0-
     &          AREA(I,J))
C CALC EVAPORATION OUTPUT- EO
      EO(I,J)=((EVAP(I)/12)/30)*AREA(I,J)
C CALC OUTFLOW
      IF (LL(I,J).GT.BASE)THEN
        OUTFLOW(I,J)=((COEF*(LL(I,J)-BASE))**EXP)*87600.0
      ELSE
        OUTFLOW(I,J)=0.0
      END IF
C CALC SEEPAGE FROM LAKE
C
C  **  COMPUTE AS SUM OF TWO COMPONENTS
C  **  LAKE SEEPAGE AND BOG SEEPAGE
C
      SEEP(I,J)=(((LL(I,J)-GW)/THK)*K)*AREAL(I,J)
     & + (((LL(I,J)-GWB)/THKB)*KB)*AREAB(I,J)
C SUM TOTAL INFLOW
      IN(I,J)=PI(I,J)+RI(I,J)
C SUM TOTAL OUTFLOW
      OUT(I,J)=EO(I,J)+OUTFLOW(I,J)+SEEP(I,J)
C CALC CHANGE IN STORAGE
      STOR(I,J)=IN(I,J)-OUT(I,J)
C CALC CHANGE IN LAKE LEVEL
      CLL(I,J)=STOR(I,J)/AREA(I,J)
C CALC NEW LAKE LEVEL
      LL(I,J+1)=CLL(I,J)+LL(I,J)
      IF(N.GE.30)THEN
        LL(I+1,1)=LL(I,J+1)
        N=0
      END IF
    3 CONTINUE
C      WRITE(14,30)
C      DO 9 I=1,NM
```

```
C       J=30
C       WRITE(14,77)I,J
C 77    FORMAT('SEEPAGE   OUTFLOW     LAKE LEVEL',2I5)
C       WRITE(14,78)SEEP(I,J),OUTFLOW(I,J),LL(I,J)
C 78    FORMAT(3F20.2)
C       WRITE(14,25)I,J
C       WRITE(14,21)PRECIP(I),EVAP(I),LL(I,J),PI(I,J),RI(I,J),
C      &EO(I,J),SEEP(I,J),IN(I,J),STOR(I,J),OUTFLOW(I,J),INFLOW(I,J),
C      &OUT(I,J),CLL(I,J),AREA(I,J)
C     9 CONTINUE
  100 FORMAT(1X,'DUCK LAKE IS DRY')
   23 FORMAT(F20.2)
   21 FORMAT(14E9.3)
   25 FORMAT(//'PRECIP',4X,'EVAP',6X,'LL',8X,'PI',8X,'RI',8X,'EO',
     &8X,'SEEP','IN',8X,'STOR',6X,'OUTFLOW',3X,'INFLOW',
     &4X,'OUT',7X,'CLL',4X,'AREA',2I3)
   30 FORMAT(///'MONTHLY REPORT FOR DUCK LAKE')
  200 RETURN
      END
```

```
      SUBROUTINE DEEPHOLE(NM,RC)
      PARAMETER ND=31
      REAL PRECIP,EVAP,THK,K,LL,PI,GWB,KB,THKB,
     &RI,EO,OF,SEEP,IN,STOR,OUTFLOW,GW,
     &OUT,CLL,AREA,INFLOW,RC(12)
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON/COMBLK3/ AREAL(500,ND), AREAB(500,ND),GWB,KB,THKB
      K=(K/12.)/30
      KB=(KB/12.)/30.
      L=0
      N=0
      DO 3 I=1,NM
      L=1+L
      IF(L.EQ.13) L=1
      DO 3 J=1,30
      N=N+1
C INITIALIZE ALL CALCULATED VARIABLES
      PI(I,J)=0.0
      RI(I,J)=0.0
      EO(I,J)=0.0
      SEEP(I,J)=0.0
      IN(I,J)=0.0
      STOR(I,J)=0.0
      OUTFLOW(I,J)=0.0
      INFLOW(I,J)=0.0
      OUT(I,J)=0.0
      AREA(I,J)=0.0
C CHECK STAGES OF LAKE LEVEL AND COMPUTE AREA OF LAKE
C
C  **  AREAL IS LAKE AREA AS PREVIOUSLY COMPUTED
C  **  NOW REVISED BASED ON HIPSOGRAPHS
C
      IF (LL(I,J).GE.1602.92) THEN
         AREAL(I,J)=(2.6*(LL(I,J)-1567.52))*43560.0
      ELSE IF (LL(I,J).GE.1595.83) THEN
         AREAL(I,J)=(9.58*(LL(I,J)-1593.31))*43560.0
      ELSE IF (LL(I,J).GE.1590.83) THEN
         AREAL(I,J)=(4.82*(LL(I,J)-1590.83))*43560.0
      ELSE
         AREAL(I,J)=0.0
      END IF
C
C  **  AREA IS NOW TOTAL AREA (BOG + LAKE)
C
      IF (LL(I,J).GE.1602.92) THEN
         AREA(I,J)=(9.99*(LL(I,J)-1593.71))*43560.0
      ELSE IF (LL(I,J).GE.1595.83) THEN
```

```
          AREA(I,J)=(9.58*(LL(I,J)-1593.31))*43560.0
       ELSE IF (LL(I,J).GE.1590.83) THEN
          AREA(I,J)=(4.82*(LL(I,J)-1590.83))*43560.0
       ELSE
          AREA(I,J)=0.0
       END IF
C
C  **  AREAB IS BOG AREA
C
       AREAB(I,J)=AREA(I,J)-AREAL(I,J)
       IF (AREAB(I,J).LT.0.0)THEN
           AREAB(I,J)=0.0
           AREAL(I,J) = AREA(I,J)
       ENDIF
C CALC PRECIP INPUT- PI
  999 PI(I,J)=((PRECIP(I)/12)/30)*AREA(I,J)
C CALC RUNOFF INPUT- RI
       RI(I,J)=((PRECIP(I)/12)/30)*RC(L)*(1014.4*43560.0-
      &           AREA(I,J))
C CALC EVAPORATION OUTPUT- EO
       EO(I,J)=((EVAP(I)/12)/30)*AREA(I,J)
C CALC OUTFLOW
       IF (LL(I,J).GT.BASE)THEN
         OUTFLOW(I,J)=((COEF*(LL(I,J)-BASE))**EXP)*87600.0
       ELSE
         OUTFLOW(I,J)=0.0
       END IF
C CALC SEEPAGE FROM LAKE
C
C  **  COMPUTE AS SUM OF TWO COMPONENTS
C  **  LAKE SEEPAGE AND BOG SEEPAGE
C
       SEEP(I,J)=(((LL(I,J)-GW)/THK)*K)*AREAL(I,J)
      & + (((LL(I,J)-GWB)/THKB)*KB)*AREAB(I,J)
C SUM TOTAL INFLOW
       IN(I,J)=PI(I,J)+RI(I,J)
C SUM TOTAL OUTFLOW
       OUT(I,J)=EO(I,J)+OUTFLOW(I,J)+SEEP(I,J)
C CALC CHANGE IN STORAGE
       STOR(I,J)=IN(I,J)-OUT(I,J)
C CALC CHANGE IN LAKE LEVEL
       CLL(I,J)=STOR(I,J)/AREA(I,J)
C CALC NEW LAKE LEVEL
       LL(I,J+1)=CLL(I,J)+LL(I,J)
       IF(N.GE.30)THEN
         LL(I+1,1)=LL(I,J+1)
       END IF
    3 CONTINUE
C       WRITE(14,30)
C       DO 9 I=1,NM
C       J=30
C       WRITE(14,77)I,J
```

```
C 77     FORMAT('SEEPAGE   OUTFLOW     LAKE LEVEL',2I5)
C        WRITE(14,78)SEEP(I,J),OUTFLOW(I,J),LL(I,J)
C 78     FORMAT(3F20.2)
C        WRITE(14,25)I,J
C        WRITE(14,21)PRECIP(I),EVAP(I),LL(I,J),PI(I,J),RI(I,J),
C       &EO(I,J),SEEP(I,J),IN(I,J),STOR(I,J),OUTFLOW(I,J),INFLOW(I,J),
C       &OUT(I,J),CLL(I,J),AREA(I,J)
C     9 CONTINUE
   10 FORMAT('ENTER DELL FOR DUCK LAKE')
  100 FORMAT(1X,'DUCK LAKE IS DRY')
   23 FORMAT(F20.2)
   21 FORMAT(14E9.3)
   25 FORMAT(//'PRECIP',4X,'EVAP',6X,'LL',8X,'PI',8X,'RI',8X,'EO',
     &8X,'SEEP','IN',8X,'STOR',6X,'OUTFLOW',3X,'INFLOW',
     &4X,'OUT',7X,'CLL',4X,'AREA',2I3)
   30 FORMAT(///'MONTHLY REPORT FOR DEEPHOLE LAKE')
  200 RETURN
      END
```

```
      SUBROUTINE SAND(NM,RC)
      PARAMETER ND=31
      REAL PRECIP,EVAP,THK,K,LL,PI,
     &RI,EO,OF,SEEP,IN,STOR,OUTFLOW,GW,
     &OUT,CLL,AREA,INFLOW,RC(12)
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON X(500,31)
      K=(K/12.)/30.
      L=0
      N=0
      DO 3 I=1,NM
      L=L+1
      IF(L.EQ.13) L=1
      DO 3 J=1,30
      N=N+1
C INITIALIZE ALL CALCULATED VARIABLES
      PI(I,J)=0.0
      RI(I,J)=0.0
      EO(I,J)=0.0
      SEEP(I,J)=0.0
      IN(I,J)=0.0
      STOR(I,J)=0.0
      OUTFLOW(I,J)=0.0
      OUT(I,J)=0.0
      AREA(I,J)=0.0
C CHECK STAGES OF LAKE LEVEL AND COMPUTE AREA OF LAKE
C
C  **  NOW REVISED BASED ON HIPSOGRAPHS
C
       IF (LL(I,J).LT.1581.96) THEN
         AREA(I,J)=((LL(I,J)-1575.66)*10.8)*43560.0
       ELSE IF (LL(I,J).LT.1586.96) THEN
         AREA(I,J)=((LL(I,J)-1579.22)*24.8)*43560.0
      ELSE IF (LL(I,J).GT.1589.8)THEN
         AREA(I,J)=((LL(I,J)-1567.24)/0.101)*43560.0
       ELSE
         AREA(I,J)=((LL(I,J)-1568.77)/0.094)*43560.0
       END IF
C CALC PRECIP INPUT- PI
  999 PI(I,J)=((PRECIP(I)/12)/30)*AREA(I,J)
C CALC RUNOFF INPUT- RI
      RI(I,J)=((PRECIP(I)/12)/30)*RC(L)*(711.6*43560.0-
     &           AREA(I,J))
C CALC EVAPORATION OUTPUT- EO
      EO(I,J)=((EVAP(I)/12)/30)*AREA(I,J)
C CALC OUTFLOW
```

```
      IF (LL(I,J).GT.BASE)THEN
C MODIFIED OUTFLOW EQ. 7/24/85 (ADDED .3 TO 1590.0)
        OUTFLOW(I,J)=((COEF*(LL(I,J)-BASE))**EXP)*87600.
      ELSE
        OUTFLOW(I,J)=0.0
      END IF
C CALC SEEPAGE FROM LAKE
      SEEP(I,J)=(((LL(I,J)-GW)/THK)*K)*AREA(I,J)
C SUM TOTAL INFLOW
      IN(I,J)=PI(I,J)+RI(I,J)+INFLOW(I,J)
C SUM TOTAL OUTFLOW
      OUT(I,J)=EO(I,J)+OUTFLOW(I,J)+SEEP(I,J)
C CALC CHANGE IN STORAGE
      STOR(I,J)=IN(I,J)-OUT(I,J)
C CALC CHANGE IN LAKE LEVEL
      CLL(I,J)=STOR(I,J)/AREA(I,J)
C CALC NEW LAKE LEVEL
      LL(I,J+1)=CLL(I,J)+LL(I,J)
      IF(N.GE.30)THEN
        LL(I+1,1)=LL(I,J+1)
      END IF
    3 CONTINUE
C      WRITE(14,30)
C      DO 9 I=1,12
C      J=30
C      WRITE(14,77)I,J
C 77   FORMAT('SEEPAGE   OUTFLOW     LAKE LEVEL',2I5)
C      WRITE(14,78)SEEP(I,J),OUTFLOW(I,J),LL(I,J)
C 78   FORMAT(3F20.2)
C      WRITE(14,25)I,J
C      WRITE(14,21)PRECIP(I),EVAP(I),LL(I,J),PI(I,J),RI(I,J),
C     &EO(I,J),SEEP(I,J),IN(I,J),STOR(I,J),OUTFLOW(I,J),INFLOW(I,J),
C     &OUT(I,J),CLL(I,J),AREA(I,J)
C    9 CONTINUE
   10 FORMAT('ENTER DELL FOR LITTLE SAND LAKE')
   21 FORMAT(14E9.3)
   25 FORMAT(//'PRECIP',4X,'EVAP',6X,'LL',8X,'PI',8X,'RI',8X,'EO',
     &8X,'SEEP','IN',8X,'STOR',6X,'OUTFLOW',3X,'INFLOW',
     &4X,'OUT',7X,'CLL',4X,'AREA',2I3)
   30 FORMAT(///'MONTHLY REPORT FOR LITTLE SAND LAKE')
      RETURN
      END
```

```
      SUBROUTINE SKUNK(NM,RC)
      PARAMETER ND=31
      REAL PRECIP,EVAP,THK,K,LL,PI,GWB,KB,THKB,
     &RI,EO,OF,SEEP,IN,STOR,OUTFLOW,
     &OUT,AREA,INFLOW,RC(12),GW,S,V
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON/COMBLK3/ AREAL(500,ND), AREAB(500,ND),GWB,KB,THKB
      K=(K/12.)/30.
      KB=(KB/12.)/30.
      L=0
      N=0
      DO 3 I=1,NM
      L=1+L
      IF(L.EQ.13) THEN
       L=1
      END IF
      DO 3 J=1,30
      N=N+1
C INITIALIZE ALL CALCULATED VARIABLES
      PI(I,J)=0.0
      RI(I,J)=0.0
      EO(I,J)=0.0
      SEEP(I,J)=0.0
      IN(I,J)=0.0
      STOR(I,J)=0.0
      OUTFLOW(I,J)=0.0
      INFLOW(I,J)=0.0
      OUT(I,J)=0.0
      AREA(I,J)=0.0
C CHECK STAGES OF LAKE LEVEL AND COMPUTE AREA OF LAKE
C
C  **  AREAL IS LAKE AREA AS PREVIOUSLY COMPUTED
C  **  NOW REVISED BASED ON HIPSOGRAPHS
C
      IF (LL(I,J).LT.1592.8)THEN
         PRINT 1201
         AREAL(I,J)=1.0
      ELSE IF (LL(I,J).LT.1595.09) THEN
         AREAL(I,J)=(0.35*(LL(I,J)-1592.8))*43560.0
      ELSE IF (LL(I,J).LT.1597.09) THEN
        AREAL(I,J)=(LL(I,J)-1594.29)*43560.0
      ELSE
         AREAL(I,J)=(3.6*(LL(I,J)-1596.31))*43560.0
      END IF
 1201 FORMAT('WARNING SKUNK LAKE IS DRY')
C
```

```
C  **  AREA IS NOW TOTAL AREA (BOG + LAKE)
C
       IF (LL(I,J).LT.1592.8)THEN
          PRINT 1201
          AREA(I,J)=1.0
       ELSE IF (LL(I,J).LT.1595.09) THEN
          AREA(I,J)=(0.35*(LL(I,J)-1592.8))*43560.0
       ELSE IF (LL(I,J).LT.1597.09) THEN
         AREA(I,J)=(1.82*(LL(I,J)-1594.65))*43560.0
       ELSE
          AREA(I,J)=(10.9*(LL(I,J)-1596.68))*43560.0
       END IF
C
C  **  AREAB IS BOG AREA
C
       AREAB(I,J)=AREA(I,J)-AREAL(I,J)
       IF (AREAB(I,J).LT.0.0)AREAB(I,J)=0.0
C CALC PRECIP INPUT- PI
       PI(I,J)=((PRECIP(I)/12)/30)*AREA(I,J)
C CALC RUNOFF INPUT- RI
       RI(I,J)=((PRECIP(I)/12)/30)*RC(L)*(121.7*43560.0-
      &          AREA(I,J))
C CALC EVAPORATION OUTPUT- EO
       EO(I,J)=((EVAP(I)/12)/30)*AREA(I,J)
C CALC OUTFLOW
       OUTFLOW(I,J)=0.0
C CALC SEEPAGE FROM LAKE
C
C  **  COMPUTE AS SUM OF TWO COMPONENTS
C  **  LAKE SEEPAGE AND BOG SEEPAGE
C
       SEEP(I,J)=(((LL(I,J)-GW)/THK)*K)*AREAL(I,J)
      & + (((LL(I,J)-GWB)/THKB)*KB)*AREAB(I,J)
C SUM TOTAL INFLOW
       IN(I,J)=PI(I,J)+RI(I,J)
C SUM TOTAL OUTFLOW
       OUT(I,J)=EO(I,J)+OUTFLOW(I,J)+SEEP(I,J)
C CALC CHANGE IN STORAGE
       STOR(I,J)=IN(I,J)-OUT(I,J)
C CALC VOLUME AT END OF DAY
       V(I,J)=V(I,J)+STOR(I,J)
       IF (V(I,J).LT.0.0) V(I,J) = 0.0
C CALC  LAKE STAGE
       IF (V(I,J).GT.268300.)THEN
         S(I,J)=SQRT((V(I,J)-228393.)/237402.)
         LL(I,J+1)=S(I,J)+1596.68
       ELSE IF (V(I,J).GT.39975.8)THEN
         S(I,J)=SQRT((V(I,J)-32301.5)/39639.6)
         LL(I,J+1)=S(I,J)+1594.65
       ELSE
         S(I,J) = SQRT(V(I,J)/7623)
         LL(I,J+1)= S(I,J)+1592.8
```

```
      END IF
      V(I,J+1)=V(I,J)
      IF(N.GE.30)THEN
        V(I+1,1)=V(I,J+1)
        LL(I+1,1)=LL(I,J+1)
        N=0
      END IF
    3 CONTINUE
C       WRITE(14,30)
C       DO 9 I=1,NM
C       J=30
C       WRITE(14,77)I,J
C 77    FORMAT('SEEPAGE   OUTFLOW      LAKE LEVEL',2I5)
C       WRITE(14,78)SEEP(I,J),OUTFLOW(I,J),LL(I,J)
C 78    FORMAT(3F20.2)
C       WRITE(14,25)I,J
C       WRITE(14,21)PRECIP(I),EVAP(I),LL(I,J),PI(I,J),RI(I,J),
C      &EO(I,J),SEEP(I,J),IN(I,J),STOR(I,J),OUTFLOW(I,J),INFLOW(I,J),
C      &OUT(I,J),CLL(I,J),AREA(I,J)
C     9 CONTINUE
  100 FORMAT(1X,'SKUNK LAKE IS DRY')
   23 FORMAT(F20.2)
   21 FORMAT(14E9.3)
   25 FORMAT(//'PRECIP',4X,'EVAP',6X,'LL',8X,'PI',8X,'RI',8X,'EO',
     &8X,'SEEP','IN',8X,'STOR',6X,'OUTFLOW',3X,'INFLOW',
     &4X,'OUT',7X,'CLL',4X,'AREA',2I3)
   30 FORMAT(///'MONTHLY REPORT FOR SKUNK LAKE')
  999 RETURN
      END
```

```
      SUBROUTINE OAK(NM,RC)
      PARAMETER ND=31
      REAL PRECIP,EVAP,THK,K,LL,PI,
     &RI,EO,OF,SEEP,IN,STOR,OUTFLOW,
     &OUT,CLL,AREA,INFLOW,RC(12),GW
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON/COMBLK3/ AREAL(500,ND), AREAB(500,ND),GWB,KB,THKB
      K=(K/12.)/30.
      L=0
      N=0
      DO 3 I=1,NM
      L=1+L
      IF(L.EQ.13) THEN
       L=1
      END IF
      DO 3 J=1,30
      N=N+1
C INITIALIZE ALL CALCULATED VARIABLES
      PI(I,J)=0.0
      RI(I,J)=0.0
      EO(I,J)=0.0
      SEEP(I,J)=0.0
      IN(I,J)=0.0
      STOR(I,J)=0.0
      OUTFLOW(I,J)=0.0
      INFLOW(I,J)=0.0
      OUT(I,J)=0.0
      AREA(I,J)=0.0
C CHECK STAGES OF LAKE LEVEL AND COMPUTE AREA OF LAKE
      IF (LL(I,J).LT.1627.0)THEN
         PRINT 1201
         AREA(I,J) = 1594296.0
      ELSE IF (LL(I,J).GE.1627.0)THEN
        AREA(I,J)=(36.6+2.245*(LL(I,J)-1627.0))*43560.0
      END IF
 1201 FORMAT('WARNING OAK LAKE IS DRY')
C CALC PRECIP INPUT- PI
      PI(I,J)=((PRECIP(I)/12)/30)*AREA(I,J)
C CALC RUNOFF INPUT- RI
      RI(I,J)=((PRECIP(I)/12)/30)*RC(L)*(422.3*43560.0-
     &          AREA(I,J))
C CALC EVAPORATION OUTPUT- EO
      EO(I,J)=((EVAP(I)/12)/30)*AREA(I,J)
C CALC OUTFLOW
      IF (LL(I,J).GT.BASE)THEN
        OUTFLOW(I,J)=((COEF*(LL(I,J)-BASE))**EXP)*87600.0
```

```
      ELSE
        OUTFLOW(I,J)=0.0
      END IF
C CALC SEEPAGE FROM LAKE
      SEEP(I,J)=(((LL(I,J)-GW)/THK)*K)*AREA(I,J)
C SUM TOTAL INFLOW
      IN(I,J)=PI(I,J)+RI(I,J)
C SUM TOTAL OUTFLOW
      OUT(I,J)=EO(I,J)+OUTFLOW(I,J)+SEEP(I,J)
C CALC CHANGE IN STORAGE
      STOR(I,J)=IN(I,J)-OUT(I,J)
C CALC CHANGE IN LAKE LEVEL
      CLL(I,J)=STOR(I,J)/AREA(I,J)
C CALC NEW LAKE LEVEL
      LL(I,J+1)=CLL(I,J)+LL(I,J)
      IF(N.GE.30)THEN
        LL(I+1,1)=LL(I,J+1)
        N=0
      END IF
    3 CONTINUE
C      WRITE(14,30)
C      DO 9 I=1,NM
C      J=30
C      WRITE(14,77)I,J
C 77   FORMAT('SEEPAGE   OUTFLOW     LAKE LEVEL',2I5)
C      WRITE(14,78)SEEP(I,J),OUTFLOW(I,J),LL(I,J)
C 78   FORMAT(3F20.2)
C      WRITE(14,25)I,J
C      WRITE(14,21)PRECIP(I),EVAP(I),LL(I,J),PI(I,J),RI(I,J),
C     &EO(I,J),SEEP(I,J),IN(I,J),STOR(I,J),OUTFLOW(I,J),INFLOW(I,J),
C     &OUT(I,J),CLL(I,J),AREA(I,J)
C    9 CONTINUE
  100 FORMAT(1X,'OAK LAKE IS DRY')
   23 FORMAT(F20.2)
   21 FORMAT(14E9.3)
   25 FORMAT(//'PRECIP',4X,'EVAP',6X,'LL',8X,'PI',8X,'RI',8X,'EO',
     &8X,'SEEP','IN',8X,'STOR',6X,'OUTFLOW',3X,'INFLOW',
     &4X,'OUT',7X,'CLL',4X,'AREA',2I3)
   30 FORMAT(///'MONTHLY REPORT FOR OAK LAKE')
  200 RETURN
      END
```

```
      SUBROUTINE TOTMON(NY,NM)
      PARAMETER ND=31
      REAL PRECIP,EVAP,THK,K,LL,PI,GWB,KB,THKB
      REAL MOTOTLL,MOTOTSEEP,MOTOTEO,MOTOTOUTFLOW,MOTOTOUT
      REAL MOTOTPI,MOTOTRI,MOTOTINFLOW,MOTOTIN,MOTOTAR
      REAL ANNLL,ANNSEEP,ANNEO,ANNOUTFLOW,ANNOUT
      REAL ANNPI,ANNRI,ANNINFLOW,ANNIN,ANNAR
      REAL RI,EO,OF,SEEP,IN,STOR,OUTFLOW,GW
      REAL OUT,CLL,AREA,INFLOW,RC(12)
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON/TABLEBLK/MOTOTLL(35,12),MOTOTSEEP(35,12),MOTOTEO(35,12),
     &MOTOTOUTFLOW(35,12),MOTOTOUT(35,12),MOTOTPI(35,12),
     &MOTOTRI(35,12),MOTOTINFLOW(35,12),MOTOTIN(35,12),MOTOTAR(35,12)
    - ANNLL =0.0
      ANNAR =0.0
      ANNSEEP =0.0
      ANNEO =0.0
      ANNOUTFLOW =0.0
      ANNOUT =0.0
      ANNPI =0.0
      ANNRI =0.0
      ANNINFLOW =0.0
      ANNIN =0.0
      DO 20 L=1,35
      DO 20 I=1,12
      MOTOTLL(L,I)=0.0
      MOTOTAR(L,I)=0.0
      MOTOTSEEP(L,I)=0.0
      MOTOTEO(L,I)=0.0
      MOTOTOUTFLOW(L,I)=0.0
      MOTOTOUT(L,I)=0.0
      MOTOTPI(L,I)=0.0
      MOTOTRI(L,I)=0.0
      MOTOTINFLOW(L,I)=0.0
      MOTOTIN(L,I)=0.0
 20   CONTINUE
      M=0
      DO 25 L=1,NY
      DO 23 I=1,12
      M=M+1
      DO 24 J=1,30
C TOTAL MONTHLY OUTFLOW COMPONENTS
      MOTOTLL(L,I)=MOTOTLL(L,I)+LL(M,J)
      MOTOTAR(L,I)=MOTOTAR(L,I)+AREA(M,J)
      MOTOTSEEP(L,I)=MOTOTSEEP(L,I)+SEEP(M,J)
      MOTOTEO(L,I)=MOTOTEO(L,I)+EO(M,J)
      MOTOTOUTFLOW(L,I)=MOTOTOUTFLOW(L,I)+OUTFLOW(M,J)
```

```
C TOTAL MONTHLY OUTFLOW
      MOTOTOUT(L,I)=MOTOTOUT(L,I)+OUT(M,J)
C TOTAL MONTHLY INFLOW COMPONENTS
      MOTOTPI(L,I)=MOTOTPI(L,I)+PI(M,J)
      MOTOTRI(L,I)=MOTOTRI(L,I)+RI(M,J)
      MOTOTINFLOW(L,I)=MOTOTINFLOW(L,I)+INFLOW(M,J)
C TOTAL MONTHLY INFLOW
      MOTOTIN(L,I)=MOTOTIN(L,I)+IN(M,J)
 24   CONTINUE
      IF (L.GE.3)THEN
      ANNLL = ANNLL + MOTOTLL (L,I)
      ANNAR = ANNAR + MOTOTAR (L,I)
      ANNSEEP = ANNSEEP + MOTOTSEEP (L,I)
      ANNEO = ANNEO + MOTOTEO (L,I)
      ANNOUTFLOW = ANNOUTFLOW + MOTOTOUTFLOW (L,I)
      ANNOUT = ANNOUT + MOTOTOUT (L,I)
      ANNPI = ANNPI + MOTOTPI (L,I)
      ANNRI = ANNRI + MOTOTRI (L,I)
      ANNINFLOW = ANNINFLOW + MOTOTINFLOW (L,I)
      ANNIN = ANNIN + MOTOTIN (L,I)
      END IF
 23   CONTINUE
 25   CONTINUE
      FACT = 1./(FLOAT(M-2)*30.)
      ANNLL = ANNLL *FACT
      ANNAR = ANNAR *FACT
      ANNSEEP = ANNSEEP *FACT
      ANNEO = ANNEO *FACT
      ANNOUTFLOW = ANNOUTFLOW *FACT
      ANNOUT = ANNOUT *FACT
      ANNPI = ANNPI *FACT
      ANNRI = ANNRI *FACT
      ANNINFLOW = ANNINFLOW *FACT
      ANNIN = ANNIN *FACT
      FACT = 4320.
      ANNSEEP = ANNSEEP *FACT/ANNAR
      ANNEO = ANNEO *FACT/ANNAR
      ANNOUTFLOW = ANNOUTFLOW *FACT/ANNAR
      ANNOUT = ANNOUT *FACT/ANNAR
      ANNPI = ANNPI *FACT/ANNAR
      ANNRI = ANNRI *FACT/ANNAR
      ANNINFLOW = ANNINFLOW *FACT/ANNAR
      ANNIN = ANNIN *FACT/ANNAR
      WRITE(*,100) ANNLL
  100 FORMAT (' AVERAGE LAKE LEVEL =        ',F8.2,' FEET')
      WRITE(*,101) (ANNAR /43560.)
  101 FORMAT (' AVERAGE LAKE AREA =         ',F8.2,' ACRES')
      WRITE(*,102) ANNSEEP
  102 FORMAT (' AVERAGE SEEPAGE =           ',F8.2,' INCHES PER YEAR')
      WRITE(*,103) ANNEO
  103 FORMAT (' AVERAGE EVAPORATION =       ',F8.2,' INCHES PER YEAR')
      WRITE(*,104) ANNOUTFLOW
```

```
  104 FORMAT (' AVERAGE SURFACE OUTFLOW = ',F8.2,' INCHES PER YEAR')
      WRITE(*,105) ANNOUT
  105 FORMAT (' AVERAGE TOTAL OUTFLOW =   ',F8.2,' INCHES PER YEAR')
      WRITE(*,106) ANNPI
  106 FORMAT (' AVERAGE PRECIPITATION =   ',F8.2,' INCHES PER YEAR')
      WRITE(*,107) ANNRI
  107 FORMAT (' AVERAGE UPLAND RUNOFF =   ',F8.2,' INCHES PER YEAR')
      WRITE(*,108) ANNINFLOW
  108 FORMAT (' AVERAGE SURFACE INFLOW =  ',F8.2,' INCHES PER YEAR')
      WRITE(*,110) ANNIN
  110 FORMAT (' AVERAGE TOTAL INFLOW =    ',F8.2,' INCHES PER YEAR'/'1')
C CONVERT TO CUBIC FEET PER SECOND
C (LL IN FEET AND AREA IN ACRES)
      FACT = 1/(30.*86400.)
      DO 50 L=1,35
      DO 50 I=1,12
      MOTOTLL(L,I)=MOTOTLL(L,I)/30.
      MOTOTAR(L,I)=MOTOTAR(L,I)/(30.*43560.)
      MOTOTSEEP(L,I)=MOTOTSEEP(L,I)*FACT
      MOTOTEO(L,I)=MOTOTEO(L,I)*FACT
      MOTOTOUTFLOW(L,I)=MOTOTOUTFLOW(L,I)*FACT
      MOTOTOUT(L,I)=MOTOTOUT(L,I)*FACT
      MOTOTPI(L,I)=MOTOTPI(L,I)*FACT
      MOTOTRI(L,I)=MOTOTRI(L,I)*FACT
      MOTOTINFLOW(L,I)=MOTOTINFLOW(L,I)*FACT
      MOTOTIN(L,I)=MOTOTIN(L,I)*FACT
 50   CONTINUE
      N=1954
      DO 52 L=3,33
      N=N+1
C OUTPUT LAKE LEVEL IN FEET AND SEEPAGE & OUTFLOW IN CFS
      WRITE(15,88)N,(MOTOTLL(L,I),I=1,12)
      WRITE(16,89)N,(MOTOTSEEP(L,I),I=1,12)
      WRITE(17,89)N,(MOTOTOUTFLOW(L,I),I=1,12)
 52   CONTINUE
 88   FORMAT(I5,12F8.2)
 89   FORMAT(I5,12F8.3)
      PRINT 30
 30   FORMAT('TOTAL COMPLETE!!!!!!!!!!!')
      RETURN
      END
```

```
      SUBROUTINE TABMON(NY,LAKE,RC)
      PARAMETER ND=31
      REAL MOTOTLL,MOTOTSEEP,MOTOTEO,MOTOTOUTFLOW,MOTOTOUT
      REAL MOTOTPI,MOTOTRI,MOTOTINFLOW,MOTOTIN,MOTOTAR
      COMMON/TABLEBLK/MOTOTLL(35,12),MOTOTSEEP(35,12),MOTOTEO(35,12),
     &MOTOTOUTFLOW(35,12),MOTOTOUT(35,12),MOTOTPI(35,12),
     &MOTOTRI(35,12),MOTOTINFLOW(35,12),MOTOTIN(35,12),MOTOTAR(35,12)
      INTEGER LAKE
      CHARACTER *3 MON(12)
      DATA (MON(I),I=1,12)/'OCT','NOV','DEC','JAN','FEB','MAR','APR',
     &'MAY','JUN','JUL','AUG','SEP'/
      N=1969
      DO 77 L=18,33
      N=N+1
      IF(LAKE.EQ.1) WRITE(13,10)(MON(I),I=1,12)
 10   FORMAT('1',//,50X,'MONTHLY WATER BALANCE, DUCK LAKE',
     &  /,6A20,/,6A20)
      IF(LAKE.EQ.2) WRITE(13,20)(MON(I),I=1,12)
 20   FORMAT('1',//,50X,'MONTHLY WATER BALANCE, LITTLE SAND LAKE',
     &/,6A20,/,6A20)
      IF(LAKE.EQ.3) WRITE(13,80)(MON(I),I=1,12)
 80   FORMAT('1',//,50X,'MONTHLY WATER BALANCE, DEEP HOLE LAKE ',
     &/,6A20,/,6A20)
      IF(LAKE.EQ.4) WRITE(13,90)(MON(I),I=1,12)
 90   FORMAT('1',//,50X,'MONTHLY WATER BALANCE, SKUNK LAKE ',
     &/,6A20,/,6A20)
      IF(LAKE.EQ.5) WRITE(13,91)(MON(I),I=1,12)
 91   FORMAT('1',//,50X,'MONTHLY WATER BALANCE, OAK LAKE ',
     &/,6A20,/,6A20)
 88   FORMAT(I5,6F20.2,/,5X,6F20.2)
 89   FORMAT(I5,6F20.4,/,5X,6F20.4)
      WRITE(13,30)
 30   FORMAT('LAKE LEVEL')
      WRITE(13,88)N,(MOTOTLL(L,I),I=1,12)
      WRITE(13,59)
 59   FORMAT('AREA (ACRES)')
      WRITE(13,88)N,(MOTOTAR(L,I),I=1,12)
      WRITE(13,60)
 60   FORMAT('SEEPAGE        ')
      WRITE(13,89)N,(MOTOTSEEP(L,I),I=1,12)
      WRITE(13,31)
 31   FORMAT('EVAPORATION    ')
      WRITE(13,89)N,(MOTOTEO(L,I),I=1,12)
      WRITE(13,32)
 32   FORMAT('OUTFLOW       ')
      WRITE(13,89)N,(MOTOTOUTFLOW(L,I),I=1,12)
      WRITE(13,33)
 33   FORMAT('TOTAL OUT     ')
      WRITE(13,89)N,(MOTOTOUT(L,I),I=1,12)
      WRITE(13,34)
 34   FORMAT('PRECIP        ')
      WRITE(13,89)N,(MOTOTPI(L,I),I=1,12)
```

```
      WRITE(13,35)
35    FORMAT('RUNOFF        ')
      WRITE(13,89)N,(MOTOTRI(L,I),I=1,12)
      WRITE(13,36)
36    FORMAT('INFLOW        ')
      WRITE(13,89)N,(MOTOTINFLOW(L,I),I=1,12)
      WRITE(13,37)
37    FORMAT('TOTAL IN      ')
      WRITE(13,89)N,(MOTOTIN(L,I),I=1,12)
      WRITE(13,38)
38    FORMAT('NET IN      ')
      WRITE(13,89)N,((MOTOTIN(L,I)-MOTOTOUT(L,I)),I=1,12)
77    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GETVAR(LAKE)
      PARAMETER ND=31
      CHARACTER*20 LAKE
      CHARACTER*1 ANSW
      REAL PRECIP,EVAP,THK,K,LL,PI,GWB,KB,THKB,
     &RI,EO,OF,SEEP,IN,STOR,OUTFLOW,GW,
     &OUT,CLL,AREA,INFLOW,RC(12)
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON/COMBLK3/ AREAL(500,ND), AREAB(500,ND),GWB,KB,THKB
C INITIALIZE LL ARRAY
      DO 33 I=1,500
      DO 33 J=1,30
      LL(I,J)=0.0
   33 CONTINUE
C PROMPT FOR THICKNESS OF SEDIMENT
 99   WRITE(*,1)LAKE
      READ(*,*)THK
 1    FORMAT('ENTER THICKNESS OF SEDIMENT FOR ',20A)
C PROMPT FOR K IN FT/YEAR
      WRITE(*,3)LAKE
      READ(*,*)K
 3    FORMAT('ENTER K IN FT/YR FOR ',20A)
C PROMPT FOR GROUND WATER LEVEL
      WRITE(*,4)LAKE
      READ(*,*)GW
 4    FORMAT('ENTER GROUND WATER LEVEL FOR ',20A)
C PROMPT FOR THICKNESS OF WETLAND SEDIMENT
      WRITE(*,101)LAKE
      READ(*,*)THKB
101   FORMAT('ENTER THICKNESS OF WETLAND SEDIMENT FOR ',20A)
C PROMPT FOR WETLAND K IN FT/YEAR
      WRITE(*,103)LAKE
      READ(*,*)KB
103   FORMAT('ENTER WETLAND K IN FT/YR FOR ',20A)
C PROMPT FOR WETLAND GROUND WATER LEVEL
      WRITE(*,104)LAKE
      READ(*,*)GWB
 104  FORMAT('ENTER WETLAND GROUND WATER LEVEL FOR ',20A)
C PROMPT FOR CONSTANTS IN RATING EQUATION
C PROMPT FOR BASE ELEVATION
      WRITE(*,105)LAKE
      READ(*,*)BASE
105   FORMAT('ENTER BASE ELEVATION FOR RATING CURVE FOR ',20A)
C PROMPT FOR COEFFICIENT
      WRITE(*,106)LAKE
      READ(*,*)COEF
106   FORMAT('ENTER COEFFICIENT OF RATING CURVE FOR ',20A)
```

```
C PROMPT FOR EXPONENT
      WRITE(*,107)LAKE
      READ(*,*)EXP
 107  FORMAT('ENTER EXPONENT OF RATING CURVE FOR ',20A)
C INPUT INITIAL LAKE LEVEL
      WRITE(*,5)LAKE
    5 FORMAT(1X,'INPUT INITIAL LAKE LEVEL FOR ',20A)
      READ(*,*)LL(1,1)
C CHECK VALUES FOR ACCURACY
      WRITE(*,50)LAKE
 50   FORMAT('THE VALUES YOU HAVE ENTERED FOR ',20A,'ARE AS FOLLOWS')
      WRITE(*,60)
 60   FORMAT('    K/T     GW      KB/TB'
     &'   GWB    LL(1,1)')
      WRITE(*,70)(K/THK),GW,(KB/THKB),GWB,LL(1,1)
 70   FORMAT(F8.4,F8.2,F8.4,2F8.2/)
      WRITE(*,65)
 65   FORMAT('    ELEV     COEF      EXP    -- OF RATING CURVE')
      WRITE(*,75)BASE,COEF,EXP
 75   FORMAT(F8.2,2F8.4)
      WRITE(*,80)
 80   FORMAT('ARE THEY CORRECT? Y/N')
      READ(*,90)ANSW
 90   FORMAT(1A)
      IF(ANSW.EQ.'N') GO TO 99
      RETURN
      END
```

```
      SUBROUTINE GETVARS(LAKE)
      PARAMETER ND=31
      CHARACTER*20 LAKE
      CHARACTER*1 ANSW
      REAL PRECIP,EVAP,THK,K,LL,PI,S,V,GWB,KB,THKB,
     &RI,EO,OF,SEEP,IN,STOR,OUTFLOW,GW,
     &OUT,CLL,AREA,INFLOW,RC(12)
      COMMON/COMBLK1/ PRECIP(500),EVAP(500),THK,K,LL(500,ND),
     &PI(500,ND),RI(500,ND),EO(500,ND),
     &BASE,COEF,EXP
      COMMON/COMBLK2/ SEEP(500,ND),IN(500,ND),STOR(500,ND),
     &OUTFLOW(500,ND),OUT(500,ND),CLL(500,ND),AREA(500,ND),
     &INFLOW(500,ND),GW,S(500,ND),V(500,ND)
      COMMON/COMBLK3/ AREAL(500,ND), AREAB(500,ND),GWB,KB,THKB
C INITIALIZE LL ARRAY
      DO 33 I=1,500
      DO 33 J=1,30
      LL(I,J)=0.0
   33 CONTINUE
C PROMPT FOR THICKNESS OF SEDIMENT
 99   WRITE(*,1)LAKE
      READ(*,*)THK
 1    FORMAT('ENTER THICKNESS OF SEDIMENT FOR ',20A)
C PROMPT FOR K IN FT/YEAR
      WRITE(*,3)LAKE
      READ(*,*)K
 3    FORMAT('ENTER K IN FT/YR FOR ',20A)
C PROMPT FOR GROUND WATER LEVEL
      WRITE(*,4)LAKE
      READ(*,*)GW
 4    FORMAT('ENTER GROUND WATER LEVEL FOR ',20A)
C PROMPT FOR THICKNESS OF WETLAND SEDIMENT
      WRITE(*,101)LAKE
      READ(*,*)THKB
101   FORMAT('ENTER THICKNESS OF WETLAND SEDIMENT FOR ',20A)
C PROMPT FOR WETLAND K IN FT/YEAR
      WRITE(*,103)LAKE
      READ(*,*)KB
103   FORMAT('ENTER WETLAND K IN FT/YR FOR ',20A)
C PROMPT FOR WETLAND GROUND WATER LEVEL
      WRITE(*,104)LAKE
      READ(*,*)GWB
 104  FORMAT('ENTER WETLAND GROUND WATER LEVEL FOR ',20A)
C INPUT INITIAL LAKE LEVEL
      WRITE(*,5)LAKE
    5 FORMAT(1X,'INPUT INITIAL LAKE LEVEL FOR ',20A)
      READ(*,*)LL(1,1)
C CALCULATE LAKE VOLUME
C           WRITE(*,7)LAKE
C         7 FORMAT(1X,'INPUT INITIAL LAKE VOLUME FOR ',20A)
C           READ(*,*)V(1,1)
```

```
      IF (LL(1,1).LE.1592.8) THEN
            V(1,1) = 0.0
      ELSE IF (LL(1,1).LE.1595.09) THEN
            V(1,1) = 7623. * (LL(1,1)-1592.8)**2.
      ELSE IF (LL(1,1).LE.1597.09) THEN
            V(1,1) = 39639.6 * (LL(1,1)-1594.65)**2.+32301.5
      ELSE
            V(1,1) = 237402. * (LL(1,1)-1596.68)**2.+228393.
      END IF
C CHECK VALUES FOR ACCURACY
      WRITE(*,50)LAKE
 50   FORMAT('THE VALUES YOU HAVE ENTERED FOR ',20A,'ARE AS FOLLOWS')
      WRITE(*,60)
 60   FORMAT('     K/T      GW      KB/TB'
     &'   GWB   LL(1,1)            V(1,1)')
      WRITE(*,70)(K/THK),GW,(KB/THKB),GWB,LL(1,1),V(1,1)
 70   FORMAT(F8.4,F8.2,F8.4,2F8.2,F20.2)
      WRITE(*,80)
 80   FORMAT('ARE THEY CORRECT? Y/N')
      READ(*,90)ANSW
 90   FORMAT(1A)
      IF(ANSW.EQ.'N') GO TO 99
      RETURN
      END
```