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GREAT LAKES BASINS RUNOFF MODELING

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Large-scale watershed models are required to estimate basin runoff to the Great Lakes for use in routing determinations and operational hydrology studies. Data limitations, large-basin applicability, and economic efficiency preclude the use of existing large-watershed models. An interdependent tank-cascade model is described that uses a mass balance coupled with linear reservoir concepts. It is physically based and uses climatological considerations not possible for small watersheds; analytical solutions are employed to bypass numerical inaccuracies. Snowmelt and net supply computations are separable from the mass balance determinations and are based on a simple heat balance. Partial area concepts are used to determine infiltration and surface runoff. Losses are determined from joint consideration of available energy for actual and potential evapotranspiration and of available moisture in the soil horizons by using climatological concepts. Heuristic calibration procedures are described that give insight into the use of the model. The model is applied, for a 30-d computation interval, to the Genesee River Basin in New York State and compared with past 6-h computation interval applications of the SSARR and NWSH models to the same data set.

1. INTRODUCTION

Agencies concerned with managing the Laurentian Great Lakes water levels for purposes of flood control, navigation, and hydropower must devise operational regulations consistent with the expected hydrology of the area. In this regard, routing models such as the Great Lakes Hydrologic Response Model (Quinn, 1978) are invaluable in estimating water levels throughout the lakes. Input parameters include overwater precipitation, lake evaporation, and basin runoff. Large-scale watershed models are required to estimate basin runoff to the lakes, and the Great Lakes Environmental Research Laboratory (GLERL) is determining an appropriate model. The model must have limited data requirements. Allowable data inputs are daily precipitation and air temperature. Also allowed are any data that can be abstracted easily from available maps or climatic summaries. This research objective is mandated by the limited data availability for large areas in the Great Lake basins and by time series analysis and simulation restrictions. The model is planned for use in subsequent operational hydrology analyses of water levels in the Great Lakes. It is also desired that the model concepts be physically based, so that understanding of watershed response to natural forces is facilitated, and the model is economical to use. The model may be

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applied to as many as 100 basins in the Great Lakes area and the integrated response used in simulation studies.

During the initial phases of this study, two existing models were evaluated for simulating the detailed hydrologic response of individual watersheds. The U.S. Corps of Engineer's Streamflow Synthesis and Reservoir Regulation model (SSARR) and the National Weather Service Hydrologic model (NWSH) were evaluated in terms of reproducing volumes of runoff from the Genesee River Basin in New York State (Potok, 1980). The SSARR model was then used to simulate runoff from the southeast Lake Michigan basin (Derecki and Potok, 1979). These models, particularly the SSARR model, showed potential for use in simulating or forecasting runoff into the Great Lakes. However, they require many parameter determinations, which hinders their physical relevance and makes them expensive to fit. They require too much data in an area where only daily precipitation and temperature are available over large areas. They are expensive to use and therefore their effectiveness depends upon the ability to group watersheds of similar hydrologic characteristics into a single regional "equivalent" watershed. Unfortunately, the application of such lumped-parameter models to very large areas must necessarily fail to represent areal distributions of watershed and meteorological characteristics.

This paper presents an interdependent "tank cascade" model that has been tested on the Genesee River Basin in New York State. It was developed from large-scale (climatological) concepts and designed for weekly or monthly volumes of runoff. The model consists of water and heat balances; as do other water-budgeting models, but with alternative physical interpretations given to its components. The model is physically based and uses climatological considerations not possible with small watersheds. In particular, evapotranspiration losses for large areas may now be considered as a function of readily available data. The analytical solutions are presented in favor of numerical solutions to bypass the associated numerical error. The calibration procedure developed for use of this model is given, along with an illustration of its use. The model is compared to the SSARR and NWSH models in an example application on the Genesee River Basin.

2. TANK CASCADE MODELS

There are many conceptual models of watershed hydrology that use the "tank cascade" concept, wherein one component of the watershed drains into other components. The Stanford Watershed Model (Crawford and Linsley, 1966) and its many derivatives (including the SSARR and NWSH models) are well-known examples. In these earlier developments, relationships between various components in the watershed (e.g., surface storage, interception storage, upper and lower soil zones, groundwater storage, and channel storage) are described with classical equations of evaporation, infiltration, and inter-tank flows. Solution of these equations often proceeds numerically with accounting-type calculations. Many variations on the tank cascade concept are included to simulate nuances observed in nature. For example, minimum storage volumes must be filled in various tanks before any inter-tank flows are allowed; this corresponds to satisfaction of interception and surface depression storage, and of groundwater and soil zone storages above which runoff can occur. Other nuances pertain to satisfaction of evaporation before infiltration and similar flows. While these variations allow better matching of peak flow rates, they introduce complexities that prohibit analytical solutions, requiring instead that numerical solutions proceed in small time steps. These variations appear to be unnecessary for volumetric determinations over large time periods (as opposed to finding peak flow rates), and they introduce many parameters to be determined in model calibration. It is difficult to use these models in practical applications because of their extensive data or calibration/optimization requirements. These requirements become excessive when considering applications over large areas like the Great Lake basins.

The tank cascade concept has also been applied in a series of models to determine total runoff hydrographs from very limited data (Edson, 1951; Kalinin and Miljukov, 1958; Nash, 1959, 1960; W.M.O., 1975). In these applications, many variations to the concept, mentioned above, are not included so that the solution is analytically tractable. They are useful for determining runoff hydrographs; monthly runoff estimates are possible also, presupposing that adequate data are available for determining snowmelt and evapotranspiration. The absence of constraints on tank interflows allows efficient parameter estimation techniques to be employed in some practical applications (Tingsanchali and Loria, 1981).

In light of the requirements for the GLERL large watershed model, where weekly or monthly runoff volumes from large areas are required, a tank cascade model was defined by using physical concepts. (See fig. 1.) The main mathematical feature of this arrangement is that it may be described by strictly continuous equations; none of the complexities associated with inter-tank flow rate dependence on partial filling are introduced. For a sufficiently large watershed, these nuances are not observed due to the spatial integration of the rainfall, snowmelt, and evapotranspiration processes. Since the solution is analytically tractable, large time steps may be employed without introducing numerical error or excessive computational requirements. The integration of data inputs over large time steps may introduce errors that can only be assessed by example applications in the selection of the appropriate time step. However, for large watershed areas, there is some temporal integration of inputs that may make the approximation of uniform inputs over each time interval inconsequential.

The watershed hydrology schematic of fig. 1 is similar to existing concepts of the physical process for large watersheds. To elaborate, daily precipitation, temperature, and insolation (the latter available from meteorological summaries as a function of location) may be used to determine snowpack accumulations and net supply. The net supply is divided into surface runoff and infiltration to the upper soil zone in relation to the upper soil zone moisture content (USZM). Percolation to the lower soil zone and evapotranspiration are also dependent on USZM. Likewise, interflow from the lower soil zone to the surface, evapotranspiration, and deep percolation to the groundwater zone depend on the lower soil zone moisture content (LSZM).

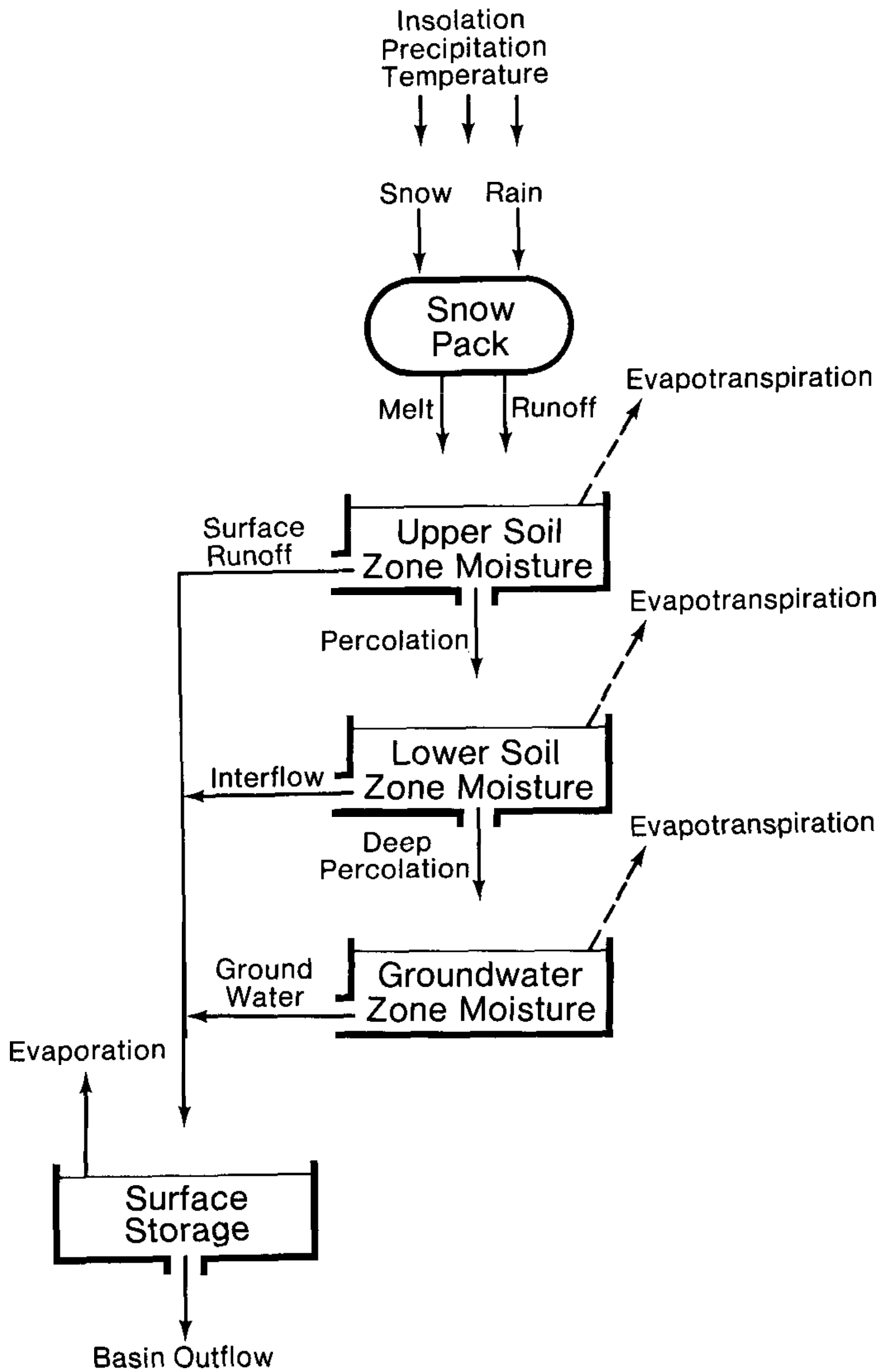

FIGURE 1.--*GLERL large-basin runoff model schematic.*

Groundwater flow and evapotranspiration from the groundwater zone depend on the groundwater zone moisture content (GZM). Finally, basin outflow and evaporation from the surface storage (SS) depend on its content. Additionally, evaporation and evapotranspiration are dependent on potential evapotranspiration as determined by joint consideration of the available moisture and the heat balance over the watershed.

The upper soil zone is the void space in the surface soil layerto a depth that can be considered to control infiltration, usually a few centimeters. The lower soil zone is located beneath the upper soil zone and above the water table. The groundwater zone is located beneath the water table. These definitions are inexact since the water table fluctuates in time, implying that these zones are not static. Likewise, all moisture in these zones may not be involved in basin outflow. For example, moisture beneath the water table is part of the groundwater zone only if it is part of the flow toward the stream channel network on the watershed surface. Moisture that flows from the watershed as groundwater movement is not part of the GZM. While the location and extent of these zones may be poorly defined, conceptually they are zones that give rise to flow rates as pictured in fig. 1.

A more classical approach to watershed hydrology with a tank cascade model would eliminate the surface storage "tank" in fig. 1. The summation of surface runoff, interflow, and groundwater would then constitute basin outflow. This is the concept used in hydrograph separation techniques, such as that given by Barnes (1940) where each component of outflow recession is defined as coming from its respective storage. The schematic of fig. 1 is more appealing since outflow components enter into the channel network before appearing at the basin outflow point.

3. MASS BALANCE

Precipitation falling onto the watershed surface and snowmelt constitute the net supply to the watershed. Interception can be considered as part of evapotranspiration and surface depression storage is too transient for consideration since peak flow rates are not of interest. Both are well within the error of measurement for average areal precipitation and are neglected. At any instant, the net supply rate is divided between surface runoff and infiltration. Surface runoff is proportional to the relative size of the contributing "wetted" area of the watershed (partial-area concept), as well as to the net supply rate

$$r = ns\ A_p/A_w \tag{1}$$

$$i = ns - r, \tag{2}$$

where r = surface runoff rate (cubic meters per day), ns = net supply rate (cubic meters per day), A_p = area of wetted contributing watershed portion (square meters), A_w = area of the watershed (square meters), and i = infiltration rate (cubic meters per day). By further approximating the relative size of the contributing area as the relative content of the upper soil zone (a good assumption for a very thin zone), areal infiltration becomes

$$i = ns \left(1 - \frac{USZM}{USZC}\right), \tag{3}$$

where USZM = volume of water in the upper soil zone (cubic meters) and USZC = capacity of the upper soil zone (cubic meters). Equation (3) may be interpreted as indicating that infiltration is proportional to the volume remaining in the upper soil zone. This is the basis for Horton's infiltration-capacity relationship at a point (Croley, 1977, pp. 168-170), although Horton's model uses volume remaining beneath the point (small area), not over a large area. Equation (3) also indicates that infiltration is proportional to the net supply rate. This is an areal concept for infiltration that has been empirically verified (Kumar, 1980); it does not work for infiltration at a point, which is better described by infiltration-capacity concepts.

Since hydrograph recessions are described successfully by exponential decay relationships (Linsley, Kohler, and Paulhus, 1975, pp. 225-229), the linear reservoir concept is deemed appropriate for describing outflow rates from the various storages within the watershed. The concept describes an outflow rate as proportional to the storage remaining. It is expanded here to describe percolation and deep percolation, as well as the traditional descriptions of interflow, groundwater flow, and basin outflow. The form of the equation is

$$g = \alpha S, \tag{4}$$

where g = outflow rate from a storage (cubic meters per day), α = linear reservoir constant (inverse days), and S = volume of water in storage (cubic meters). In eq. (4), S is USZM and α is α_{per} for g equal to percolation; S is LSZM and α is α_{int} or α_{dp} for g equal to interflow or deep percolation, respectively; S is GZM and α is α_{gw} for g equal to groundwater flow; and S is SS and α is α_{sf} for g equal to basin outflow.

The linear reservoir concept is modified when considering evaporation or evapotranspiration (evaporation plus transpiration) from any zone of the watershed.

$$e = \beta S e_p, \tag{5}$$

where e = evaporation or evapotranspiration rate (cubic meters per day), β = partial linear reservoir constant (inverse cubic meters), and e_p = potential evaporation or evapotranspiration rate, respectively (cubic meters per day). In eq. (5), evaporation or evapotranspiration is taken as proportional both to the potential rate, determined from heat balance considerations over the watershed, and to the available water volume (reflecting both areal coverage and extent of supply). This is in agreement with existing climatological and hydrological concepts for evapotranspiration opportunity. In eq. (5), S is USZM and β is β_{eu} for e equal to upper zone evapotranspiration, S is LSZM and β is β_{el} for e equal to lower zone evapotranspiration, S is GZM and β is β_{eg} for e equal to groundwater zone evapotranspiration, and S is SS and β is β_{es} for e equal to surface zone evaporation.

By combining eqs. (3), (4), and (5) with the definitions given above, the one-dimensional mass continuity equation may be written for each zone of the watershed. (See fig. 1.) For all storage zones then

$$ns - \frac{ns}{USZC}\,USZM - \alpha_{per}\,USZM - \beta_{eu}\,e_p USZM = \frac{\delta}{\delta t}\,USZM \tag{6}$$

$$\alpha_{per}\,USZM - \alpha_{int}\,LSZM - \alpha_{dp}\,LSZM - \beta_{el}\,e_p\,LSZM = \frac{\delta}{\delta t}\,LSZM \tag{7}$$

$$\alpha_{dp}\,LSZM - \alpha_{gw}\,GZM - \beta_{eg}\,e_p GZM = \frac{\delta}{\delta t}\,GZM \tag{8}$$

$$\frac{ns}{USZC}\,USZM + \alpha_{int}\,LSZM + \alpha_{gw}\,GZM - \alpha_{sf}\,SS - \beta_{es}\,e_p\,SS = \frac{\delta}{\delta t}\,SS. \tag{9}$$

In each case, mass continuity yields a first-order linear differential equation of the general form

$$\delta S + (\Sigma)\,S\,\delta t = f(t)\,\delta t, \tag{10}$$

where (Σ) = sum of linear reservoir constants on storage for all outflows, f(t) = sum of time-dependent inflows into the storage, and t = time. The general solution may be obtained from standard procedures (Rainville, 1964, pp. 36-39)

$$S_t = e^{-(\Sigma)t} \quad S_0 + \int_0^t f(u)\, e^{(\Sigma)u}\, \delta u, \tag{11}$$

where the subscript is time. Since data on precipitation and temperature are available only in time increments of a day or larger, the solutions to eqs. (6)-(9) are given here by assuming that the net supply and potential evapotranspiration are distributed uniformly over the time increment. Storage values at the end of the time increment are computed from values at the beginning. In the analytic solution, results from one storage zone are used in other zones where their outputs appear as inputs. There are several different solutions, depending upon the relative magnitudes of all coefficients in eqs. (6)-(9). As an example, the equations are solved for the daily time increment ($0 < t < d$)

$$USZM_d = (USZM_0 - \frac{ns}{B})\, e^{-Bd} + \frac{ns}{B} \tag{12}$$

$$LSZM_d = (LSZM_0 - \frac{A}{D-B} - \frac{C}{D})\, e^{-Dd} + \frac{A}{D-B}\, e^{-Bd} + \frac{C}{D} \tag{13}$$

$$GZM_d = (GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H})\, e^{-Hd} + \frac{E}{H-D}\, e^{-Dd} + \frac{F}{H-B}\, e^{-Bd} + \frac{G}{H} \tag{14}$$

$$SS_d = (SS_0 - \frac{L}{P-H} - \frac{M}{P-D} - \frac{N}{P-B} - \frac{O}{P})e^{-Pd} + \frac{L}{P-H}\, e^{-Hd}$$

$$+ \frac{M}{P-D}\, e^{-Dd} + \frac{N}{P-B}\, e^{-Bd} + \frac{O}{P}, \tag{15}$$

where

$$P = \alpha_{sf} + \beta_{es}\, e_p \tag{16}$$

$$O = \alpha_{gw}\, \frac{G}{H} + \frac{\alpha_{int}}{\alpha_{dp}}\, G + \frac{ns}{USZC}\, \frac{C}{\alpha_{p1}} \tag{17}$$

$$N = \frac{\alpha_{gw}}{H-B} F + \frac{\alpha_{int}}{\alpha_{dp}} F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}} \tag{18}$$

$$M = \frac{\alpha_{gw}}{H-D} E + \frac{\alpha_{int}}{\alpha_{dp}} E \tag{19}$$

$$L = \alpha_{gw} \quad GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H} \tag{20}$$

$$H = \alpha_{gw} + \beta_{eg} \; e_p \tag{21}$$

$$G = \alpha_{dp} \frac{C}{D} \tag{22}$$

$$F = \frac{\alpha_{dp}}{D-B} A \tag{23}$$

$$E = \alpha_{dp} \quad LSZM_0 - \frac{A}{D-B} - \frac{C}{D} \tag{24}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} \; e_p \tag{25}$$

$$C = \alpha_{pl} \frac{ns}{B} \tag{26}$$

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu} \; e_p \tag{27}$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right). \tag{28}$$

The subscripts 0 and d on the storage volumes represent the beginning and the end of the day, respectively. This solution applies for the case where $D \neq B$, $H \neq D$, $H \neq B$, $P \neq H$, $P \neq D$, $P \neq B$, $B \neq 0$, $D \neq 0$, $H \neq 0$, $P \neq 0$, $USZC \neq 0$, $\alpha_{pl} \neq 0$, and $\alpha_{dp} \neq 0$. As long as α_{pl}, α_{int}, α_{gw}, α_{sf}, and USZC are non-zero, then there are 30 possible analytic results, depending upon the values of B, D, H, P, and α_{dp}: 15 for $\alpha_{dp} = 0$ and 15 for $\alpha_{dp} \neq 0$. (See fig. 2.) Since these quantities (B, D,, H, and P) involve the variables ns and e_p, which change from day to day, then the appropriate analytical result, as well as its solution, varies with time. Mathematical continuity between solutions is preserved however. These results are summarized in appendix B. A watershed model must have all solution possibilities present for effective implementation.

The flow volumes over the daily time increment may then be determined directly since outflow volumes are related by their ratio of linear reservoir coefficients.

$$R = \left(NS + USZM_0 - USZM_d\right) \frac{ns}{USZC} \frac{1}{B} \tag{29}$$

$$I = NS - R \tag{30}$$

$$PL = (NS + USZM_0 - USZM_d)\frac{\alpha_{pl}}{B} \tag{31}$$

$$E_u = (NS + USZM_0 - USZM_d)\ \frac{\beta_{eu}\ e_p}{B} \tag{32}$$

$$IF = (PL + LSZM_0 - LSZM_d)\ \frac{\alpha_{int}}{D} \tag{33}$$

$$DP = (PL + LSZM_0 - LSZM_d)\frac{\alpha_{dp}}{D} \tag{34}$$

$$E_\ell = (PL + LSZM_0 - LSZM_d)\ \frac{\beta_{el}\ e_p}{D} \tag{35}$$

$$GW = (DP + GZM_0 - GZM_d)\frac{\alpha_{gw}}{H} \tag{36}$$

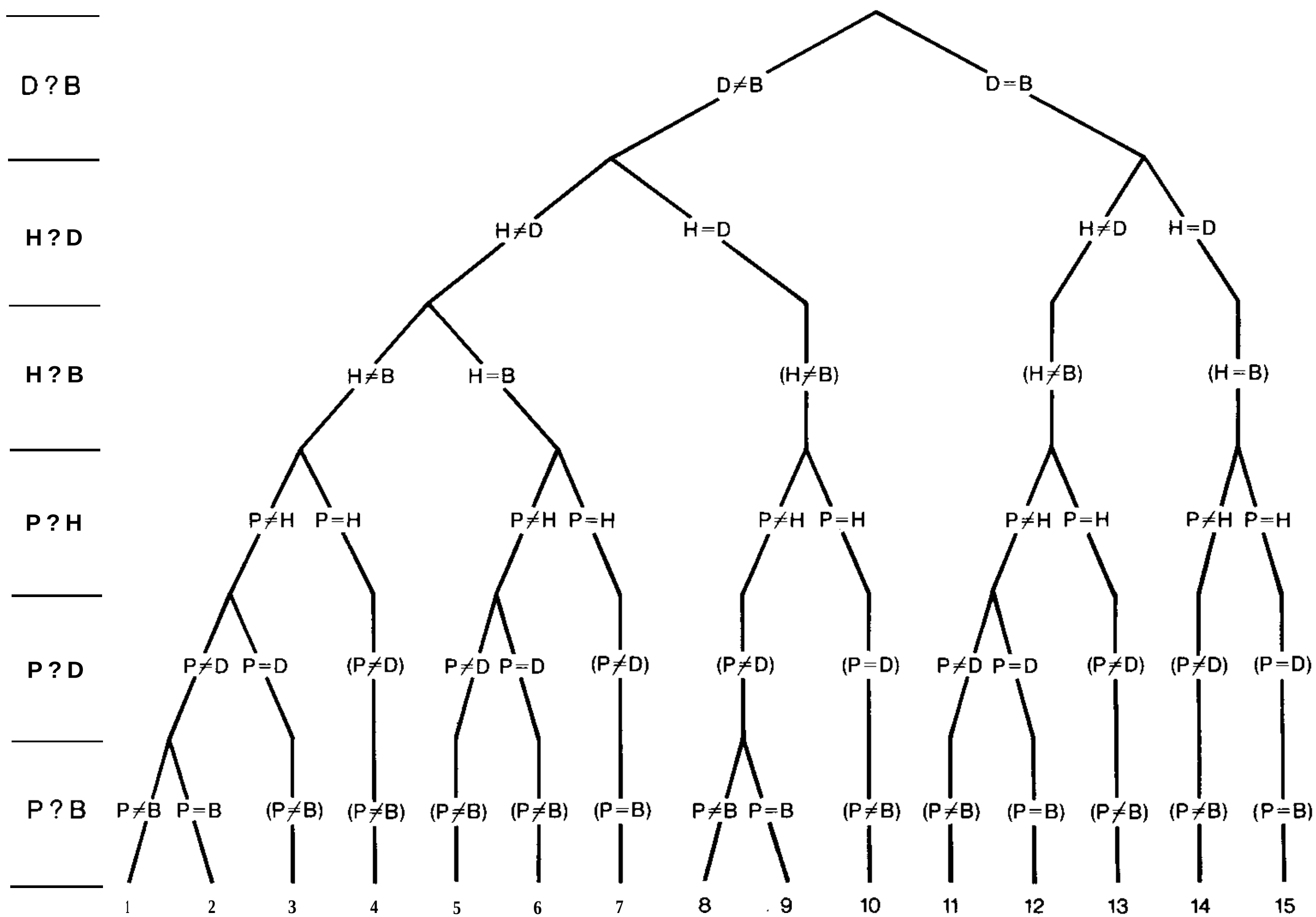

FIGURE 2.--*Analytical* solution possibilities.

$$E_g = (DP + GZM_0 - GZM_d)\frac{\beta_{eg}\ e_p}{H} \quad (37)$$

$$BO = (R + IF + GW + SS_0 - SS_d)\ \frac{\alpha_{sf}}{P} \quad (38)$$

$$E_s = (R + IF + GW + SS_0 - SS_d)\ \frac{\beta_{es}\ e_p}{P}, \quad (39)$$

where R = daily surface runoff volume (cubic meters), NS = daily net supply volume (cubic meters), I = daily infiltration volume (cubic meters), PL = daily percolation volume (cubic meters), E_u = daily upper soil zone evapotranspiration volume (cubic meters), IF = daily interflow volume (cubic meters), DP = daily deep percolation volume (cubic meters), E_ℓ = daily lower soil zone evapotranspiration volume (cubic meters), GW = daily groundwater volume (cubic meters), E_g = daily groundwater zone evapotranspiration volume (cubic meters), BO = daily basin outflow volume (cubic meters), and E_s = daily surface zone evaporation volume (cubic meters). Given all coefficients, starting values of storage in each of the component zones, net supply rate, and potential evapotranspiration rate, the values of B, D, H, and P can be computed from eqs. (27), (25), (21), and (16), respectively. Based upon their values, the appropriate analytical results [eqs. (17)-(20), (22)-(24), (26), and (28)] are used to compute the remaining intermediate values. The appropriate analytical solution [eqs. (12)-(15)] is then used to compute the end-of-day storage values (which become the beginning-of-day values for the next day). Finally, the daily flow volumes can be obtained from eqs. (29)-(39).

The analytic solutions of Eqs. (6)-(9) are "continuous"; that is they are amenable to ordinary solution techniques. Furthermore, solutions may proceed for either flow rates or storage volumes directly without the complication of constraints consideration. All derivatives of the solutions with respect to individual parameters exist and are continuous; therefore, analytical gradient-search procedures are possible in parameter determination. The solutions are physically satisfying; non-negative flow rates and storage volumes are guaranteed with any physically plausible set of inputs. The solution equations are unchanged for other time increments; the daily time interval, d, is simply replaced in the equations. The net supply and potential evapotranspiration are considered to be uniform over the time interval and the choice of time interval must assess the validity of this treatment.

4. NET SUPPLY

The determination of the net supply rates involves the consideration of rainfall, snowfall, snowpack accumulation, and snowmelt. Several attempts at comprehensive heat balances and many empirical treatments were attempted, but were abandoned because of of the limited data availability. The following treatment yields better agreement with Genesee River data than do conventional "degree-day" treatments.

Snow accumulation is governed by the concept that precipitation under warm air temperatures occurs as rainfall and under cold temperatures, as snow or ice which accumulates in the snowpack. Snow accumulation is thus governed by the following concept:

$$\frac{\delta}{\delta t} SNW = -m , \quad T > 0$$

$$= p , \quad T < 0, \tag{40}$$

where SNW = equivalent water volume present in the snowpack (cubic meters), m = snowmelt rate (cubic meters per day), p = precipitation rate (cubic meters per day), and T = air temperature (degrees Celsius). Daily air temperature is estimated typically as the average of daily maximum and minimum temperatures. The simplification of allowing melt only during above-zero air temperatures appeared realistic in example comparisons for volumetric determinations over the week or month. Ignoring evaporation from, and condensation to, the snowpack is justified by the limited data requirements for which the model is designed. The net supply rate is then given as

$$ns = p + m , \quad T > 0$$

$$= o \quad , \quad T < 0. \tag{41}$$

Snowmelt is determined from the simple concept that there are no heat additions from which melt could later occur during periods of sub-zero air temperatures. For periods of above-zero air temperatures, snowmelt results from absorbed insolation and precipitation. However, it is constrained by the available snowpack

$$m = 0 \quad , \quad T < 0$$

$$= SNW_0/d \quad , \quad T > 0, \quad \int_0^d \frac{rr\,(1-a_s) + \rho\, p\, T}{\gamma_m}\, \delta t > SNW_0 \tag{42}$$

$$= [rr\,(1-a_s) - \rho\, p\, T]/\gamma_m \quad , \quad T > 0, \quad \int_0^d \frac{rr\,(1-a_s) + \rho\, p\, T}{\gamma_m}\, \delta t < SNW_0,$$

where rr = solar insolation at the watershed surface (calories per day), a_s = albedo of the snow surface, ρ = density of water (= 10^6 g/m^3), and γ_m = latent heat of fusion (= 79.7 cal/g). Other components of the heat balance are not representable with limited data, but may be compensated for, to some extent, in parameter determinations of a_s. The solar insolation at the surface of the watershed may be estimated from extraterrestrial radiation and cloud cover:

$$rr = 10000\ A_w\ \tau\ (b_1 + b_2\ X), \tag{43}$$

where τ = extraterrestrial solar radiation (langleys per day) available in standard climatologic summaries as a function of latitude and time of the year, b_1 and b_2 = empirical constants, and X = ratio of hours of bright sunshine to maximum possible hours of bright sunshine. In the absence of cloud cover data, X may be estimated (Crawford and Linsley, 1966, p. 50) from

$$X = \min\ \frac{T_{max} - T_{min}}{15}\ ,\ 1.0\ , \tag{44}$$

where T_{max} = maximum daily air temperature (degrees Celsius) and T_{min} = minimum daily air temperature (degrees Celsius).

5. EVAPOTRANSPIRATION

Potential evaporation is the evaporation that would occur if adequate moisture were available. It is often taken as the amount expected from an open water surface and is used as an estimate of potential evapotranspiration over land and vegetative surfaces (Gray, 1973, pp. 339-353). Very often, engineering calculations of potential evapotranspiration use climatic indicators of temperatures, wind speeds, humidities, etc., by assuming that these quantities are independent of the actual evapotranspiration that does occur. This is adequate for estimates over small areas where evapotranspiration has only a small effect on these quantities. However, over a large area, climatological observations suggest that actual evapotranspiration affects these quantities and hence affects potential evapotranspiration (evapotranspiration opportunity or capacity). Morton (1965) made use of this concept to compute regional evapotranspiration from climatological observations. Witherspoon (1970) used an approximation of Morton's work to compute basin evapotranspiration in a volumetric flow model for Lake Ontario. Bouchet (1963) postulated that the energy represented as potential evapotranspiration is the absorbed insolation less the energy used for regional evapotranspiration. This concept is modified here for use on a smaller-than-regional scale by considering that a portion, W, of the net heat balance after absorbed insolation is available for either potential or actual evapotranspiration. That is, part of it is used in evapotranspiration and the rest of it determines the potential evapotranspiration

$$W = \rho\ \gamma_v\ PE + \rho\ \gamma_v\ (E_u + E_\ell + E_g + E_s), \tag{45}$$

where W = a portion of heat balance after absorbed insolation (calories), γ_v = latent heat of vaporization ($\cong$ 596 cal/g), and PE = daily potential evapotranspiration volume (cubic meters). The evaporation from stream channels and other water surfaces (surface zone) in a large basin is very small compared to the basin evapotranspiration; groundwater zone evapotranspiration is also taken here to be relatively very small. Thus on a daily basis,

$$\int_0^d \rho\ e_p\ \gamma_v\ \delta t + \int_0^d \rho\ (\beta_{eu}\ \mathrm{USZM} + \beta_{el}\ \mathrm{LSZM})\ e_p\ \gamma_v\ \delta t \cong W. \tag{46}$$

By taking e_p as uniform over the day, eq. (46) yields:

$$e_p \cong \frac{1}{d\rho\gamma_v}\ \frac{W}{1 + \beta_{eu}\ \overline{\mathrm{USZM}} + \beta_{el}\ \overline{\mathrm{LSZM}}}, \tag{47}$$

where USZM = average water volume in the upper soil zone (cubic meters) over the day and LSZM = average water volume in the lower soil zone over the day (cubic meters). As expected, both potential and actual evapotranspiration depend upon the available water supply. If the water supply is large, actual evapotranspiration approaches the limit of the water supply or $W/(\rho\gamma_v)$ and potential evapotranspiration approaches zero. If the water supply is small, actual evapotranspiration approaches zero and potential evapotranspiration approaches $W/(\rho\gamma_v)$. The average storages can be computed from the mass balance equations as

$$\mathrm{USZM} = \frac{1}{d\ \alpha_{pl}}\ \frac{A}{B}\ (1 - e^{-Bd}) + \frac{c}{\alpha_{pl}} \tag{48}$$

$$\mathrm{LSZM} = \frac{1}{d\ \alpha_{dp}}\ \frac{E}{D}\ (1 - e^{-Dd}) + \frac{1}{d\ \alpha_{dp}}\ \frac{F}{B}\ (1 - e^{-Bd}) + \frac{G}{\alpha_{dp}}. \tag{49}$$

This solution applies for the case $D \neq B$, USZC $\neq 0$, $\alpha_{pl} \neq 0$, and $\alpha_{dp} \neq 0$. As long as USZC and α_{pl} are non-zero, then for either $D = B$ or $\alpha_{dp} = 0$ or both, alternative expressions result. (See appendix B.) Since e_p is involved in the intermediate variables B and D, an iterative solution is used to determine e_p each day in the mass balance if W is known.

The determination of W from observable meteorological variables is difficult (recall the limitation to daily precipitation and air temperature). During times of snow cover, e_p is zero with respect to the upper and lower soil zones. During times of no snow cover, the remainder of the heat balance on the watershed surface after absorbed insolation consists of short-wave reflection, net long-wave radiation exchange, sensible heat transfer, net hydrospheric and atmospheric advection, latent heat transfer, and energy advected by evaporation. Energy advected by evapotranspiration is small compared to latent heat transfer and is neglected in eq. (46).

Daily air temperature is taken here as an integrated reflection of the portion W of the remaining heat balance after absorbed insolation. This concept is satisfying in that air temperature is considered an indicator of the heat balance, rather than an independent variable in the determination of potential evaporation as is done classically. At low temperatures, it is expected that W is small since potential and actual evapotranspiration are low at low temperatures. Over the daily cycle, this energy is rarely negative (net condensation) and is considered here as strictly positive. The variation of W with air temperature may be expected to look something like the dashed line in fig. 3. As a first approximation, a broken-line relation like the solid line in fig. 3 is used, expressed mathematically as

$$
\begin{aligned}
W &= K\,(T - T_b) && ,\ T > T_b && ,\ SNW = 0 \\
&= 0 && ,\ T > T_b && ,\ SNW \neq 0 \\
&= 0 && ,\ T < T_b, &&
\end{aligned}
\tag{50}
$$

where K = units constant (calories per degree Celsius) and T_b = "base" temperature (degrees Celsius).

There were several alternatives to the "heat balance" used here to compute snowmelt and evapotranspiration. These were considered early in the model development, but were impeded by the limited-data design objectives. Comprehensive heat balances that considered all advection terms through control volumes defined over the upper soil zone or upper and lower soil zones were written in the early modeling. Net long-wave radiation transfer and sensible heat transfer were estimated directly by using empirical relations. These relations required unavailable data, which were estimated based on engineering judgment. Freezing of the upper soil zone, snowpack and ice formation and decay, and Penmann's potential evapotranspiration were all computed as part of these comprehensive heat balances. The net supply and evapotranspiration models presented here resulted in a two-fold improvement in modeling over these earlier efforts, as measured by the root mean

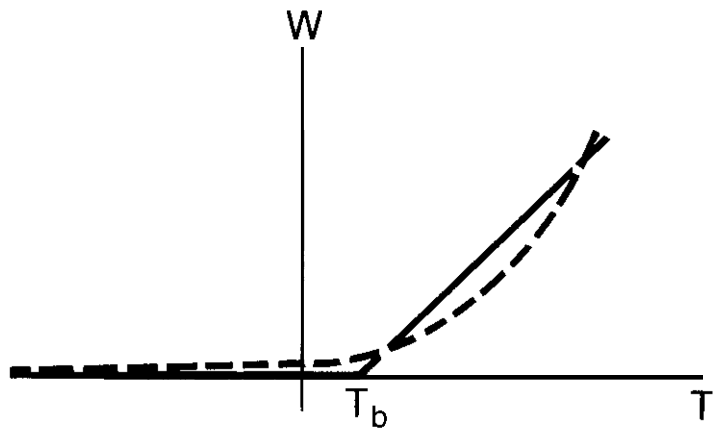

FIGURE 3.--*Daily potential plus actual evapotranspiration, W, as conceptual function of daily air temperature, T.*

square error of model output (basin output). Presumably, these models are superior because of their limited data requirements. Also, the use of air temperatures as an indicator of what has occurred in the watershed is superior to its use as an independent variable in computing potential evapotranspiration and net supply. This change in perspective is fundamental to modeling large-scale watershed hydrology from a climatological viewpoint.

6. CALIBRATION

The following input data are required to apply the model: daily precipitation, daily minimum and maximum temperatures, a climatological summary of daily extraterrestrial solar radiation, and for comparison purposes, daily basin outflows. Conversion of units for precipitation from inches per day or centimeters per day to cubic meters per day and for insolation [see eq. (43)] from langleys per day to calories per day involves the area of the watershed. Daily precipitation and temperatures are taken as weighted areal averages of data available at selected stations in and around the basin. Daily basin outflow is reported in either cubic feet per second or cubic meters per second and is converted to cubic meters per day.

There are five variables to be initialized prior to modeling: SNW, USZM, LSZM, GZM, and SS as SNW_0, $USZM_0$, $LSZM_0$, GZM_0, and SS_0, respectively. While SNW_0 is easy to determine as zero during major portions of the year, these variables are generally difficult to estimate. If the model is to be used in forecasting or for short simulations, then it is important to determine these variables accurately prior to use of the model. They may be taken as the values at the end of a previous model run, preceding the time period of interest, for forecasting uses of the model. If the model is to be used for calibration or for long simulations, then the initial values are unimportant. The effect of the initial values diminishes with the length of the simulation and after 1 year of simulated results, the effects are absent from a practical point of view. In calibration runs, the first year of data is used for initializing the model and the remainder is used for measuring the "goodness-of-fit" of the model to the data.

There are 15 parameters to be determined in an application: a_s, T_b, K, b_1, b_2, USZC, α_{per}, α_{int}, α_{dp}, α_{gw}, α_{sf}, β_{eu}, β_{el}, β_{eg}, and β_{es}. The coefficients for computing solar insolation, b_1 and b_2, are available from the climatological summary for the area. Furthermore, as expected, β_{eg} and β_{es} are near zero with respect to β_{eu} and β_{el}, indicating that open-water evaporation and groundwater evapotranspiration are a relatively small part of the watershed evapotranspiration process; these coefficients may be set to zero with negligible error. The capacity of the upper soil zone, USZC, may be set arbitrarily. Inspection of eqs. (6) and (47) reveals that if USZC is changed from one value to another, then by changing α_{per} and β_{eu} appropriately, USZM will change such that the same infiltration, runoff, percolation, potential evapotranspiration, and change of storage will result. Thus, USZC is set arbitrarily herein to correspond to 2 cm of water over the watershed area. Likewise, β_{el} may be computed to satisfy the following long term boundary condition on average flow rate, as a function of the other parameter values:

$$\int_\Omega bo \; \delta t = \int_\Omega q \; \delta t, \tag{51}$$

where Ω = the time period of record, bo = basin outflow given by the model, and q = actual flow rate from the watershed to be modeled. Actually, any one of several parameters could be adjusted, theoretically, to satisfy eq. (51). The lower soil zone partial linear reservoir constant on evapotranspiration is selected since it allows a practical range for the integral in eq. (51) from zero (all net supply evaporated) to well above the actual total outflow (no evaporation). A trial-and-error investigation of the behavior of eq. (51) as a function of β_{el} is coupled with linear interpolation to determine β_{el}, given the values of the other parameters. Inspection of eqs. (12)-(28) and (47)-(49) indicates that USZM, LSZM, and e_p are functions of the following variables: $USZM_0$, $LSZM_0$, α_{pl}, β_{eu}, USZC, $(\alpha_{int} + \alpha_{dp})$, β_{el}, ns, and W. The same is generally true for the other analytical solutions corresponding to eqs. (12)-(28) and (47)-(49). (See appendix B.) Also, integration of eqs. (6)-(9) over a long period, Ω, for $\beta_{eg} = \beta_{es} = 0$ gives

$$\int_\Omega bo \; \delta t \cong \int_\Omega ns \; \delta t - \beta_{eu} \int_\Omega e_p \; USZM \; bt - \beta_{el} \int_\Omega e_p \; LSZM \; bt \tag{52}$$

Thus, only the sum of α_{int} and α_{dp} determines e_p, USZM, LSZM, and $\int_\Omega$ bo bt, regardless of the values of α_{int} and α_{dp}. Of course, the individual values of α_{int} and α_{dp} affect the time distribution of basin outflow since they fix the proportion of outflow from the lower soil zone that enters surface storage directly and that which passes through the groundwater zone first. Thus, the value of β_{el} determined by consideration of the boundary condition of eq. (51) is valid for any combination of α_{int} and α_{dp} values such that their sum is the same. Actually, eq. (52) is approximate, with the approximation improving as Ω becomes large. Therefore, the degree of insensitivity of β_{el} to α_{dp} and α_{int} depends upon the length of the data set used in the calibration. Finally, inspection of the behavior of the sum-of-squared errors of the model basin outflow, as compared to the actual outflow, Σ (q -bo)^2, indicates that its variation with α_{dp} (where $\alpha_{int} + \alpha_{dp}$ = constant) is closely parabolic. An interval-halving technique for determining α_{dp} that minimizes Σ (q - bo)^2 as a function of other parameters can be programmed to make the determination of α_{dp} automatic.

There are then only eight parameters remaining to be determined in an application of the model: a_s, T_b, K, α_{per}, ($\alpha_{int} + \alpha_{dp}$), α_{gw}, α_{sf}, and β_{eu}. Experience with the model indicates that, in a minimization of the root mean square error of basin outflows, values of some of the parameters are not greatly sensitive to values of the others. Parameters a_s, T_b, K, α_{gw}, and α_{sf} are not particularly sensitive to each other. That is, the value of one of these parameters, which gives the minimum sum-of-squared errors as a function of these other parameters, does not change much as these other parameters change. Independent optimization over each of these parameters can replace the more costly optimization over all of these parameters. The remaining parameters, α_{per}, β_{eu}, and ($\alpha_{int} + \alpha_{dp}$), are interdependent and are dependent upon the first set; they must be determined in a joint optimization. These observations are combined in a systematic parameter-search to minimize the sum-of-squared errors summarized in fig. 4. The schematic of fig. 4 is used herein for parameter determination, and it is implemented in the computer program of appendix C.

A gradient-search approach would require the determination of the derivative of Σ (Q - b_o)^2 with respect to each parameter. Since these derivatives are not analytically tractable in a practical sense (there are too many variations and combinations of the analytical solutions for all days of a simulation), numerical determinations of these derivatives would be required. The implicit assumption in cost-effective numerical determinations is that each derivative is independent of changes in other parameters; i.e., to include the effects of changes in all parameters simultaneously would require excessive computations. Thus, a numerical gradient-search procedure could replace the determination of a_s, T_b, K, α_{gw}, and α_{sf} in fig. 4, but could not be used for all of the parameter determinations.

7. APPLICATION

To compare the GLERL model with the other models, the model calibration used the same data base used in the previous SSARR and NWSH model applications for the Genesee River Basin. Since there are regulated reservoirs and

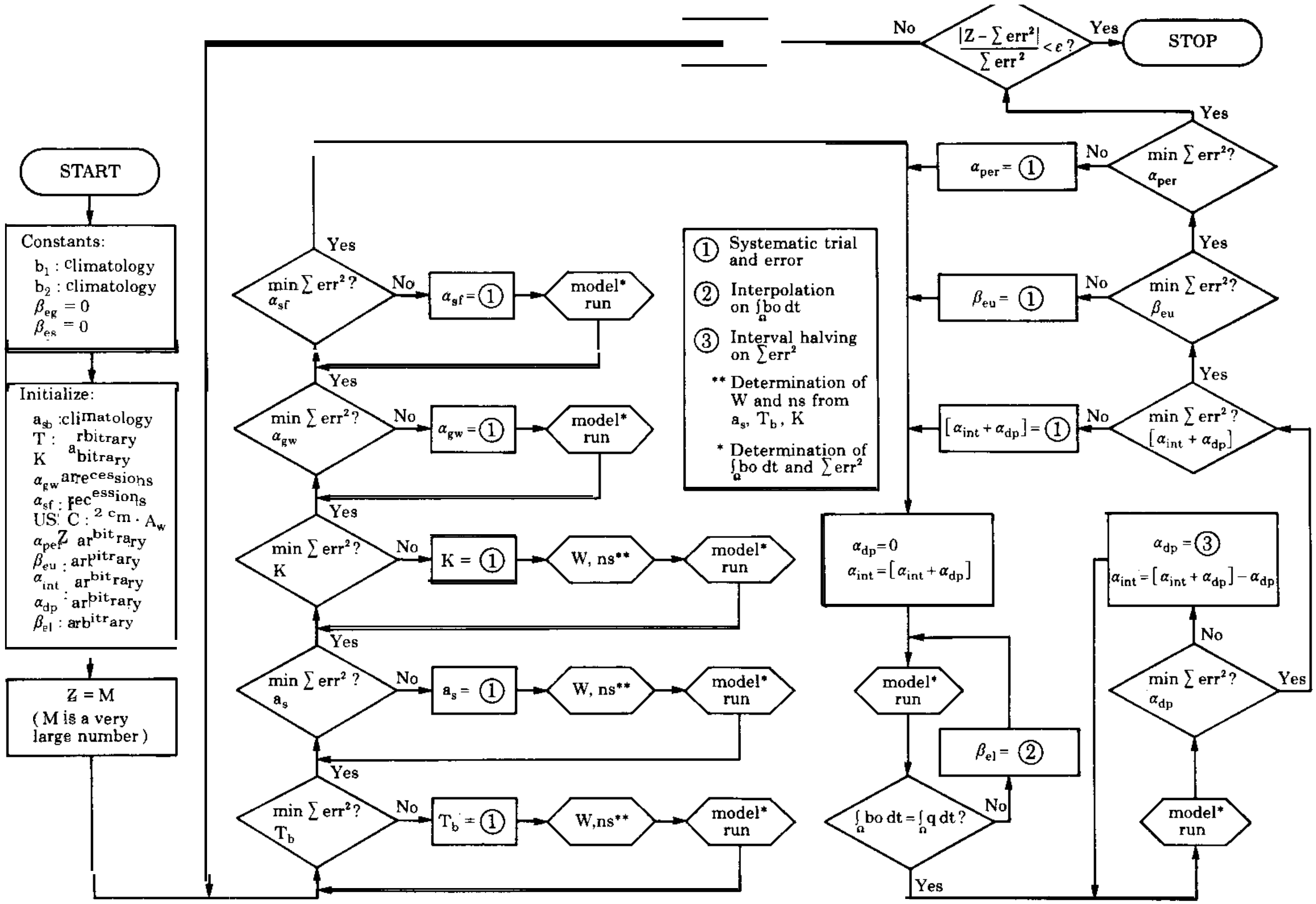

FIGURE 4.—*Parameter determination procedure.*

interbasin flows (New York State Barge Canal) in the lower part of the basin, and since the regulations were not programmed into the earlier models, the upstream part of the basin above Portageville was considered in the earlier applications and that portion is considered here. The Genesee River at Portageville drains 2,541 km^2 of western New York and Pennsylvania. There are 11 meteorological stations whose Theissen polygons intersect this area; 10 record daily precipitation and 7 record daily minimum and maximum air temperatures. (See fig. 5.) The basin has a mean annual air temperature of 8°C and receives an average annual precipitation of about 82 cm distributed rather evenly throughout the year in a fairly stable areal distribution. Snowfall and snowmelt occur throughout the winter season. Pertinent hydrological information is available elsewhere (U.S.C.O.E., 1969; G.L.B.C., 1976). Climatologic data are available from the National Climatic Center and basin outflow data at Portageville are available from the U.S. Geological Survey. The period of study covers water years 1957 through 1972, in agreement with the past applications. Summary statistics are available in table 1.

The GLERL model was applied by using the calibration procedure outlined in fig. 4. It required about 2 man-days of interactive computing in FORTRAN IV on the CDC Cyber 750 computer to determine the parameter values in table 1 after an input file was prepared for Theissen-weighted average daily precipitation and temperature. (See appendices C, D, E, and F.) Simulation speed is good; the model requires about 22K words of storage and uses 0.017 s per year of simulation (including auxiliary computations related to the determination of the "goodness-of-fit"). The value of ε in fig. 4 was set initially to 0.001 to enable a rough determination of all parameters. After this initial determination, ε was set to 0.00001, which enabled the determination of model parameters to about two significant digits. (See table 1.) Although net supply computations use a daily time interval, all mass balance computations use a 30-d computation interval. That is, the model averages net supply, ns, and evapotranspiration (potential and actual), W, over 30-d periods prior to calculations of the intrabasin flows identified in fig. 1. The final parameter set, identified in table 1, achieved a 30-d flow correlation of 0.92 with a root mean square error on 30-d basin outflows of $1.01 \cdot 10^{15}$ m^3, which is 1.25 cm over the watershed area. (See table 2.) This is equivalent to an explained variance of 0.85. The 360-d correlation is also 0.92, with a root mean square error of 1.30 cm. (See table 2.)

The optimum parameter fit resulted in a very large linear reservoir coefficient for surface storage, α_{sf}; this is equivalent to no storage effects on the surface. Thus, this model fit is equivalent to no surface storage "tank" in fig. 1. Removal of the surface storage tank would simplify the model and its calibration. This is suggested for further applications that use a 30-d computation interval. However, experiments with the 1-d computation interval for the mass balance indicate that the surface zone tank cannot be removed. For the Genesee River at Portageville, the linear reservoir coefficient, α_{sf}, is between 0.1 and 0.2 for the daily computation interval. Surface storage effects thus are important for computation of daily flows, but are not significant for 30-d flows.

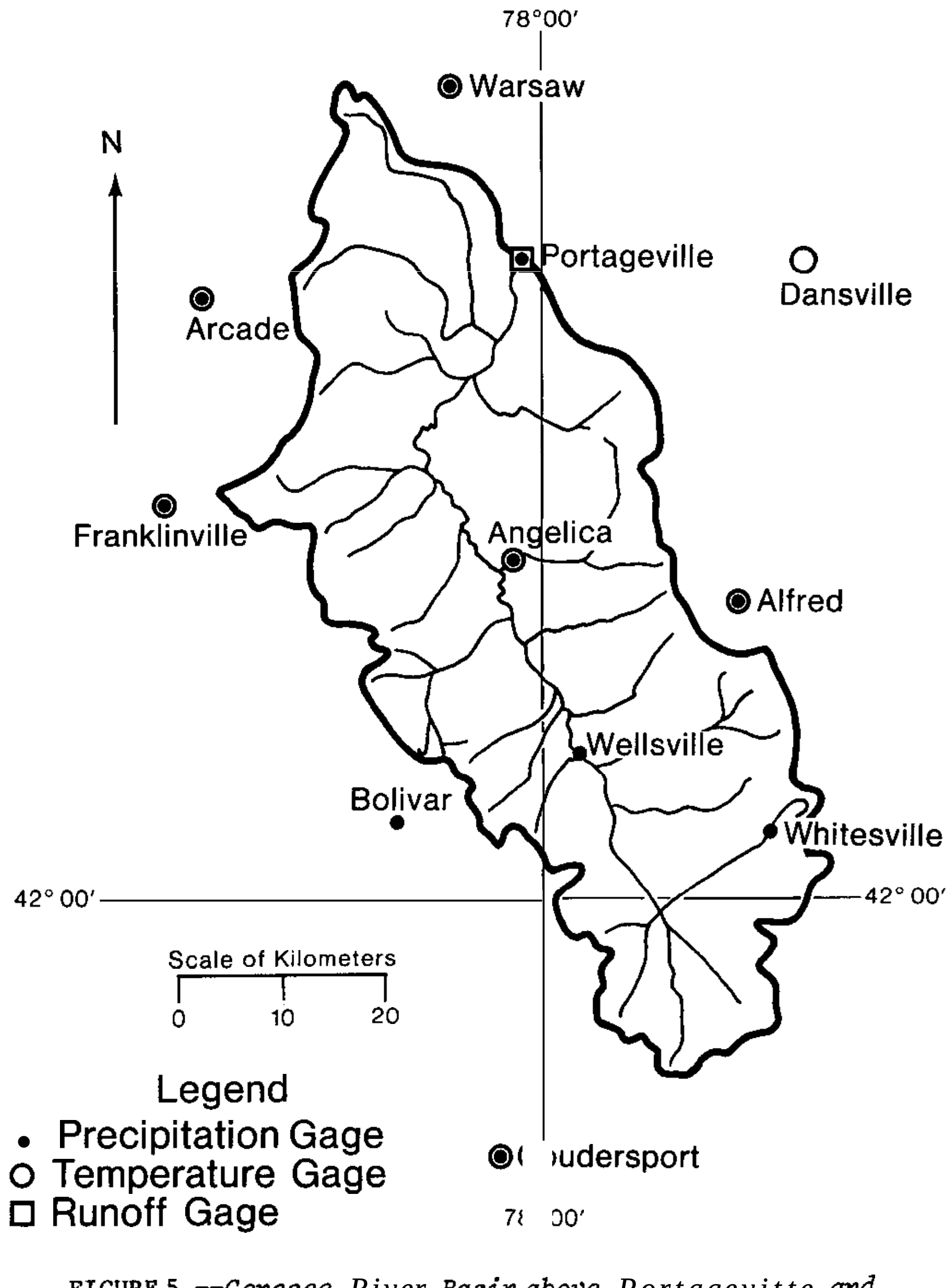

FIGURE 5.--*Genesee River Basin above Portageville and meteorological stations.*

TABLE 1.--*Summary Statistics*

Area	2,541,000,000 m^2	
Initialization period	June 20, 1956-September 30, 1957 (468 d)	
Calibration period	October 1, 1957-September 30, 1972 (5,479 d)	
Daily averages		
Precipitation	5,960,000 m^3	(0.23 cm)
Flow	2,830,000 m^3	(0.11 cm)
Evapotranspiration	3,130,000 m^3	(0.12 cm)
Potential evapotranspiration	1,252,000 m^3	(0.05 cm)
Model parameters		
a	0.809	
T	3.0 °C	
K	$0.392 \cdot 10^{15}$ cal °C^{-1}	(0.03 cm °C^{-1})
USZC	50,820,000 m^3	(2.00 cm)
α_{per}	0.27 d^{-1}	
β_{eu}	0.00000116 m^{-3}	
α_{int}	0.0000060 d^{-1}	
α_{dp}	0.049 d^{-1}	
β_{el}	0.000000083 m^{-3}	
α_{gw}	0.049 d^{-1}	
β_{eg}	0	
α_{sf}	$0.1 \cdot 10^{99}$ d^{-1}	
β_{es}	0	
Model averages		
Flow	84,700,000 m^3 (30 d)$^{-1}$	[3.33 cm (30 d)$^{-1}$]
Evapotranspiration	93,800,000 m^3 (30 d)$^{-1}$	[3.69 cm (30 d)$^{-1}$]
USZM	7,890,000 m^3	(0.31 cm)
LSZM	34,200,000 m^3	(1.35 cm)
GZM	34,300,000 m^3	(1.35 cm)
SS	$0.285 \cdot 10^{-91}$ m^3	(0.00 cm)

TABLE 2.--*Model Comparison*

	Model	
	GLERL	SSARR/NWS
Data base		
Daily precipitation	6/20/56-9/30/72	10/1/56-9/30/72
Daily air temperatures	6/20/56-9/30/72	10/1/56-9/30/72
Daily basin outflow	10/1/57-9/30/72	10/1/56-9/30/72
Solar insolation	climatic summary over the annual cycle required	
Daily pan evaporation	none	estimated over the annual cycle
Area-elevation curve	none	required
Calibration		
Number of parameters	10*	21 minimum (SSARR) 37 (NWS)
Initial values	arbitrary	required
Data adjustment	none	Theissen weights adjusted for improvement
Computation time interval	30 days	6 hours
Evaluation		
Excluded data during poor simulation	none	3/63, 7/72, 8/72, and 9/27
Root mean square error		
Monthly	1.25 cm (0.39**)	SSARR: 1.26 cm (0.40**) NWS: 1.21 cm (0.38**)
Annual	1.30 cm (0.43**)	SSARR: 2.02 cm (0.66**) NWS: 3.50 cm (1.15**).

* Of the 15 required parameters, two are determined easily a priori, two are zero, and one is arbitrary.

**Expressed as a fraction of the standard deviation of monthly or annual basin outflows.

The NWSH model used previously (Potok, 1980) was developed by the Hydrologic Research Laboratory (1972) and supplemented for snowmelt (Anderson, 1973). This model uses a 6-h increment for internal computations and requires determination of 37 parameter values. The SSARR model was developed by the North Pacific Division, U.S. Corps of Engineers (1975). It uses a 1- to 24-h increment for internal computations and the results summarized here were achieved with a 6-h interval (Potok, 1980). It uses index curves that must be input in their entirety. In its simplest configuration, it requires 27 parameters if daily pan evaporation is unavailable (15 if pan evaporation is available), plus a minimum of 3 tables specifying the functional relationships between certain variables. If the minimum of a two-parameter equation is assumed for each of these relations, then the SSARR model requires determination of a minimum of 33 parameter values (21 if daily pan evaporation is available). Both models also require determination of initial amounts of water stored in the various zones within the watershed.

As used in the earlier studies, daily pan evaporation was estimated for both models from mean monthly temperatures with the Thornthwaite equation. The Theissen weights were varied (changing the input data) to effect a good fit. Furthermore, poor simulation results were obtained during 1963 and 1972; these were judged to result from poor data. These periods of data were then excluded from the SSARR and NWSH model evaluations (Potok, 1980). A comparison of the GLERL, SSARR, and NWSH models is summarized in table 2.

The SSARR and NWSH models agreeed with their altered data sets, as just outlined, which are comparable to that used in the GLERL model for monthly flows. However, the agreement on an annual basis is much poorer, as indicated in table 2. The GLERL model requires fewer types of data, fewer parameter determinations, and arbitrary initial values. It uses a computation interval 120 times as large as the SSARR and NWSH models, which means 1/120 as many mass balance determinations. Typical results of the GLERL model are presented for 6 years in fig. 6. This period contains the worst fit (1962) of the entire evaluation and does not depict the best fit (1972) where the peak 30-day flow of record (483,000,000 m^3) was modeled with 3.3 percent relative error (499,000,000 m^3). Inspection of the 30-d precipitation totals in fig. 6 reveals the evapotranspiration capability of this model. During the late summer and fall of each year, basin outflow reaches the annual minimum, even though precipitation is fairly uniform throughout the year. The ability of the model to estimate the proper evapotranspiration during these low flow periods suggests that the climatic concepts of eqs. (47) and (50) are good.

8. SUMMARY

The model has several advantages in that it is an accurate, fast model with relatively simple calibration and data requirements for large watersheds. The unimportance of surface routing for sufficiently small basins at a 30-d computation interval will enable simpler calibration in the future. It is a conceptual model with good physical interpretations. Since soil moisture and snowpack storage are identified, the model has potential for

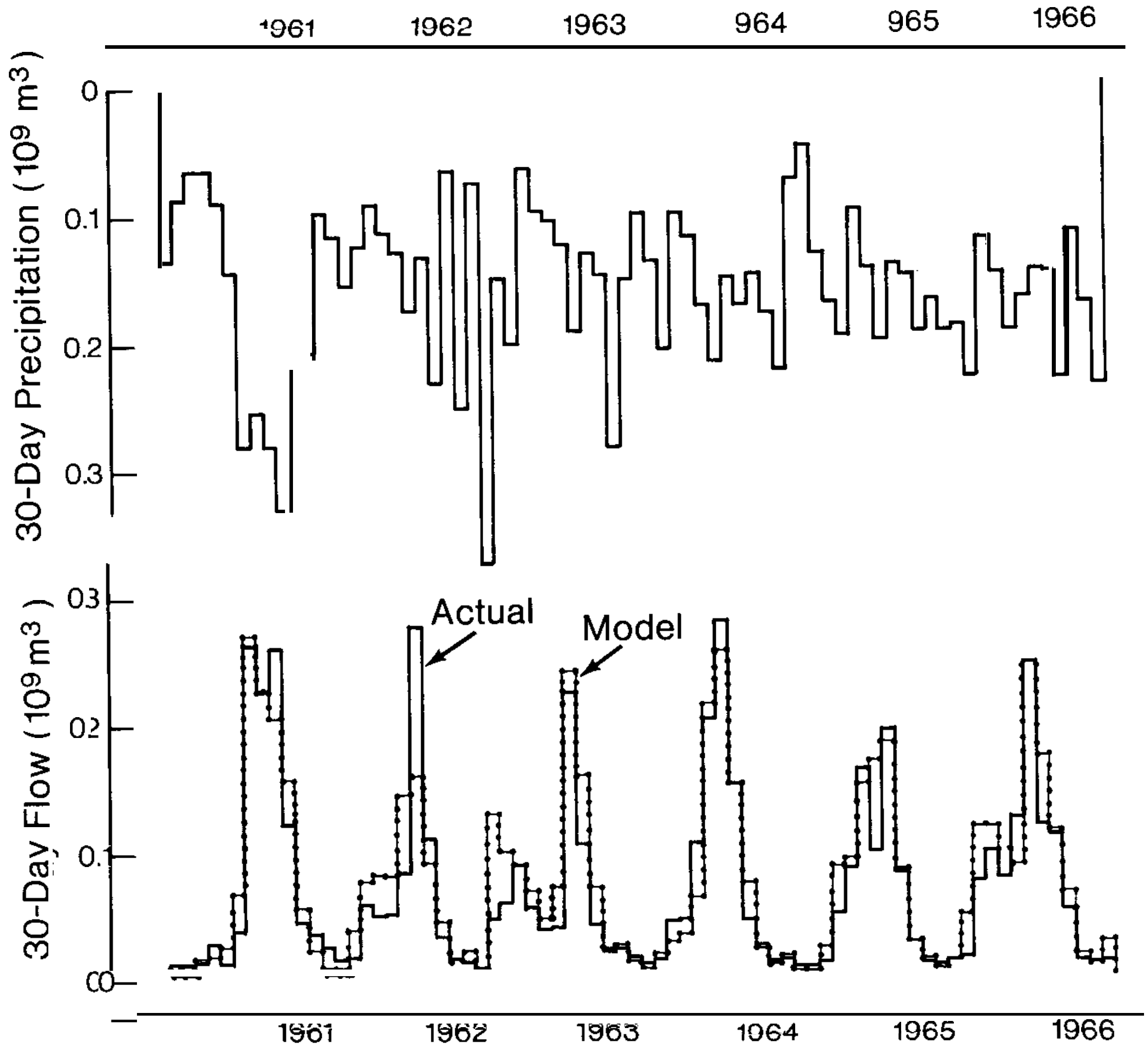

FIGURE 6.- *GLERL model fit to Genesee River at Portageville.*

use in predictive studies. Coupled with meteorological forecasts, the model should provide short-term forecasting abilities. Since the model is fast and economical, it may be used in operational hydrology studies where simulation for a large number of simple input time series are required. The calibration procedure will be improved through use of numerical gradient-search procedures to enable simple model use by engineers. The model now is to be applied to 20 large basins around Lake Ontario and the outputs combined to represent basin outflow to the lake. The parameter set obtained from one basin will provide initial values for the next basin to minimize calibration expense. Finally, the GLERL models will be incorporated into the Great Lakes routing models for use in forecasting and simulation of lake levels.

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Appendix A.—SYMBOLS

A_s albedo of the snow surface

A_p area of wetted contributing watershed portion (m^2)

A_w area of the watershed (m^2)

b_o basin outflow rate given by the model ($m^3\ d^{-1}$)

b_1 empirical constant for determining effects of cloud cover

b_2 empirical constant for determining effects of cloud cover

B sum of linear reservoir constants on USZM (d^{-1})

BO d-day basin outflow volume (m^3)

d computation interval in mass balance (d)

D sum of linear reservoir constants on LSZM (d^{-1})

DP d-day deep percolation volume (m^3)

e evaporation or evapotranspiration rate ($m^3\ d^{-1}$)

e_p potential evaporation or evapotranspiration rate ($m^3\ d^{-1}$)

E_g d-day groundwater zone evapotranspiration volume (m^3)

E_ℓ d-day lower soil zone evapotranspiration volume (m^3)

E_s d-day surface storage evaporation volume (m^3)

E_u d-day upper soil zone evapotranspiration volume (m^3)

f(t) sum of time-dependent inflows into storage S ($m^3\ d^{-1}$)

g outflow rate from a storage ($m^3\ d^{-1}$)

GW d-day groundwater volume (m^3)

GZM volume of water in groundwater zone (m^3); may be subscripted with time

H sum of linear reservoir constants on GZM (d^{-1})

i infiltration rate ($m^3\ d^{-1}$)

I d-day infiltration volume (m^3)

IF d-day interflow volume (m^3)

K proportionality constant for evapotranspiration energy (cal $°C^{-1}$)

LSZM volume of water in lower soil zone (m^3); may be subscripted with time

LSZM d-day average water volume in lower soil zone (m^3)

m snowmelt rate ($m^3 \ d^{-1}$)

ns net supply rate ($m^3 \ d^{-1}$)

NS d-day net supply volume (m^3)

p precipitation rate ($m^3 \ d^{-1}$)

P sum of linear reservoir constants on SS (d^{-1})

PE d-day potential evapotranspiration volume equivalent (m^3)

PL d-day percolation volume (m^3)

q actual basin outflow rate ($m^3 \ d^{-1}$)

r surface runoff rate ($m^3 \ d^{-1}$)

rr solar insolation at the watershed surface (cal d^{-1})

R d-day surface runoff volume (m^3)

S volume of water remaining in storage (m^3); may be subscripted with time

SNW water volume equivalent in snowpack (m^3); may be subscripted with time

SS volume of water in surface storage (m^3); may be subscripted with time

t time (d)

T mean daily air temperature (°C)

T_b base temperature for evapotranspiration energy (°C)

T_{max} maximum daily air temperature (°C)

T_{min} minimum daily air temperature (°C)

USZC capacity of the upper soil zone (m^3)

USZM volume of water in upper soil zone (m^3); may be subscripted with time

USZM d-day average water volume in upper soil zone (m^3)

W energy of actual and potential evapotranspiration for watershed (cal)

X ratio of hours of bright sunshine to maximum possible hours of bright sunshine

α linear reservoir constant (d^{-1})

α_{dp} linear reservoir constant on LSZM for deep percolation (d^{-1})

α_{gw} linear reservoir constant on GZM for groundwater flow (d^{-1})

α_{int} linear reservoir constant on LSZM for interflow (d^{-1})

α_{per} linear reservoir constant on USZM for pecolation (d^{-1})

α_{sf} linear reservoir constant on SS for basin outflow (d^{-1})

β partial linear reservoir constant (m^{-3})

β_{eg} partial linear reservoir constant on GZM for evapotranspiration (m^{-3})

β_{el} partial linear reservoir constant on LSZM for evapotranspiration (m^{-3})

β_{es} partial linear reservoir constant on SS for evaporation (m^{-3})

β_{eu} partial linear reservoir constant on USZM for evapotranspiration (m^{-3})

ε sum of squared error relative difference convergence precision

γ_m latent heat of fusion (cal g^{-1})

γ_v latent heat of vaporization (cal d^{-1})

ρ density of water (g m^{-3})

(Σ) sum of linear reservoir constants on storages (d^{-1})

τ extraterrestrial solar radiation (langleys d^{-1})

Ω set of all times within period of record

Appendix B.--ANALYTICAL SOLUTION FOR TANK CASCADE

In this appendix, eqs. (12)-(28) are derived from eqs. (6)-(9) and similar results for other parameter values are summarized herein.

By applying eqs. (10) and (11) to eq. (6),

$$USZM_t = e^{-Bt}\left[USZM_0 - \frac{ns}{B}\right] + \frac{ns}{B} \qquad , \; B \neq 0, \quad USZC \neq 0, \tag{A1}$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p. \tag{A2}$$

Note that the average upper soil zone moisture over the day is given from eq. (A1) as

$$\overline{USZM} = \frac{1}{d}\int_0^d USZM_t \, \delta t$$

$$= \frac{USZM_0 - \frac{ns}{B}}{Bd}\left(1 - e^{-Bd}\right) + \frac{ns}{B}. \tag{48}$$

Percolation is then given as

$$pl_t = \alpha_{pl}\, USZM_t = A\, e^{-Bt} + C, \tag{A3}$$

where

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \tag{A4}$$

$$C = \alpha_{pl} \frac{ns}{B}. \tag{A5}$$

By applying eqs. (10) and (11) to eq. (7),

$$LSZM_t = e^{-Dt} [LSZM_0 + \int_0^t pl_u \; e^{Du} \; \delta u], \tag{A6}$$

where

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} \; e_p \tag{A7}$$

and for $D \neq B$ and $D \neq 0$,

$$\int_0^t pl_u \; e^{Du} \, 6'' = \frac{A}{D-B} [e^{(D-B)t} - 1] + \frac{C}{D} [e^{Dt} - 1]. \tag{A8}$$

Note that the average lower soil zone moisture over the day is given from eqs. (A6), (A7), and (A8) as

$$\overline{LSZM} = \frac{1}{d} \int_0^d LSZM_t \; \delta t$$

$$= \frac{LSZM_0 - \frac{A}{D-B} - \frac{C}{D}}{Dd} \left(1 - e^{-Dd}\right) + \frac{\frac{A}{D-B}}{Bd} \left(1 - e^{-Bd}\right) + \frac{C}{D} \quad , D \neq B \tag{49}$$

$$= \frac{LSZM_0 - \frac{C}{D}}{Dd} \left(1 - e^{-Dd}\right) + \frac{A}{D^2 d} \left[1 - (Dd + 1)\, e^{-Dd}\right] + \frac{C}{D} \quad , D = B.$$

By combining eqs. (A6) and (A8), deep percolation is given as:

$$dp_t = \alpha_{dp}\, LSZM_t = E\, e^{-Dt} + F\, e^{-Bt} + G, \tag{A9}$$

where

$$E = \alpha_{dp} \left[LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right] \tag{A10}$$

$$F = \alpha_{dp} \frac{A}{D-B} \tag{A11}$$

$$G = \alpha_{dp} \frac{C}{D} \tag{A12}$$

By applying eqs. (10) and (11) to eq. (8),

$$GZM_t = e^{-Ht} \left[GZM_0 + \int_0^t dp_u\, e^{Hu}\, \delta u\right], \tag{A13}$$

where

$$H = \alpha_{gw} + \beta_{eg}\, e_p \tag{A14}$$

and for $H \neq D$, $H \neq B$, and $H \neq 0$,

$$\int_0^t dp_u \; e^{Hu} \; \delta u = \frac{E}{H-D} \left[e^{(H-D)t} - 1\right] + \frac{F}{H-B} \left[e^{(H-B)t} - 1\right] + \frac{G}{H} \left[e^{Ht} - 1\right]. \qquad \text{(A15)}$$

Inflow to the surface storage is given as the sum of net supply (minus infiltration), interflow, and groundwater flow and from eqs. (A3), (A9), (A13), and (A15); this is

$$in_t = \frac{ns}{USZC} \, USZM_t + \alpha_{int} \, LSZM_t + \alpha_{gw} \, GZM_t$$

$$= \frac{ns}{USZC} \frac{1}{\alpha_{pl}} \, pl_t + \frac{\alpha_{int}}{\alpha_{dp}} \, dp_t + \alpha_{gw} \, GZM_t$$

$$= L \, e^{-Ht} + M \, e^{-Dt} + N \, e^{-Bt} + O \qquad , \alpha_{pl} \neq 0, \; \alpha_{dp} \neq 0, \qquad \text{(A16)}$$

where

$$L = \alpha_{gw} \left[GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right] \qquad \text{(A17)}$$

$$M = \alpha_{gw} \frac{E}{H-D} + \alpha_{if} \frac{E}{\alpha_{dp}} \qquad \text{(A18)}$$

$$N = \alpha_{gw} \frac{F}{H-B} + \alpha_{if} \frac{F}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}} \qquad \text{(A19)}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{if} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad \text{(A20)}$$

By applying eqs. (10) and (11) to eq. (9),

$$SS_t = e^{-Pt} \left[SS_0 + \int_0^t in_u \, e^{Pu} \, \delta u\right], \tag{A21}$$

where

$$P = \alpha_{sf} + \beta_{es} \, e_p \tag{A22}$$

and for $P \neq H$, $P \neq D$, $P \neq B$, and $P \neq 0$,

$$\int_0^t in_u \, e^{Pu} \, \delta u = \frac{L}{P-H} \left[e^{(P-H)t} - 1\right] + \frac{M}{P-D} \left[e^{(P-D)t} - 1\right] + \frac{N}{P-B} \left[e^{(P-B)t} - 1\right]$$

$$+ \frac{O}{P} \left[e^{Pt} - 1\right]. \tag{A23}$$

Finally, the first four equations on the following page are obtained by taking $t = d$ in eq. (A1), eqs. (A6) and (A8), eqs. (A13) and (A15), and eqs. (A21) and (A23), respectively. The solutions for other combinations of non-zero values of B, D, H, and P are summarized on the following pages; the first 15 solutions (pages) are for $\alpha_{dp} \neq 0$ and the second 15 are for $\alpha_{dp} = 0$. Each solution set is substituted in place of eqs. (12)-(28) in the text for appropriate values of B, D, H, P, and α_{dp}.

$D \neq B,\ H \neq D,\ H \neq B,\ P \neq H,\ P \neq D,\ P \neq B,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right) e^{-Hd} + \frac{E}{H-D} e^{-Dd} + \frac{F}{H-B} e^{-Bd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} - \frac{M}{P-D} - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H} e^{-Hd} + \frac{M}{P-D} e^{-Dd} + \frac{N}{P-B} e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p$$

$$E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B}$$

$$G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p$$

$$L = \alpha_{gw} \left(GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right)$$

$$M = \alpha_{gw} \frac{E}{H-D} + \alpha_{int} \frac{E}{\alpha_{dp}}$$

$$N = \alpha_{gw} \frac{F}{H-B} + \alpha_{int} \frac{F}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\, e_p$$

$D \neq B$, $H \neq D$, $H \neq B$, $P \neq H$, $P \neq D$, $P = B$, $\alpha_{dp} \neq 0$.

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right) e^{-Hd} + \frac{E}{H-D} e^{-Dd} + \frac{F}{H-B} e^{-Bd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} - \frac{M}{P-D} + Nd - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H} e^{-Hd} + \frac{M}{P-D} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B} \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right)$$

$$M = \alpha_{gw} \frac{E}{H-D} + \alpha_{int} \frac{E}{\alpha_{dp}} \qquad N = \alpha_{gw} \frac{F}{H-B} + \alpha_{int} \frac{F}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D \neq B$, $H \neq D$, $H \neq B$, $P \neq H$, $P = D$, $\alpha_{dp} \neq 0$.

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right) e^{-Hd} + \frac{E}{H-D} e^{-Dd} + \frac{F}{H-B} e^{-Bd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} + Md - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H} e^{-Hd} + \frac{N}{P-B} e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B} \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right)$$

$$M = \alpha_{gw} \frac{E}{H-D} + \alpha_{int} \frac{E}{\alpha_{dp}} \qquad N = \alpha_{gw} \frac{F}{H-B} + \alpha_{int} \frac{F}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D \neq B,\ H \neq D,\ H \neq B,\ P = H,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B}\, e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right) e^{-Hd} + \frac{E}{H-D}\, e^{-Dd} + \frac{F}{H-B}\, e^{-Bd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 + Ld - \frac{M}{P-D} - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{M}{P-D}\, e^{-Dd} + \frac{N}{P-B}\, e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p$$

$$E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B}$$

$$G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p$$

$$L = \alpha_{gw} \left(GZM_0 - \frac{E}{H-D} - \frac{F}{H-B} - \frac{G}{H}\right)$$

$$M = \alpha_{gw} \frac{E}{H-D} + \alpha_{int} \frac{E}{\alpha_{dp}}$$

$$N = \alpha_{gw} \frac{F}{H-B} + \alpha_{int} \frac{F}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\, e_p$$

$D \neq B,\ H \neq D,\ H = B,\ P \neq H,\ P \neq D,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} + Fd - \frac{G}{H}\right) e^{-Hd} + \frac{E}{H-D} e^{-Dd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} - \frac{M}{P-D} + \frac{N}{(P-H)^2} - \frac{O}{P}\right) e^{-Pd} + \left\{\frac{L}{P-H} + \frac{N}{(P-H)^2}\left[(P-H)d - 1\right]\right\} e^{-Hd}$$

$$+ \frac{M}{P-D} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B} \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{E}{H-D} - \frac{G}{H}\right) + \alpha_{int} \frac{F}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$M = \alpha_{gw} \frac{E}{H-D} + \alpha_{int} \frac{E}{\alpha_{dp}} \qquad N = \alpha_{gw} F$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D \neq B$, $H \neq D$, $H = B$, $P \neq H$, $P = D$, $\alpha_{dp} \neq 0$.

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - Fd - \frac{G}{H}\right) e^{-Hd} + \frac{E}{H-D} e^{-Dd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} + Md + \frac{N}{(P-H)^2} - \frac{O}{P}\right) e^{-Pd} + \left\{\frac{L}{P-H} + \frac{N}{(P-H)^2}\left[(P-H)d - 1\right]\right\} e^{-Hd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl}\left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl}\frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = \alpha_{dp}\left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp}\frac{A}{D-B} \qquad G = \alpha_{dp}\frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = \alpha_{gw}\left(GZM_0 - \frac{E}{H-D} - \frac{G}{H}\right) + \alpha_{int}\frac{F}{\alpha dp} + \frac{ns}{USZC}\frac{A}{\alpha}$$

$$M = \alpha_{gw}\frac{E}{H-D} + \alpha_{int}\frac{E}{\alpha_{dp}} \qquad N = \alpha_{gw}\; F$$

$$O = \alpha_{gw}\frac{G}{H} + \alpha_{int}\frac{G}{\alpha_{dp}} + \frac{ns}{USZC}\frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D \neq B,\ H \neq D,\ H = B,\ P = H,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - Fd - \frac{G}{H}\right) e^{-Hd} + \frac{E}{H-D} e^{-Dd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 + Ld - \frac{M}{(P-D)} + \frac{N}{2} d^2 - \frac{O}{P}\right) e^{-Pd} + \frac{M}{P-D} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B} \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{E}{H-D} - \frac{G}{H}\right) + \alpha_{int} \frac{F}{\alpha dp} + \frac{ns}{USZC} \frac{A}{\alpha}$$

$$M = \alpha_{gw} \frac{E}{H-D} + \alpha_{int} \frac{E}{\alpha_{dp}} \qquad N = \alpha_{gw}\ F$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\ e_p$$

$D \neq B,\ H = D,\ P \neq H,\ P \neq B,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 + Ed - \frac{F}{H-B} - \frac{G}{H}\right) e^{-Hd} + \frac{F}{H-B} e^{-Bd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} + \frac{M}{(P-H)^2} - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \left\{\frac{L}{P-H} + \frac{M}{(P-H)^2} [(P-H)d - 1]\right\} e^{-Hd}$$

$$+ \frac{N}{P-B} e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C - a_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B} \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{F}{H-B} - \frac{G}{H}\right) + \alpha_{int} \frac{E}{\alpha_{dp}}$$

$$M = \alpha_{gw}\ E \qquad N = \alpha_{gw} \frac{F}{H-B} + \alpha_{int} \frac{E}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\ e_p$$

$D \neq B$, $H = D$, $P \neq H$, $P = B$, $\alpha_{dp} \neq 0$.

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 + Ed - \frac{F}{H-B} - \frac{G}{H}\right) e^{-Hd} + \frac{F}{H-B} e^{-Bd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} + \frac{M}{(P-H)^2} + Nd - \frac{O}{P}\right) e^{-Pd} + \left\{\frac{L}{P-H} + \frac{M}{(P-H)^2}\left[(P-H)d - 1\right]\right\} e^{-Hd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu} e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B} \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg} e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{F}{H-B} - \frac{G}{H}\right) + \alpha_{int} \frac{E}{\alpha_{dp}}$$

$$M = \alpha_{gw} E \qquad N = \alpha_{gw} \frac{F}{H-B} + a_{int} \frac{E}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{dp}}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es} e_p$$

$D \neq B,\ H = D,\ P = H,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 + Ed - \frac{F}{H-B} - \frac{G}{H}\right) e^{-Hd} + \frac{F}{H-B} e^{-Bd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 + Ld + \frac{M}{2} d^2 - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{N}{P-B} e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu} e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right)$$

$$F = \alpha_{dp} \frac{A}{D-B} \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg} e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{F}{H-B} - \frac{G}{H}\right) + \alpha_{int} \frac{E}{\alpha_{dp}}$$

$$M = \alpha_{gw} E \qquad N = \alpha_{gw} \frac{F}{H-B} + \alpha_{int} \frac{E}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{dp}}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es} e_p$$

$D = B,\ H \neq D,\ P \neq H,\ P \neq D,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - \frac{F}{(H-B)^2} - \frac{G}{H}\right) e^{-Hd} + \left\{\frac{E}{H-D} + \frac{F}{(H-D)^2}\left[(H-D)d-1\right]\right\} e^{-Dd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} - \frac{M}{P-D} + \frac{N}{(P-D)^2} - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H}\, e^{-Hd} + \left\{\frac{M}{P-D} + \frac{N}{(P-D)^2}\left[(P-D)d - 1\right]\right\} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl}\left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl}\frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = \alpha_{dp}\left(LSZM_0 - \frac{C}{D}\right)$$

$$F = \alpha_{dp}\, A \qquad G = \alpha_{dp}\frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = \alpha_{gw}\left(GZM_0 - \frac{E}{H-D} + \frac{F}{(H-D)^2} - \frac{G}{H}\right)$$

$$M = \alpha_{gw}\left(\frac{E}{H-D} - \frac{F}{(H-D)^2}\right) + \alpha_{int}\frac{E}{\alpha_{dp}} + \frac{ns}{USZC}\frac{A}{\alpha_{pl}} \qquad N = \alpha_{gw}\frac{F}{H-D} + \alpha_{int}\frac{F}{\alpha_{dp}}$$

$$O = \alpha_{gw}\frac{G}{H} + \alpha_{int}\frac{G}{\alpha_{dp}} + \frac{ns}{USZC}\frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D = B,\ H \neq D,\ P \neq H,\ P = D,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - \frac{F}{(H-B)^2} - \frac{G}{H}\right) e^{-Hd} + \left\{\frac{E}{H-D} + \frac{F}{(H-D)^2}[(H-D)d-1]\right\} \frac{F}{H-B} e^{-Dd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} + Md + \frac{N}{2} d^2 - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H} e^{-Hd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu} e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{C}{D}\right)$$

$$F = \alpha_{dp} A \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg} e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{E}{H-D} + \frac{F}{(H-D)^2} - \frac{G}{H}\right)$$

$$M = \alpha_{gw} \left(\frac{E}{H-D} - \frac{F}{(H-D)^2}\right) + \alpha_{int} \frac{E}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}} \qquad N = \alpha_{gw} \frac{F}{H-D} + \alpha_{int} \frac{F}{\alpha_{dp}}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es} e_p$$

$D = B,\ H \neq D,\ P = H,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 - \frac{E}{H-D} - \frac{F}{(H-B)^2} - \frac{G}{H}\right) e^{-Hd} + \left\{\frac{E}{H-D} + \frac{F}{(H-D)^2}\left[(H-D)d-1\right]\right\} \frac{F}{H-B} e^{-Dd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 + Ld - \frac{M}{P-D} + \frac{N}{(P-D)^2} - \frac{O}{P}\right) e^{-Pd} + \left\{\frac{M}{P-D} + \frac{N}{(P-D)^2}\left[(P-D)d - 1\right]\right\} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl}\left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl}\frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = \alpha_{dp}\left(LSZM_0 - \frac{C}{D}\right)$$

$$F = \alpha_{dp}\, A \qquad G = \alpha_{dp}\frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = \alpha_{gw}\left(GZM_0 - \frac{E}{H-D} + \frac{F}{(H-D)^2} - \frac{G}{H}\right)$$

$$M = \alpha_{gw}\left(\frac{E}{H-D} - \frac{F}{(H-D)^2}\right) + \alpha_{int}\frac{E}{\alpha_{dp}} + \frac{ns}{USZC}\frac{A}{\alpha_{pl}} \qquad N = \alpha_{gw}\frac{F}{H-D} + \alpha_{int}\frac{F}{\alpha_{dp}}$$

$$O = \alpha_{gw}\frac{G}{H} + \alpha_{int}\frac{G}{\alpha_{dp}} + \frac{ns}{USZC}\frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D = B$, $H = D$, $P \neq H$, $\alpha_{dp} \neq 0$.

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 + Ed + \frac{F}{2} d^2 - \frac{G}{H}\right) e^{-Hd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} + \frac{M}{(P-H)^2} - 2 \frac{N}{(P-H)^3} - \frac{O}{P}\right) e^{-Pd}$$

$$+ \left\{\frac{L}{P-H} + \frac{M}{(P-H)^2} [(P-H)d - 1] + \frac{N}{P-H} d^2 - 2 \frac{N}{(P-H)^3} [(P-H)d - 1] \right\} e^{-Hd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu} e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{C}{D}\right)$$

$$F = \alpha_{dp} A \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg} e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{G}{H}\right) + \alpha_{int} \frac{E}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$M = \alpha_{gw} E + \alpha_{int} \frac{F}{\alpha_{dp}} \qquad N = \alpha_{gw} \frac{F}{2}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es} e_p$$

$D = B,\ H = D,\ P = H,\ \alpha_{dp} \neq 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = \left(GZM_0 + Ed + \frac{F}{2} d^2 - \frac{G}{H}\right) e^{-Hd} + \frac{G}{H}$$

$$SS_d = \left(SS_0 + Ld + \frac{M}{2} d^2 + \frac{N}{3} d^3 - \frac{O}{P}\right) e^{-Pd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = \alpha_{dp} \left(LSZM_0 - \frac{C}{D}\right)$$

$$F = \alpha_{dp}\, A \qquad G = \alpha_{dp} \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = \alpha_{gw} \left(GZM_0 - \frac{G}{H}\right) + \alpha_{int} \frac{E}{\alpha_{dp}} + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$M = \alpha_{gw}\, E + \alpha_{int} \frac{F}{\alpha_{dp}} \qquad N = \alpha_{gw} \frac{F}{2}$$

$$O = \alpha_{gw} \frac{G}{H} + \alpha_{int} \frac{G}{\alpha_{dp}} + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D \neq B,\ H \neq D,\ H \neq B,\ P \neq H,\ P \neq D,\ P \neq B,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0\, e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{M}{P-D} - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{M}{P-D} e^{-Dd} + \frac{N}{P-B} e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B} \qquad G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = 0.$$

$$M = \alpha_{int}\, E \qquad N = \alpha_{int}\, F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{int}\, G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D \neq B,\ H \neq D,\ H \neq B,\ P \neq H,\ P \neq D,\ P = B,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0 \ e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{M}{P-D} + Nd - \frac{O}{P}\right) e^{-Pd} + \frac{M}{P-D} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu} \ e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} \ e_p$$

$$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B}$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg} \ e_p$$

$$L = 0.$$

$$M = \alpha_{int} \ E$$

$$N = \alpha_{int} \ F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{int} \ G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es} \ e_p$$

$D \neq B,\ H \neq D,\ H \neq B,\ P \neq H,\ P = D,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 + Md - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{N}{P-B} e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p$$

$$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B}$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p$$

$$L = 0.$$

$$M = \alpha_{int}\ E$$

$$N = \alpha_{int}\ F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\ e_p$$

$D \neq B,\ H \neq D,\ H \neq B,\ P = H,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{M}{P-D} - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{M}{P-D} e^{-Dd} + \frac{N}{P-B} e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p$$

$$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B}$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p$$

$$L = 0.$$

$$M = \alpha_{int}\ E$$

$$N = \alpha_{int}\ F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\ e_p$$

$D \neq B,\ H \neq D,\ H = B,\ P \neq H,\ P \neq D,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} - \frac{M}{P-D} - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H} e^{-Hd} + \frac{M}{P-D} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl}\left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl}\ \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p$$

$$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B}$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p$$

$$L = \alpha_{int}\ F + \frac{ns}{USZC}\ \frac{A}{\alpha_{pl}}$$

$$M = \alpha_{int}\ E$$

$$N = 0.$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC}\ \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\ e_p$$

$D \neq B$, $H \neq D$, $H = B$, $P \neq H$, $P = D$, $\alpha_{dp} = 0$.

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0 \, e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} - Md - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H} e^{-Hd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu} \, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} \, e_p$$

$$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B}$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg} \, e_p$$

$$L = \alpha_{int} \, F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$M = \alpha_{int} \, E$$

$$N = 0.$$

$$O = \alpha_{int} \, G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es} \, e_p$$

$D \neq B$, $H \neq D$, $H = B$, $P = H$, $\alpha_{dp} = 0$.

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0 \; e^{-Hd}$$

$$SS_d = \left(SS_0 + Ld - \frac{M}{P-D} - \frac{O}{P}\right) e^{-Pd} + \frac{M}{P-D} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu} \; e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el} \; e_p$$

$$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B}$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg} \; e_p$$

$$L = \alpha_{int} \; F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$M = \alpha_{int} \; E$$

$$N = 0.$$

$$O = \alpha_{int} \; G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es} \; e_p$$

$D \neq B,\ H = D,\ P \neq H,\ P \neq B,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B}\, e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0\, e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H}\, e^{-Hd} + \frac{N}{P-B}\, e^{-Bd} + \frac{O}{P},$$

where

$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$

$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$

$C = \alpha_{pl} \frac{ns}{B}$

$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p$

$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$

$F = \frac{A}{D-B}$

$G = \frac{C}{D}$

$H = \alpha_{gw} + \beta_{eg}\, e_p$

$L = \alpha_{int}\, E$

$M = 0.$

$N = \alpha_{int}\, F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$

$O = \alpha_{int}\, G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$

$P = \alpha_{sf} + \beta_{es}\, e_p$

$D \neq B,\ H = D,\ P \neq H,\ P = B,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} + Nd - \frac{O}{P}\right) e^{-Pd} + \frac{L}{P-H} e^{-Hd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl}\ \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl}\ \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p$$

$$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B}$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p$$

$$L = \alpha_{int}\ E$$

$$M = 0.$$

$$N = \alpha_{int}\ F + \frac{ns}{USZC}\ \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC}\ \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\ e_p$$

$D \neq B,\ H = D,\ P = H,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 - \frac{A}{D-B} - \frac{C}{D}\right) e^{-Dd} + \frac{A}{D-B} e^{-Bd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 + Ld - \frac{N}{P-B} - \frac{O}{P}\right) e^{-Pd} + \frac{N}{P-B} e^{-Bd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p$$

$$E = LSZM_0 - \frac{A}{D-B} - \frac{C}{D}$$

$$F = \frac{A}{D-B}$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p$$

$$L = \alpha_{int}\ E$$

$$M = 0.$$

$$N = \alpha_{int}\ F + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\ e_p$$

$D = B,\ H \neq D,\ P \neq H,\ P \neq D,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{M}{P-D} + \frac{N}{(P-D)^2} - \frac{O}{P}\right) e^{-Pd} + \left\{\frac{M}{P-D} + \frac{N}{(P-D)^2}\ [(P-D)d - 1]\right\} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl}\ \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl}\ \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p$$

$$E = LSZM_0 - \frac{C}{D}$$

$$F = A$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p$$

$$L = 0.$$

$$M = \alpha_{int}\ E + \frac{ns}{USZC}\ \frac{A}{\alpha_{pl}}$$

$$N = \alpha_{int}\ F$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC}\ \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\ e_p$$

$D = B,\ H \neq D,\ P \neq H,\ P = D,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 + Md + \frac{N}{2} d^2 - \frac{O}{P}\right) e^{-Pd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl}\ \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl}\ \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p$$

$$E = LSZM_0 - \frac{C}{D}$$

$$F = A$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p$$

$$L = 0.$$

$$M = \alpha_{int}\ E + \frac{ns}{USZC}\ \frac{A}{\alpha_{pl}}$$

$$N = \alpha_{int}\ F$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC}\ \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\ e_p$$

$D = B,\ H \neq D,\ P = H,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{M}{P-D} + \frac{N}{(P-D)^2} - \frac{O}{P}\right) e^{-Pd} + \left\{\frac{M}{P-D} + \frac{N}{(P-D)^2}\ [(P-D)d\ - 1]\right\} e^{-Dd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl}\ \left(USZM_0 - \frac{ns}{B}\right)$$

$$C = \alpha_{pl}\ \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p$$

$$E = LSZM_0 - \frac{C}{D}$$

$$F = A$$

$$G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p$$

$$L = 0.$$

$$M = \alpha_{int}\ E + \frac{ns}{USZC}\ \frac{A}{\alpha_{pl}}$$

$$N = \alpha_{int}\ F$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC}\ \frac{C}{\alpha_{pl}}$$

$$P = \alpha_{sf} + \beta_{es}\ e_p$$

$D = B$, $H = D$, $P \neq H$, $\alpha_{dp} = 0$.

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = GZM_0 \; e^{-Hd}$$

$$SS_d = \left(SS_0 - \frac{L}{P-H} + \frac{M}{(P-H)^2} - \frac{O}{P}\right) e^{-Pd} + \left\{\frac{L}{P-H} + \frac{M}{(P-H)^2}\,[(P-H)d - 1]\right\} e^{-Hd} + \frac{O}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\, e_p$$

$$A = \alpha_{pl} \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl} \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\, e_p \qquad E = LSZM_0 - \frac{C}{D}$$

$$F = A \qquad G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\, e_p \qquad L = \alpha_{int}\, E + \frac{ns}{USZC} \frac{A}{\alpha_{pl}}$$

$$M = \alpha_{int}\, F \qquad N = 0.$$

$$O = \alpha_{int}\, G + \frac{ns}{USZC} \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\, e_p$$

$D = B,\ H = D,\ P = H,\ \alpha_{dp} = 0.$

$$USZM_d = \left(USZM_0 - \frac{ns}{B}\right) e^{-Bd} + \frac{ns}{B}$$

$$LSZM_d = \left(LSZM_0 + Ad - \frac{C}{D}\right) e^{-Dd} + \frac{C}{D}$$

$$GZM_d = GZM_0\ e^{-Hd}$$

$$SS_d = \left(SS_0 + Ld + \frac{M}{2} d^2 - \frac{0}{P}\right) e^{-Pd} + \frac{0}{P},$$

where

$$B = \frac{ns}{USZC} + \alpha_{pl} + \beta_{eu}\ e_p$$

$$A = \alpha_{pl}\ \left(USZM_0 - \frac{ns}{B}\right) \qquad C = \alpha_{pl}\ \frac{ns}{B}$$

$$D = \alpha_{int} + \alpha_{dp} + \beta_{el}\ e_p \qquad E = LSZM_0 - \frac{C}{D}$$

$$F = A \qquad G = \frac{C}{D}$$

$$H = \alpha_{gw} + \beta_{eg}\ e_p \qquad L = \alpha_{int}\ E + \frac{ns}{USZC}\ \frac{A}{\alpha_{pl}}$$

$$M = \alpha_{int}\ F \qquad N = 0.$$

$$O = \alpha_{int}\ G + \frac{ns}{USZC}\ \frac{C}{\alpha_{pl}} \qquad P = \alpha_{sf} + \beta_{es}\ e_p$$

Appendix C.--FORTRAN PROGRAM FOR CALIBRATION

The FORTRAN program in this appendix may be used for calibration or simulation; its use is illustrated in appendices D, E, and F. The user must change lines 37, 48, 49, 50, and 51 to agree with his or her intended application. Line 37 defines the average mid-month cloudless day insolation (10 langleys/d) for January through December, respectively. Line 48 gives the watershed area (square meters); lines 49 and 50 define the beginning and the end of the data set portion to be used in calibration (Ω, to be contained within the input file); line 51 gives the number of days to be used in the mass balance computation period. The user may also change lines 42 and 43 if evaporation from the surface or evapotranspiration from the groundwater zone are considered to be important.

The program reads an input file called "ZDATA." A partial listing of such a file is given as appendix D; it contains the date, minimum daily temperature, maximum daily temperature, daily precipitation volume over the watershed, and daily basin outflow volume from the watershed for each day in the units noted. The first four lines are header information skipped over by the program. Missing data is denoted by "-9999."

The program is designed to be used interactively; a typical example of an interactive terminal session is given as appendix E. The program first prompts for entry of values of K, a_s, T_b, α_{gw}, and α_{sf}. These values are repeated after their entry and the operator is asked if they are correct. If not, the input query is repeated (as in the example). When correct values are entered, the program outputs summary statistics on the data set: calibration period and daily averages for the watershed of temperature (degrees Celsius), precipitation (cubic meters), basin outflow (cubic meters), W (cubic meters), net supply (cubic meters), evapotranspiration (cubic meters), and potential evapotranspiration (cubic meters). The sample mean and variance of basin outflow volumes over the computation interval are given next (30-d flow volumes are used in the example of appendix E). The program next prompts for entry of values of USZC, α_{per}, β_{eu}, and (α_{int} + α_{dp}). These values are repeated and the operator is asked if they are correct. If so, the program proceeds to find values for α_{int}, α_{dp}, and β_{el} that satisfy the constraint of eq. (51) and minimize the sum of squared errors on basin outflow. This is represented in appendix E by the long columns of figures. At this point, the computed values of α_{int} and β_{el} are given, followed by summary information on the fit. First, model averages over the computation interval (30-d averages in appendix E) are given for basin outflow and evapotranspiration and the goodness-of-fit is summarized by giving the sum of squared errors (between the model and the actual basin outflow volumes over the computation interval) and the explained variance. These four values are given again for a model variation not described heretofore. The variation consists of routing only surface runoff from the upper soil zone through the surface storage and then combining with interflow and groundwater flow in fig. 1. For the example in appendix E, these numbers are the same as for the original model since α_{sf} is very large (thereby functionally eliminating the surface storage zone tank in fig. 1). The next five values are the averages over the entire calibration period for surface storage, surface storage for the model variation described above, upper soil zone moisture, lower soil zone moisture, and groundwater moisture. The last four vaues in appendix E are the values of USZC, α_{per}, β_{eu}, and (α_{int} + α_{dp}), repeated for the operator's convenience for the next trial iteration. The operator is then asked if he or she wants another iteration; if the response is "yes" (Y), the operator is prompted for the next values of USZC, αper, βeu, and (α_{int} + α_{dp}) and program flow is similar to that before. If the operator responds "over" (O), then the initial prompt is repeated and program flow proceeds, as outlined above, from that point. If the operator responds "no" (N), then summary statistics are sent to a print file and the program is terminated.

Appendix F contains the partial print file resulting from the application exemplified by tables 1 and 2 and by the preceding appendices and it should be self-explanatory.

```
      PROGRAM WASSERS(ZDATA,TAPE5=ZDATA,INPUT,TAPE4=INPUT,OUTPUT,
     +TAPE6=OUTPUT,RESULT,TAPE7=RESULT)
      IMPLICIT REAL (A-H,J-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/FFF,NSS,SSS,EVAPS,DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
      DIMENSION R(14),INDPM(13)
      DIMENSION DATA(4,11109)
      DIMENSION IERR(6)
      DATA IERR/6*0/
      DATA INDPM/0,31,59,90,120,151,181,212,243,273,304,334,366/
C*****
C***** PROGRAM FOR INTERACTIVE INVESTIGATION OF MODEL - HONTHLY
C*****
C*****
C AREA    = WATERSHED AREA, SQ. M.
C FLOU    = ACTUAL BASIN OUTFLOU VOLUME, CUB. M.
C ID      = CALENDAR DAY OF THE YEAR
C IM      = CALENDAR MONTH OF 'THE YEAR
C INDPGOD= NUMBER OF DAYS PER GROUP OF DAYS, DAYS
C INODAYS- NUMBER OF DAYS TO BE CONSIDERED IN DATA SET, DAYS
c IY      = CALENDAR YEAR
C PRECIP = DAILY PRECIPITATION VOLUME (LIQUID EQUIVALENT). CUB. M.
C R       = AVERAGE MID-MONTH CLOUDLESS-DAY INSOLATION, LANGLEYS/DAY
C            (INPUT IN UNITS OF 10*LANGLEYS/DAY)
C RR      = DAILY SURFACE INSOLATION, CAL.
C SNU     = SNOUPACK VOLUME (LIQUID EQUIVALENT), CUB. M.
c TA      = AVERAGE DAILY AIR TEHYERATURE. DEG. C.
C TMAX    = MAXIMUM DAILY AIR TEMPERATURE, DEG. C.
C THIN    = MINIMUM DAILY AIR TEMPERATURE, DEG. C.
C*****
C****
C***** INPUT CONSTAN'TS
C*****
      DATA R/24.,34.,48.,63.,73.,71.,75.,65.,52.,38.,26.,20./
      CALL SYSTEMC(115,IERR)
      EPSILON=1.E-7
      DPSILON=1.E-200
      GPSILON=1.E-3
      ALPGEV=0.
      ALPSEV=0.
      R(14)=R(1)*10.
      DO 33 IXY=1,12
   33 R(14-IXY)=R(13-IXY)*10.
      R(1)=R(13)
      AREA = 2540778335.
      ISTART = 468
      INODAYS= 5947
      INDPGOD=30
      DAY=FLOAT(INDPGOD)
      IIST=ISTART/INDPGOD
      A1=-999.
```

```
      A2=-999.
      A3=-999.
      ALPLEV=.65E-07
  565 WRITE(6,564)
  564 FORMAT(55HCONSTANT, ALBEDS, TBASE, ALPGU,  ALPSF (5E13.6E2 FORMAT))
      READ(4,759) CONS,ALBEDS,TBASE,ALPGW,ALPSF
  759 FORMAT(E11.6E2,4E13.6E2)
      WRITE(6,559)CONS,ALBEDS,TBASE,ALPGW,ALPSF
  566 WRITE(6,561)
      READ(4,556) I
      IF(I.EQ.1HY) GOTO 567
      IF(I.NE.1HN) GOTO 566
      GOTO 565
  567 IF(CONS.EQ.A1.AND.ALBEDS.EQ.A2.AND.TBASE.EQ.A3)GOTO 554
      A1=CONS
      A2=ALBEDS
      A3=TBASE
      REWIND 5
      SNW=0.
      IKNTR=0
      TIME
      AVGTA = 0.
      AVGPR = 0.
      AVGF =  0.
      AVGHPLE= 0.
      AVGNS = 0.
      READ(5,1000)
      READ(5,1000)
      READ(5,1000)
      READ(5,1000)
 1000 FORMAT(3A10)
      READ(5,1010) ID,IM,IY,TMIN,TMAX,PRECIP,FLOW
      BACKSPACE 5
C*****
C***** DAILY LOOP - DATA PREPERATION (BEGINNING)
C*****
      DO 300 I=1,INODAYS
C*****
C*****         INPUT AND FILL IN DAILY DATA
C*****
      REABi5.1010) ID,IM,IY,NTMIN,NTMAX,NPRECIP,NFLOW
 1010 FORMAT(1X,I3,I3,I5,5X,2F10.2,2F20.0)
      IF(NTMIN.GT.NTMAX.OR.NTMIN.LT.-900..OR.NTMAX.LT.-900.) GOTO 920
      GOTO 921
  920 NTMIN=TMIN
      NTMAX=TMAX
  921 TMIN=NTMIN
      TMAX=NTMAX
      IF(NPRECIP.LT.-900.) NPRECIP=PRECIP
      IF(NFLOW.LT.-900.) NFLOW=FLOW
      PRECIP=NPRECIP
      FLOW=NFLOW
C*****
C*****         COMPUTE DAILY INSOLATION
```

```
C*****
      X=(TMAX-TMIN)/15.
      X=AMIN1(X,1.0)
      IF(ID.GT.15) GOT0 203
      IF(IM.EQ.1) GOT0 200
      II=INDPM(IM)-INDPM(IM-1)
      IF(II.NE.28) GOT0 201
      IF(INT((FLOAT(IY)+.5)/4.)*4.NE.IY) GOT0 201
      II-29
      GOT0 201
  200 II-31
  201 NDYS=FLOAT(II)
      NDY=NDYS-15.+FLOAT(ID)
      RR=(R(IM+1)-R(IM))/NDYS*NDY+R(IM)
      GOT0 204
  203 II=INDPM(IM+1)-INDPM(IM)
      IF(II.NE.28) GOT0 202
      IF(INT((FLOAT(IY)+.5)/4.)*4.NE.IY) GOT0 202
      II=29
  202 NDYS=FLOAT(II)
      NDY=FLOAT(ID)-15.
      RR=(R(IM+2)-R(IM+1))/NDYS*NDY+R(IM+1)
  204 RR=RR*(0.355+0.68*X)*10000.*AREA
C*****
C*****        HEAT BALANCE
C*****
      TA=(TMIN+TMAX)/2.
      x=1.
      IF(TA.LE.0.)GOTO 900
      HELT=0.
      IF(SNW.LT.1.)GOTO 901
      MELT=(RR*(1.-ALBEDS)+PRECIP*1000000.*TA)/79.7/1000000.
      IF(MELT.GT.SNW)MELT=SNW
      GOT0 Y04
  901 x-o.
  904 SNU=SNW-MELT
      NS=PRECIP+MELT
      GOTO 905
  900 IF(SNW.GT.1..OR.PRECIP.GT.1.)GOTO 903
      X=0.
  903 SNW=SNW+PRECIP
      NS=0.
  905 DATA(1,I)=NS
      DATA(2,I)=TA
      DATA(3,I)=FLOW
      DATA(4,I)=X
      IF(I.LE.ISTART)GOTO 300
      AVGTA=AVGTA+TA
      AVGPR=AVGPR+PRECIP
      AVGF=AVGF+FLOW
      AVGNS=AVGNS+NS
      IKNTR=IKNTR+1
  300 CONTINUE
C*****
```

```
C***** DAILY LOOP - DATA PREPARATION (END)
C*****
C*****
C***** SUMMARY INFORMATION
C*****
      FI=IKNTR
      AVGTA=AVGTA/FI
      AVGPR=AVGPR/FI
      AVGF=AVGF/FI
      AVGNS=AVGNS/FI
      AVGEVP=AVGNS-AVGF
      AVGHPLE=0.
      no 910 I=1,INODAYS
      HPLSE=(DATA(2,I)-TBASE)*CONS
      IF(HPLSE.LT.0..OR.DATA(4,I).GT..5)HPLSE=0.
      HPLSE=HPLSE/(596.-.52*DATA(2,I))/1000000.
      DATA(4,I)=HPLSE
      IF(I.LE.ISTART)GOTO 910
      AVGHPLE=AVGHPLE+HPLSE
  910 CONTINUE
      AVGHPLE=AVGHPLE/FI
      AVGEVPP=AVGHPLE-AVGEVP
      WRITE(6,550) ISTART,INODAYS
      URITEi6.559) AVGTA,AVGPR,AVGF,AVGHPLE
      WRITE(6,559) AVGNS,AVGEVP,AVGEVPP
  550 FORMAT(1X,8HFROM DAY,I6,7H TO DAY,I6,/)
C*****
C***** CONVERT TO GROUPS OF DAYS INPUTS
C*****
      VAR=0.
      MEAN=0.
      NS=0.
      HPLSE=0.
      FLOW=0.
      II=0
      III-0
      DO 400 I=1,INODAYS
      NS=NS+DATA i 1 , I)
      HPLSE=HPLSE+DATA(4,I)
      FLOW=FLOW+DATA(3,I)
      II=II+1
      IF(II.NE.INDPGOD)GOTO 400
      III=III+1
      DATA(1,III)=NS
      DATA(4,III)=HPLSE
      DATA(3,III)=FLOW
      IF(III.LE.IIST)GOTO 710
      VAR=VAR+FLOW**2
      MEAN=MEAN+FLOW
  710 NS=0.
      HPLSE=0.
      FLOW=0.
      II=0.
  405 CONTINUE
```

```
      FI=FLOAT(III-IIST)
      VAR=VAR/FI
      MEAN=MEAN/FI
      VAR=VAR-MEAN**2
      WRITE(6,711) MEAN,VAR
  711 FORMAT(/,7HMEAN = ,E13.6E2,16H     VARIANCE = ,E13.6E2,/)
C*****
C***** INPUT PARAMETERS
C*****
  554 WRITE(6.560)
  560 FORMAT(35HUSZC, ALPPER, ALPUEV, ALPINT+ALPDPR,
     +       18H (5E13.6E2 FORMAT))
      READ(4,759) USZC,ALPPER,ALPUEV,ALPDPR
      WRITE(6,559)USZC,ALPPER,ALPUEV,ALPDPR
  563 WRITE(6,561)
  561 FORMAT(22HIS THIS CORRECT (Y/N)?)
      READ(4,556) I
      IF(I.EQ.1HY) GOTO 562
      IF(I.NE.1HN) GOTO 563
      GOTO 554
  562 ALPINT=0.
      ICNTR=0
      ICNT=0
C*****
C***** INPUT INITIAL VARIABLE VALUES
C*****
  703 USZM=.09E8
      LSZM=.43E8
      GZM=.27E9
      IF(ALPDPR.LT.EPSILON)GZM=0.
      SS=.12E8
      SSS=.12E8
C*****
C***** INITIALIZE
C*****
      AVGFM = 0.
      VARM=0.
      PROD=0.
      VARM2=0.
      PROD2=0.
      AVGSSZ = 0.
      AVGFM2 = 0.
      AVGSSS = 0.
      AVGUSZ = 0.
      AVGLSZ = 0.
      AVGGZ = 0.
      AVGEVH = 0.
      AVGEV2 = 0.
      SSQERR = 0.
      SSQEH2 = 0.
C*****
C***** DAILY LOOP (BEGINNING)
C*****
      DO 100 I=1,III
```

```
C*****
C*****        INPUT DAILY PREPARED DATA
C*****
      NS    = DATA(1,I)
      HPLSE=DATA(4,I)
      FLOW  = DATA(3,I)
C*****
C*****        MASS BALANCE
C*****
      CALL OUTFLOW(NS)
C*****
      DATA(2,I)=NS
      IF(I.LE.IIST)GOTO 100
      AVGFM=AVGFM+NS
      VARM=VARM+NS**2
      PROD=PROD+FLOW*NS
      VARM2=VARM2+NSS**2
      PROD2=PROD2+FLOW*NSS
      AVGSSZ=AVGSSZ+SS
      AVGFM2=AVGFM2+NSS
      AVGSSS=AVGSSS+SSS
      AVGUSZ=AVGUSZ+USZMAVG
      AVGLSZ=AVGLSZ+LSZMAVG
      AVGGZ=AVGGZ+GZM
      AVGEVM=AVGEVM+EVAP
      AVGEV2=AVGEV2+EVAPS
      SSQERR=SSQERR+(FLOW-NS)**2
      SSQER2=SSQER2+(FLOW-NSS)**2
  100 CONTINUE
C*****
C***** DAILY LOOP (END)
C*****
C*****
C***** FINDALPLEV (INTERPOLATE ON MEAN)
C*****
      Q2=AVGFM/FI
      IF(ABS(Q2-MEAN)/MEAN.LT.0.00001)GOTO 700
      AA2=ALPLEV
      IF(ICNTR.EQ.0)GOTO 704
      ALPLEV=AA1+(AA2-AA1)*(MEAN-Q1)/(Q2-Q1)
      IF(ALPLEV.LE.0.)ALPLEV=AA2/2.
  706 Q1=Q2
      AA1=AA2
      WRITE(6,559)Q1,AA1
      ICNTR=ICNTR+1
      GOTO 703
  704 ALPLEV=1.5*ALPLEV
      GOTO 706
C*****
C***** FIND ALPINT (INTERVAL-HALVING ON MSE)
C*****
  700 IF(ICNT.EQ.1)GOTO 760
      ALP1=ALPINT
      MSER1=SSQERR/FI
```

```
      WRITE(6,559) MSER1,ALP1
      ICNT=1
      PT2=0.
      PT3=MSER1
      ALPINT=ALPDPR
      ALPDPR=0.
      GOTO 703
  760 PT1=PT2
      PT2=PT3
      PT3=SSQERR/FI
      IF(ABS(PT3-PT2)/PT3.LT..00001.AND.ABS(PT3-PT1)/PT3.LT..00001)
     +                                                       GOTO 7.52
      MSER2=PT3
      ALP2=ALPINT
      ALPINT=(ALP1+ALP2)/2.
      ALPDPR=ALPDPR+ALP2-ALPINT
      IF(MSER2.GT.MSER1)GOTO 761
      MSER1=MSER2
      ALP1=ALP2
  761 WRITE(6,559) MSER2,ALP2
      GOTO 703
C****
C***** SUMMARY INFORMATION
C*****
  762 AVGFM=AVGFM/FI
      VARM=VARM/FI
      VARM=VARM-AVGFM**2
      PROD=PROD/FI
      EXVA=(PROD-MEAN**2)**2/VAR/VARM
      AVGFM2=AVGFM2/FI
      VARM2=VARM2/FI
      VARM2=VARM2-AVGFM2**2
      PROD2=PROD2/FI
      EXVA2=(PROD2-MEAN**2)**2/VAR/VARM2
      AVGSSS=AVGSSS/FI
      AVGSSZ=AVGSSZ/FI
      AVGUSZ=AVGUSZ/FI
      AVGLSZ=AVGLSZ/FI
      AVGGZ=AVGGZ/FI
      AVGEVM=AVGEVM/FI
      AVGEV2=AVGEV2/FI
      SSQERR=SSQERR/FI
      SSQER2=SSQER2/FI
      WRITE(6,558) ALPINT,ALPLEV
  558 FORMAT(/,6E13.6E2)
      WRITE(6,558) AVGFM,AVGEVM,SSQERR,EXVA
      WRITE(6,559) AVGFM2,AVGEV2,SSQER2,EXVA2
      WRITE(6,559) AVGSSZ,AVGSSS,AVGUSZ,AVGLSZ,AVGGZ
      ALPDPR=ALPINT+ALPDPR
      WRITE(6.559) USZC,ALPPER,ALPUEV,ALPDPR
  559 FORMAT(6E13.6E2)
  555 WRITE(6,557)
  557 FORMAT(30HAGAIN (Y/N) OR START OVER (0)?)
      READi4.556) I
```

```
 556 FORMAT(A1 j
     IF(I.EQ.1HY)GOTO 554
     IF(I.EQ.1HO) GOTO 565
     IF(I.NE.1HN)GOTO 555
     REWIND 7
     REWIND 5
     READ(5,1000) I1,I2,I3
     WRITE(7,1000) I1,I2,I3
     WRITE(7,1020) ISTART,INODAYS,INDPGOD
,020 FORMAT(/,8HFROM DAY,I6,7H TO DAY,I6,3H IN,I3,11H-DAY GROUPS,/)
     WRITE(7,1030)
1030 FORMAT(39H      CONSTANT        ALBEDS      TBASE(C))
     WRITE(7,559) CONS,ALBEDS,TBASE
     WRITE(7,1040) AVGTA,AVGPR,AVGF,AVGHPLE,AVGNS,AVGEVP,AVGEVPF
1040 FORMAT(/,14HDAILY AVERAGES,
   +       /,37H                      TEMPERATURE (C):,E13.6E2,
   +       /,37H               PRECIPITATION (CUB. M.):,E13.6E2,
   +       /,37H                        ELOW  (CUB. M.):,E13.6E2,
   +       /,37H     HEAT LOSS, WATER EQU.  (CUB. M.):,E13.6E2,
   +       /,37H                  NET SUPPLY (CUD. M.):,E13.6E2,
   +       /,37H          EVAPOTRANSPIRATION (CUD. M.):,E13.6E2,
   +       /,37H     POT. EVAPOTRANSPIRATION (CUD. M.):,E13.6E2)
     ALPDPR=ALPDPR-ALPINT
     WRITE(7,1050)
1050 FORMAT(/,39H     USZC(M3)  ALPPER(D-1)  ALPUEV(M-3),
   +          26H  ALPDPR(D-1)  ALPINT(D-1))
     WRITE(7,559) USZC,ALPPER,ALPUEV,ALPDPR,ALPINT
     WRITE(7,1060)
1060  FORMAT(/,39H ALPLEV(M-3)   ALPGW(D-1)  ALPGEV(M-3),
   +          26H   ALPSF(D-1)  ALPSEV(M-3))
     WRITE(7,559) ALPLEV,ALPGW,ALPGEV,ALPSF,ALPSEV
     WRITE(7,1070) INDPGOD
1070 FORMAT(/,I3,15H-DAY STATISTICS)
     WRITE(7,1080) MEAN,VAR,
   +               AVGFM,AVGEVM,AVGSSZ,AVGUSZ,AVGLSZ,AVGGZ,SSQERR,EXVA,
   +               AVGFM2,AVGEV2,AVGSSS,AVGUSZ,AVGLSZ,AVGGZ,SSQER2,EXVA2
1080  FORMAT( 37H                   FLOW MEAN (CUD. M.):,E13.6E2,
   +       /,37H              FLOW VARIANCE (CUD. M.)2:,E13.6E2,
   +      //,37H     MODEL 1              MEAN (CUR. M.):,E13.6E2,
   +       /,37H        EVAPOTRANSPIRATION (CUD. M.):,E13.6E2,
   +       /,37H                    MEAN SS (CUB. M.):,E13.6E2,
   +       /,37H                  MEAN USZM (CUB. M.):,E13.6E2,
   +       /,37H                  MEAN LSZM (CUB. M.):,E13.6E2,
           /,37H                   MEAN GZM (CUB. M.):,E13.6E2,
   +       /,37H                        MSE (CUB. M.):,E13.6E2,
   +       /,37H        COEFFICIENT OF DETERMINATION:,E13.6E2,
   +      //,37H     MODEL 2              MEAN (CUB. M.):,E13.6E2,
   +       /,37H        EVAPOTRANSPIRATION (CUB. M.):,E13.6E2,
   +       /,37H                    MEAN SS (CUB. M.):,E13.6E2,
   +       /,37H                  MEAN USZM (CUB. M.):,E13.6E2,
   +       /,37H                  MEAN LSZM (CUB. M.):,E13.6E2,
   +       /,37H                   NEAN GZM (CUB. M.):,E13.6E2,
   +       /,37H                        MSE (CUB. M.):,E13.6E2,
   +       /,37H        COEFFICIENT OF DETERMINATION:,E13.6E2,/)
```

```
      WRITE(7,1090) INDPGOD
 1090 FORMAT(30HFLOW RATES IN CUBIC METERS PER,I3,5H DAYS,
     +       /,40H                 ACTUAL                    MODEL)
      IIST=IIST+1
      DO 750 I=IIST,III
  750 WRITE(7,1100) DATA(3,I),DATA(2,I)
 1100 FORMAT(2F20.0)
      REWIND 7
      REWIND 5
      STOP
      END
      SUBROUTINE OUTFLOW (NS)
      IMPLICIT REAL (A-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/III,NSS,SSS,EVAPS,DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
C*****
C ALPDPR = LINEAR RESERVOIR CONSTANT FOR DEEP PERCOLATION, INV. DAYS
C ALPGEV = PARTIAL CONSTANT OF GROUNDWATER EVAPORATION, INV. CUB. M.
C ALPGW  = LINEAR RESERVOIR CONSTANJ FOR GROUNDWATER FLOW, INV. DAYS
C ALPINT = LINEAR RESERVOIR CONSTANT FOR INTERFLOU, INV. DAYS
C ALPLEV = PARTIAL CONSTANT OF LOWER ZONE EVAPORATION, INV. CUB. M.
C ALPPER = LINEAR RESERVOIR CONSTANT FOR PERCOLATION, INV. DAYS
C ALPSEV = PARTIAL CONSTANT OF SURFACE EVAPORATION, INV. CUB. M.
C ALPSF  = LINEAR RESERVOIR CONSTANT FOR SURFACE FLOW, INV. DAYS
C ALPUEV = PARTIAL CONSTANT OF UPPER ZONE EVAP., INV. CUB. M.
C DAY    = TIME IN ONE GROUP OF DAYS (WEEK, MONTH, ETC.), DAYS
C EVAP   = TOTAL EVAPOTRANSPIRATION VOLUME, CUB. M.
C EVPRP  = POTENTIAL EVAPOTRANSPIRATION RATE, CUB. M./DAY
C GZM    = GROUNDWATER ZONE MOISTURE, CUB. M.
C HPLSE  = TOTAL ENERGY OUT (EVAP. + POT. EVAP.) WATER EQU., CUB. M.
C LSZM   = LOWER SOIL ZONE MOISTURE, CUB. M.
C NS     = NET SUPPLY VOLUME, CUB. M.
C NS     = BASIN OUTFLOW VOLUME, CUB. M.
C NSR    = NET SUPPLY RATE, CUB. M./DRY
C R      = DUMMY VARIABLE FOR STORAGE OF INTERMEDIATE RESULTS
C SS     = SURFACE WATER STORAGE, CUB. M.
C T      = DUMMY VARIABLE FOR STORAGE OF INTERMEDIATE RESULTS
C USZC   = UPPER SOIL ZONE MOISTURE CAPACITY, CUB. M.
C USZM   = UPPER SOIL ZONE MOISTURE, CUD. M.
C VDPR   = DEEP PERCOLATION VOLUME, CUE. M.
C VGEV   = GROUNDWATER ZONE EVAPOTRANSPIRATION VOLUME, CUB. M.
C VGW    = GROUNDWATER ZONE OUTFLOW VOLUME, CUB. M.
C VIHF   = INFILTRATION VOLUME, CUB. M.
C VINT   = INTERFLOW VOLUME. CUB. M.
C ULEV   = LOWER ZONE EVAPOTRANSPIRATION VOLUNE, CUB. M.
C VPER   = PERCOLATION VOLUME. CUB. M.
C VRUN   = SURFACE RUNOFF VOLUME, CUB. M.
C VUEV   = UPPER ZONE EVAPOTRANSPIRATION VOLUME, CUB. M.
C*****
      NSR=NS/DAY
      EVPRP=HPLSE/2./DAY
```

```
      IF(EVPRP.LE.DPSILON)GOTO 903
904   B=NSR/USZC+ALPPER+ALPUEV*EVPRP
      C=NSR/B
      A=USZM-C
      USZMAVG=A/B*(1.-EXP(-B*DAY))/DAY+C
      D=ALPINT+ALPDPR+ALPLEV*EVPRP
      IF(ABS((D-B)/D).LE.EPSILON.OR.ABS(D-B).LE.DPSILON)GOTO 905
      F=ALPPER*A/(D-B)
      G=ALPPER*C/D
      E=LSZM-F-G
      LSZMAVG=(E/D*(1.-EXP(-D*DAY))+F/B*(1.-EXP(-B*DAY)))/DAY+G
      GOTO 906
905   F=ALPPER*A
      G=ALPPER*C/D
      E=LSZMG
      LSZMAVG=(E/D*(1.-EXP(-D*DAY))+F/D**2*(1.-(D*DAY+1.)
     +        *EXP(-D*DAY)))/DAY+G
906   EVPRPO=EVPRP
      EVPRP=HPLSE/DAY/(1.+ALPUEV*USZMAVG+ALPLEV*LSZMAVG)
      IF(ABS((EVPRP-EVPRPO)/EVPRP).GT.GPSILON)GOTO 904
903   B=NSR/USZC+ALPPER+ALPUEV*EVPRP
      C=ALPPER*NSR/B
      A=ALPPER*USZM-C
      T=EXP(-B*DAY)*A/ALPPER+NSR/B
      USZMAVG=(A/B*(1.-EXP(-B*DAY))/DAY+C)/ALPPER
      R=NS+USZM-T
      USZM=T
      VINF=NS-R*NSR/USZC/B
      VPER=R*ALPPER/B
      VRUN=NS-VINF
      VUEV=R-VRUN-VPER
      D=ALPINT+ALPDPR+ALPLEV*EVPRP
      IF(ABS((D-B)/D).LE.EPSILON.OR.ABS(D-B).LE.DPSILON)GOTO 100
      F=A/(D-B)
      G=C/D
      E=LSZM-F-G
      T=E*EXP(-D*DAY)+F*EXP(-B*DAY)+G
      LSZMAVG=(E/D*(1.-EXP(-D*DAY))+F/B*(1.-EXP(-B*DAY)))/DAY+G
      R=VPER+LSZM-T
      IF(ALPDPR.LT.EPSILON)GOTO 910
      E=ALPDPR*E
      F=ALPDPR*F
      G=ALPDPR*G
910   LSZM=T
      VINT=R*ALPINT/D
      VDPR=R*ALPDPR/D
      VLEV=R-VINT-VDPR
      H=ALPGW+ALPGEV*EVPRP
      IF(ABS((H-D)/H).LE.EPSILON.OR.ABS(H-D).LE.DPSILON)GOTO 200
      IF(ABS((H-B)/H).LE.EPSILON.OR.ABS(H-B).LE.DPSILON)GOTO 250
      T=(GZM-E/(H-D)-F/(H-B)-G/H)*EXP(-H*DAY)
     + +E/(H-D)*EXP(-D*DAY)+F/(H-B)*EXP(-B*DAY)+G/H
      IF(ALPDPR.LT.EPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
```

```
      IF(ALPDPR.LT.EPSILON)GOTO 911
      L=ALPGW*(GZM-E/(H-D)-F/(H-B)-G/H)
      M=E*(ALPINT/ALPDPR+ALPGW/(H-D))
      N=A*NSR/USZC/ALPPER+F*(ALPINT/ALPDPR+ALPGW/(H-B))
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 912
  911 L-0.
      M=ALPINT*E
      N=ALPINT*F+A*NSR/USZC/ALPPER
      O=ALPINT*G+C*NSR/USZC/ALPPER
  912 GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILMN.OR.ABS(P-H).LE.DPSILON)GOTO 300
      IF(ABS((P-D)/P).LE.EPSILON.OR.ABS(P-D).LE.DPSILON)GOTO 400
      IF(ABS((P-B)/P).LE.EPSILON.OR.ABS(P-B).LE.DPSILON)GOTO 500
      T=(SS-L/(P-H)-M/(P-D)-N/(P-B)-O/P)*EXP(-P*DAY)
     + +L/(P-H)*EXP(-H*DAY)+M/(P-D)*EXP(-D*DAY)+N/(P-B)*EXP(-B*DAY)+O/P
      III-O.
  600 R=VRUN+VINT+VGW+SS-T
      NS=R*ALPSF/P
      SS=T
      EVAP=VUEV+VLEV+VGEV+R-NS
      GOTO 1000
  500 T=(SS-L/(P-H)-M/(P-D)+N*DAY-O/P)*EXP(-P*DAY)
     + +L/(P-H)*EXP(-H*DAY)+M/(P-D)*EXP(-D*DAY)+O/P
      III=1.
      GOTO 600
  400 T=(SS-L/(P-H)+M*DAY-N/(P-B)-O/P)*EXP(-P*DAY)
     + +L/(P-H)*EXP(-H*DAY)+N/(P-B)*EXP(-B*DAY)+O/P
      III=2.
      GOTO 600
  300 T=(SS+L*DAY-M/(P-D)-N/(P-B)-O/P)*EXP(-P*DAY)
     + +M/(P-D)*EXP(-D*DAY)+N/(P-B)*EXP(-B*DAY)+O/P
      III=4.
      GOTO 600
  200 T=(GZM+E*DAY-F/(H-B)-G/H)*EXP(-H*DAY)
     + +F/(H-B)*EXP(-B*DAY)+G/H
      IF(ALPDPR.LT.EPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
      IF(ALPDPR.LT.EPSILON)GOTO 913
      L=ALPGW*(GZM-F/(H-B)-G/H)+ALPINT/ALPDPR*E
      M=ALPGW*E
      N=A*NSR/USZC/ALPPER+F*(ALPINT/ALPDPR+ALPGW/(H-B))
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 914
  913 L=ALPINT*E
      M=0.
      N=ALPINT*F+A*NSR/USZC/ALPPER
      O=ALPINT*G+C*NSR/USZC/ALPPER
  914 GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
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```
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 203
      IF(ABS((P-B)/P).LE.EPSILON.OR.ABS(P-B).LE.DPSILON)GOTO 204
      T=(SS-L/(P-H)+M/(P-H)**2-N/(P-B)-O/P)*EXP(-P*DAY)
     + +(L/(P-H)+M/(P-H)**2*((P-H)*DAY-1))*EXP(-H*DAY)
     + +N/(P-B)*EXP(-B*DAY)+O/P
      III=8.
      GOTO 600
  204 T=(SS-L/(P-H)+M/(P-H)**2+N*DAY-O/P)*EXP(-P*DAY)
     + +(L/(P-H)+M/(P-H)**2*((P-H)*DAY-1))*EXP(-H*DAY)+O/P
      III=9.
      GOTO 600
  203 T=(SS+L*DAY+M/2*DAY**2-N/(P-B)-O/P)*EXP(-P*DAY)
     + +N/(P-B)*EXP(-B*DAY)+O/P
      III=14.
      GOTO 600
  100 T=(LSZM+A*DAY-C/D)*EXP(-D*DAY)+C/D
      F=A
      G=C/D
      E=LSZM-G
      LSZMAVG=(E/D*(1.-EXP(-D*DAY))+F/D**2*(1.-(D*DAY+1.)
     +        *EXP(-D*DAY)))/DAY+G
      R=VPER+LSZM-T
      IF(ALPDPR.LT.EPSILON) GOTO 920
      E=ALPDPR*E
      F=ALPDPR*F
      G=ALPDPR*G
  920 LSZM=T
      VINT=R*ALPINT/D
      VDPR=R*ALPDPR/D
      VLEV=R-VINT-VDPR
      H=ALPGW+ALPGEV*EVPRP
      IF(ABS((H-D)/H).LE.EPSILON.OR.ABS(H-D).LE.DPSILON)GOTO 120
      T=(GZM-E/(H-D)+F/(H-D)**2-G/H)*EXP(-H*DAY)
     + +(E/(H-D)+F/(H-D)**2*((H-D)*DAY-1))*EXP(-D*DAY)+G/H
      IF(ALPDPR.LT.EPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
      IF(ALPDPR.LT.EPSILON)GOTO 921
      L=ALPGW*(GZM+F/(H-D)**2-E/(H-D)-G/H)
      M=ALPGW*(E/(H-D)-F/(H-D)**2)+ALPINT/ALPDPR*E
      M=M+(NSR/USZC/ALPPER)*A
      N=F*(ALPGW/(H-D)+ALPINT/ALPDPR)
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 922
  921 L=0.
      M=ALPINT*E+A*NSR/USZC/ALPPER
      N=ALPINT*F
      O=ALPINT*G+C*NSR/USZC/ALPPER
  922 GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 130
      IF(ABS((P-D)/P).LE.EPSILON.OR.ABS(P-D).LE.DPSILON)GOTO 140
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      T=(SS-L/(P-H)-M/(P-D)+N/(P-D)**2-O/P)*EXP(-P*DAY)
     + +L/(P-H)*EXP(-H*DAY)+O/P
     + +(M/(P-D)+N/(P-D)**2*((P-D)*DAY-1))*EXP(-D*DAY)
      III=16.
      GOTO 600
140   T=(SS-L/(P-H)+M*DAY+N/2*DAY**2-O/P)*EXP(-P*DAY)
     + +L/(P-H)*EXP(-H*DAY)+O/P
      III=19.
      GOTO 600
130   T=(SS+L*DAY-M/(P-D)+N/(P-D)**2-O/P)*EXP(-P*DAY)
     + +(M/(P-D)+N/(P-D)**2*((P-D)*DAY-1))*EXP(-D*DAY)+O/P
      III=20.
      GOTO 600
120   T=(GZM+E*DAY+F/2*DAY**2-G/H)*EXP(-H*DAY)+G/H
      IF(ALPDPR.LT.EPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
      IF(ALPDPR.LT.EPSILON)GOTO 923
      L=ALPGW*(GZM-G/H)+ALPINT/ALPDPR*E
      L=L+NSR/USZC/ALPPER*A
      M=ALPGW*E+ALPINT/ALPDPR*F
      N=ALPGW*F/2
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 924
923   L=ALPINT*E+A*NSR/USZC/ALPPER
      M=ALPINT*F
      N=0.
      O=ALPINT*G+C*NSR/USZC/ALPPER
924   GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 123
      T=(SS-L/(P-H)+M/(P-H)**2-2*N/(P-H)**3-O/P)*EXP(-P*DAY)
     + +(L/(P-H)+M/(P-H)**2*((P-H)*DAY-1)+N/(P-H)*DAY**2
     + -2*N/(P-H)**3*((P-H)*DAY-1))*EXP(-H*DAY)+O/P
      III=56.
      GOTO 600
123   T=(SS+L*DAY+M/2*DAY**2+N/3*DAY**3-O/P)*EXP(-P*DAY )+O/P
      III=63.
      GOTO 600
250   T=(GZM-E/(H-D)+F*DAY-G/H)*EXP(-H*DAY)
     + +E/(H-D)*EXP(-D*DAY)+G/H
      IF(ALPDPR.LT.EPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
      IF(ALPDPR.LT.EPSILON)GOTO 915
      L=ALPGW*(GZM-E/(H-D)-G/H)+ALPINT/ALPDPR*F
      L=L+A*NSR/USZC/ALPPER
      M=E*(ALPINT/ALPDPR+ALPGW/(H-D))
      N=ALPGW*F
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 916
915   L=ALPINT*F+A*NSR/USZC/ALPPER
      M=ALPINT*E
      N=0.
```

```
      O=ALPINT*G+C*NSR/USZC/ALPPER
 916  GZN=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 255
      IF(ABS((P-D)/P).LE.EPSILON.OR.ABS(P-D).LE.DPSILON)GOTO 254
      T=(SS-L/(P-H)-M/(P-D)+N/(P-H)**2-O/P)*EXP(-P*DAY)
     + +(L/(P-H)+N/(P-H)**2*((P-H)*DAY-1))*EXP(-H*DAY)
     + +M/(P-D)*EXP(-D*DAY)+O/P
      III=32.
      GOTO 500
 254  T=(SS-L/(P-H)+M*DAY+N/(P-H)**2-O/P)*EXP(-P*DAY)
     + +(L/(P-H)+N/(P-H)**2*((P-H)*DAY-1))*EXP(-H*DAY)+O/P
      III=34.
      GOTO 500
 255  T=(SS+L*DAY-M/(P-D)+N/2*DAY**2-O/P)*EXP(-P*DAY)
     + +M/(P-D)*EXP(-D*DAY)+O/P
      111-37.
      GOT0 500
1000  IF(ABS((P-B)/P).GT.EPSILON.AND.ABS(P-B).GT.DPSILON)GOTO 1050
      R=(NSR/USZC/ALPPER)
      T=(SSS+R*A*DAY-R*C/P)*EXP(-P*DAY)+R*C/P
1600  R=VRUN+SSS-T
      NSS=R*ALPSF/P+VINT+VGW
      SSS=T
      EVAPS=VUEV+VLEV+VGEV+R-R*ALPSF/P
      RETURN
1050  R=(NSR/USZC/ALPPER)
      T=(SSS-R*A/(P-B)-R*C/P)*EXP(-P*DAY)
     + +R*A/(P-B)*EXP(-B*DAY )+R*C/P
      GO TO 1600
      END
```

Appendix D.--PARTIAL LISTING OF INPUT DATA FILE

GENESEE RIVER AT PORTAGEUILLE NEW YORK
6-20-56 TO 9-30-72 : 5947 RECORDS
(1X,I3,I3,I5,5X,2F10.2,2F20.0)

DAY	MONTH	YEAR	TMIN(C)	TMAX(C)	PRECIP(M3/D)	FLOW(M3/D)
20	6	1956	9.37	22.57	0.	-9999.
21	6	1956	13.49	27.29	0.	-9999.
22	6	1956	16.02	29.40	319480.	-9999.
23	6	1956	12.77	28.15	1990867.	-9999.
24	6	1956	16.39	28.24	14544764.	-9999.
25	6	1956	15.39	22.81	7028568.	-9989.
26	6	1956	6.63	25.84	0.	-9999.
27	6	1956	16.58	25.35	10858969.	-9999.
28	6	1956	11.23	19.79	417006.	-9999.
29	6	1956	8.80	21.18	0.	-9999.
30	6	1956	5.56	28.86	0.	-9999.
1	7	1956	15.41	30.96	0.	-9999.
2	7	1956	17.04	26.88	19195725.	-9999.
3	7	1956	11.82	27.74	0.	-9999.
4	7	1956	12.36	23.35	0.	-9999.
5	?	1956	13.43	22.06	23201000.	-9999.
6	7	1956	14.98	20.27	20056641.	-9999.
7	7	1956	9.91	25.26	114340.	-9999.
8	?	1956	13.56	28.86	6564481.	-9999.
9	7	1956	15.24	26.87	69128824.	-9999.
10	7	1956	13.34	21.91	8504904.	-9999.
11	7	1956	8.86	24.82	2444866.	-9999.
12	7	1956	13.43	21.27	26621122.	-9999.
13	7	1956	14.53	21.35	33918726.	-9999.
14	7	1956	13.25	20.94	15637723.	-9999.
15	7	1956	8.78	24.42	279125.	-9999.
16	7	1956	13.84	23.33	1281284.	-9999.
17	7	1956	10.46	21.77	0.	-9999.
18	7	1956	5.97	23.80	0.	-9999.
19	7	1956	7.21	24.47	0.	-9999.
20	7	1956	15.43	21.18	7805410.	--9999.
21	7	1956	15.03	25.65	14450601.	-9999.
22	7	1956	15.01	27.01	11050658.	-9999.
23	7	1956	15.01	25.41	7953380.	-9999.
24	7	1956	14.09	25.62	3107367.	-9999.
25	7	1956	12.51	25.22	625509.	-9999.
26	7	1956	12.06	24.76	739849.	-9999.
27	7	1956	13.67	29.12	13394635.	-9999.
28	?	1956	16.27	25.77	0.	-9999.
29	7	1956	7.38	20.40	0.	-9999.
30	7	1956	4.62	20.11	0.	-9999.
31	7	1956	5.17	22.81	26904.	-9999.
1	8	1956	13.42	24.00	0.	-9999.
2	8	1956	8.86	22.21	0.	-9999.
3	8	1956	2.62	23.91	0.	-9999.
4	8	1956	6.21	25.33	0.	-1999.
5	8	1956	15.37	25.54	21886086.	-9999.
6	8	1956	16.67	22.24	33885096.	-9999.
7	8	1956	16.04	23.07	50101247.	-9999.
8	8	1956	13.84	26.42	23735709.	-9999.

9	8	1956	12.27	28.03	2502036.	-9999.
10	8	1956	16.02	23.83	46909006.	-9999 .
11	8	1956	10.69	26.16	26904.	-9999.
12	8	1956	14.19	24.60	20178.	-9999.
13	8	1956	11.87	23.42	107614.	-9999.
14	G	1956	15.54	24.99	29220683.	-9999.
15	G	1956	10.89	24.64	121066.	-9999.
lb	8	1956	9.23	28.14	0.	-9999.
17	8	1956	13.26	28.68	0.	-9999.
18	G	1956	14.47	26.29	349747.	-9999.
19	8	1956	16.58	22.85	24922831.	-9999.
20	8	1956	10.03	19.13	662501.	-9999.
21	8	1956	6.64	19.20	0474637.	-9999.
22	8	15'56	4.63	20.59	0.	-9999.
23	8	1956	9.01	22.90	0.	-9999.
24	8	1956	10.08	20.87	32977099.	-9999.
25	8	1956	5.09	21.17	154696.	-9999.
26	8	1956	5.73	22.77	0.	-9999.
27	6	1956	8.61	22.02	1119863.	-9099.
28	8	1956	13.03	27.78	3383129.	-9999.
29	8	1956	14.65	27.46	69515564.	-9999.
30	8	1756	13.72	27.40	14285817.	-9999.
31	8	1956	15.87	29.27	20685513.	-9999.
1	9	1956	15.38	28.52	14168113.	-9999.
2	9	1956	16.68	25.41	20712416.	-9999.
3	9	1956	7.49	24.47	100889.	-9999.
4	9	1956	8.48	26.83	0.	-9999.
5	9	1956	11.38	28.47	0.	-9999.
6	9	1956	14.94	24.43	22565402.	-9999.
7	9	1956	5.61	18.08	8414104.	-9999.
8	9	1956	4.47	15.86	538072.	-9999.
9	9	1956	.98	15.29	0.	-9999.
10	9	1956	.21	18.69	0.	-9999.
11	9	1956	9.96	18.69	1062693.	-9999.
12	9	1956	11.14	23.37	3480654.	-0999.
13	9	1956	9.22	25.59	0.	-9999.
14	9	1956	14.99	22.88	53807.	-9999.
15	9	1956	1.93	15.88	6655280.	-9999.
16	9	1956	5.22	17.33	53427205.	-9999.
17	9	1956	9.62	19.37	7142908.	-9999.
18	9	1956	3.77	14.18	14195017.	-9999.
19	9	1956	.88	16.50	0.	-9999.
20	9	1956	.49	11.74	14319446.	-9999.
21	9	1956	-.38	14.28	7334597.	-9999.
22	9	1956	3.03	20.12	2280081.	-9999.
23	9	1956	9.57	23.55	2929130.	-9999.
24	9	1956	5.74	18.78	11444123.	-9999.
25	9	1956	1.54	15.09	30267.	-9999.
26	9	1956	-.35	14.89	0.	-9999.
27	9	1956	-1.63	14.82	0.	-9999.
28	9	1956	-.52	20.17	0.	-9999.
29	9	1956	3.62	21.82	0.	-9999.
30	9	1956	6.98	19.47	107614.	-9999.
1	10	1956	2.65	16.69	921449.	946930.

2 10 1954	1.62	22.88	538072.	858844.
3 10 1956	4.28	i8.67	4993982.	846609.
4 10 1956	6.04	18.92	2182555.	871078.
5 10 1956	3.65	15.41	2707176.	797672.
6 10 1956	-1.34	13.47	26904.	760970.
7 10 1956	5.93	12.97	37012641.	998314.
8 10 1956	.59	19.27	10684096.	2334293.
9 10 1956	-.28	14.32	26904.	1575770.
10 10 1956	-2.91	9.46	0.	1176934.
11 10 1956	-6.06	9.78	0.	983633.
12 10 1956	-3.78	17.12	0.	915121.
13 10 1956	2.01	22.66	0.	827035.
14 10 1956	2.86	25.03	0.	758523.
15 10 1956	2.81	26.32	0.	709586.
16 10 1956	3.11	25.24	0.	492458.
17 10 1956	3.73	25.56	0.	645968.
18 10 1956	4.31	16.64	0.	611712.
19 10 1956	-5.22	15.81	0.	628840.
20 10 1956	3.57	16.77	0.	560328.
21 10 1956	6.58	21.91	0.	507244.
22 10 1956	5.61	20.29	0.	533413.
23 10 1956	11.66	18.57	20540906.	567669.
24 10 1956	4.02	15.26	3588269.	660649.
25 10 1956	-4.42	14.36	0.	773204.
26 10 1956	1.51	i3.32	0.	694905.
27 10 1956	7.01	13.53	1597402.	616606.
28 10 1956	.91	15.68	0.	616606.
29 10 1956	-.98	18.47	0.	579903.
30 10 1956	6.24	19.88	0.	555434.
31 10 1956	10.86	18.33	0.	543200.
1 11 1956	12.24	22.99	766753.	552988.
2 11 1956	12.39	20.32	45372937.	834375.
3 11 1956	11.33	17.84	2179192.	3131965.
4 11 1956	7.57	17.74	0.	1810668.
5 11 1956	5.81	17.59	0.	1421610.
6 11 1956	-.98	18.59	0.	1250339.
7 11 1956	5.11	15.72	2613013.	1108422.
8 11 1956	2.03	10.11	53807.	1044804.
9 11 1956	-.38	4.52	719672.	978739.
10 11 1956	-8.22	.12	2471769.	695546.
11 11 1956	-9.71	9.53	0.	863737.
12 11 1956	.63	13.16	753301.	836822.
13 11 1956	-1.37	4.26	12308401.	075972.
14 11 1956	-.77	15.48	0.	973646.
15 11 1956	5.29	21.36	0.	954271.
16 11 1956	1.44	15.12	3171263.	917568.
17 11 1956	-2.13	6.03	1432617.	912674.
18 11 1956	-6.34	3.61	0.	1071719.
19 11 1956	-7.91	9.01	0.	807460.
20 11 1956	-4.11	11.33	551524.	694905.
21 11 1956	1.89	12.69	32321324.	1585558.
22 11 1956	-4.24	3.12	32099369.	7927788.
23 11 1956	-9.33	-2.66	7065560.	3939425.
24 11 1956	-15.98	-1.81	5417714.	2667064.

Appendix E.--INTERACTIVE TERMINAL SESSION EXAMPLE

```
CONSTANT,  ALBEDS, TBASE,  ALPGU,  ALPSF (5E13.6E2 FORMAT)
?   .392288E+15  .800000E+00  .300000E+01  .490000E-01  .100000E+99
  .392288E+15  .800000E+00  .300000E+01  .490000E-01  .100000E+99
IS THIS CORRECT (Y/N)?
? N
CONSTANT,  ALBEDS,  TEASE,  ALPGU,  ALPSF (5E13.6E2 FORMAT)
?  .392288E+15  .809000E+00  .300000E+01  .490000E-01  .100000E+99
  .392288E+15  .809000E+00  .300000E+01  .490000E-01  .100000E+99
IS THIS CORRECT (Y/N)?
? Y
 FROM DAY    468 TO DAY 5947

  .691844E+01  .595772E+07  .282948E+07  .437982E+07
  .595772E+07  .312823E+07  .125158E+07

MEAN =   .847148E+08      VARIANCE =   .655445E+16

USZC, ALPPER, ALPUEV, ALPINT+ALPDPR (5E13.6E2 FORMAT)
? .508156E+08  .270000E+00  .116000E-05  .490000E-01
  .508156E+08  .270000E+00  .116000E-05  .490000E-01
IS THIS CORRECT (Y/N)?
? Y
  .850921E+08  .650000E-07
  .844710E+08  .975000E-07
  .846783E+08  .847442E-07
  .847189E+08  .824977E-07
  .100971E+16 0.
  .847254E+08  .827251E-07
  .847323E+08  .823543E-07
  .141443E+16  .490000E-01
  .847096E+08  .832979E-07
  .847135E+08  .830830E-07
  .111438E+16  .245000E-01
  .847121E+08  .830090E-07
  .847094E+08  .831577E-07
  .103763E+16  .122500E-01
  .847135E+08  .828653E-07
  .101756E+16  .612500E-02
  .101211E+16  .306250E-02
  .101052E+16  .153125E-02
  .101002E+16  .765625E-03
  .100984E+16  .382813E-03
  .847139E+08  .827687E-07
  .847171E+08  .825982E-07
  .100977E+16  .191406E-03
  .100973E+16  .957031E-04
  .100972E+16  .478516E-04
  .100971E+16  .239258E-04
  .100971E+16  .119629E-04

  .598145E-05  .827226E-07

  .847147E+08  .937502E+08  .100971E+16  .846170E+00
  .847147E+08  .937502E+08  .100971E+16  .846170E+00
```

```
  .284856E-91  .116530E-91  .789213E+07  .341781E+08  .343481E+08
  .508156E+08  .270000E+00  .116000E-05  .490000E-01
AGAIN (Y/N) OR START OVER (O)?
? N
```

Appendix F.--PARTIAL LISTING OF EXAMPLE OUTPUT

GENESEE RIVER AT PORTAGEVILLE

FROM DAY 468 TO DAY 5947 IN 30-DAY GROUPS

CONSTANT	ALBEDS	TBASE(C)
.392288E+15	.809000E+00	.300000E+01

DAILY AVERAGES

TEMPERATURE (C):	.691844E+01
PRECIPITATION (CUB. M.):	.595772E+07
FLOU (CUE. M.):	.282948E+07
HEAT LOSS, WATER EQU. (CUB. M.):	.437982E+07
NET SUPPLY (CUB. M.):	.595772E+07
EUAPOTRANSPIRATION (CUB. M.):	.312823E+07
POT. EUAPOTRANSPIRATION (CUB. il.,:	.125158E+07

USZC(M3)	ALPPER(D-1)	ALPUEV(M-3)	ALPDPR(D-1)	ALPINT(D-1)
.508156E+08	.270000E+00	.116000E-05	.489940E-01	.598145E-05

ALPLEV(M-3)	ALPGW(D-1)	ALPGEV(M-3)	ALPSF(D-1)	ALPSEV(M-3)
.827226E-07	.490000E-01	0.	.100000E+99	0.

30-DAY STATISTICS

FLOU MEAN (CUB. M.):	.847148E+08
FLOU VARIANCE (CUB. M.)2:	.655445E+16

MODEL 1	MEAN (CUB. M.):	.847147E+08
	EUAPOTRANSPIRATION (CUB. M.):	.937502E+08
	MEAN SS (CUB. M.):	.284856E-91
	MEAN USZM (CUB. M.):	.789213E+07
	MEAN LSZH (CUB. ii.):	.341781E+08
	MEAN GZM (CUB. M.):	.343481E+08
	MSE (CUB. M.):	.100971E+16
	COEFFICIENT OF DETERMINATION:	.846170E+00

MODEL 2	MEAN (CUB. M.):	.847147E+08
	EUAPOTRANSPIRATION (CUB. M.):	.937502E+08
	MEAN SS (CUB. M.):	.116530E-91
	MEAN USZM (CUB. M.):	.789213E+07
	MEAN LSZM (CUB. M.):	.341781E+08
	MEAN GZM (CUB. il.,:	.343481E+08
	MSE (CUB. M.):	.100971E+16
	COEFFICIENT OF DETERMINATION:	.846170E+00

FLOU RATES IN CUBIC METERS PER 30 DAYS

ACTUAL	MODEL
7636611.	4711878.
11372951.	10973428.
14294485.	51652945.
51838923.	76264636.
46597772.	62983986.
58993506.	120874258.
271257568.	203417158.
247645485.	195451409.

52930213.	89195430.
94463016.	95640487.
36815272.	29009593.
15921638.	25720708.
66576287.	38253470.
27605338.	25865859.
86133942.	61232938.
52998728.	48074090.
205608633.	70813502.
151202971.	136882174.
295921796.	'3006687915.
162162404.	166153740.
61976214.	81108239.
23519102.	29814572.
11279972.	6548410.
7330754.	3348955.
25148701.	6223526.
79794159.	136433282.
130049971.	113054554.
201938366.	140222222.
144535312.	113158060.
132934803.	121456822.
122601764.	105741606.
295960947.	219502722.
153106622.	174471299.
160111946.	137220710.
19934468.	33324255.
12765205.	10760846.
7482463.	4341413.
5857753.	4521300.
7920446.	10563408.
23423678.	13212826.
7710018.	21476100.
33524264.	62994751.
255842427.	263768052.
219873761.	223180333.
254007291.	199060579.
116824758.	153121868.
40970021.	52400761.
32198072.	18090750.
21280238.	4146939.
10934960.	4187719.
12155938.	34010489.
54826518.	73404574.
46465644.	19134430.
47395449.	75738759.
78499779.	139789761.
271061819.	15.4014993.
104778923.	85919234.
28114281.	40653514.
10563045.	8595124.
3196942.	17893296.
4475285.	3158445.
43522085.	124723997.