S Y N F L Ø   D O C U M E N T A T I O N

SYNTHETIC FLOWS MODEL

WYOMING WATER PLANNING PROGRAM

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CONTENTS

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SYNFLØ - SYNTHETIC FLOW MODEL

SUMMARY

Historic streamflow records on many Wyoming streams are too short to give a reliable picture of high and low flow conditions. Record extensions from regressions with other streams are useful when a nearby stream with a sufficient period of record is available. In many cases, however, the record extension techniques leave much to be desired, and do not ordinarily reflect extremes that may be expected to occur.

The approach modeled here generates a sequence of synthetic flow values based upon the statistics of historic flow records. The synthetic flows represent a flow sequence that has the statistics of the historic record, a flow sequence that could possibly occur. The synthetic flow sequence cannot be used to extend the historic record, but is, rather, one device for evaluating possible water supply conditions. Any number of synthetic flow sequences may be generated for a given stream, all equally valid as possible sequences.

Overview

The model described here can produce the synthetic flow sequences for multiple seasons within each year up to 12 seasons (or 12 months). For just one season, annual flows are synthesized. Intermediate season combinations might be, for example, quarterly (4 seasons of 3 months each), wet and dry seasons (2 seasons of either 6 months each or some other division of the months), or almost any other seasonal assignment up to 12 seasons. Input data for each season obviously must correspond to the season breakdown.

Statistics derived from historic flow records in 1,000 ac-ft units at the site under consideration are the basic input data. From prior examination of the historic data one of 3 flow distributions may be selected for each season, and the appropriate calculation for the synthesized flows can then be specified. The synthesized flows may be on the basis of calendar years or water years, so long as the data input is correspondingly arranged. The first 50 years of synthesized flows are dropped out, to minimize any carryover effects from initialization.

Model output consists of a table of synthetic flows by season with an annual total in column entries, with one row to each year. The table headings consist of the number of seasons used and the station identification number, and a statement as to the kind of year used (calendar or water). Column headings are for the year number, season number (12 columns), and the annual total. Zero is printed in any season column that is not used for a synthetic flow, i.e., for 4 seasons, the first 4 season columns would contain synthetic flow values (some of which may be zero) and columns 5-12 would contain only entries of zero. Following the synthesized flows, the program prints the distribution identifier for each season and the seasonal statistics from the historic record used as input.

The model dictionary should be consulted for definitions of variable names used in the model.

References

The model has been derived and adapted almost entirely from the following reference:

Fiering, Myron B., and Barbara B. Jackson, Synthetic Streamflows, Water Resources Monograph 1, American Geophysical Union, Washington, D. C., 1971.

Unless other references are specifically cited, the reference is to the above monograph.

Distributions

Three flow distributions are available in the model for calculation of the synthetic flow sequences. These are for (1) normally distributed historic flows, (2) log-normally distributed historic flows, and (3) historic flows distributed as Gamma. The seasonal historic flows will seldom match one of these distributions exactly, but will usually approximate one of them closely enough to make a selection.

1. Normal Distribution: The normal distribution has the simplest calculation form. Historic flow statistics for the average flow, the standard deviation, and the lag-one serial correlation coefficient for each season are required. The calculation form is called by entering KALL = 1. The use of the lag-one serial correlation coefficient (RLAG) implies the flow for a given season is related to the flow that occurred in the previous season. The calculation scheme accounts for this by calling up the appropriate previous statistical parameter, or flow, as required. For the first season of a year, the information for the last season of the previous year is called.

   A normally distributed random number with mean = 0 and standard deviation = 1 is required for each calculation of a synthetic flow. This is obtained from the subroutine RANDØM, called once each year to produce a set of random numbers for the year, one per season.

   About half of the random numbers will be negative, and the calculation process can at times result in a negative synthetic flow.

This negative value is retained until it is used in generating the subsequent synthetic flow, and is then reset to zero. The seasonal synthetic flows are summed as they are produced to provide annual totals.

2. Log-Normal Distribution: The log-normal distribution uses statistical parameters in natural log form. These are calculated from the historic flow statistics in such a way that the statistics of the historic flows are preserved in the synthetic flows. (If the logs of the historic flow statistics were used directly, the synthetic flows would preserve the statistics of the historic flow logs.)

Historic flow statistics required for the log-normal distribution calculation are the same as for the normal distribution. The calculation form is specified by entering KALL = 2.

The calculation scheme is similar to that for the normal distribution, except that calculations are done with the derived logs of the statistical parameters and the log of the previous season flow. The result is the log of a synthetic flow which has been reduced by a lower bound for the season (ACØN). The synthetic flow for the season is found by obtaining the antilog of the synthetic flow log, and adding the appropriate ACØN value. Annual totals are summed and the check for negative flows is made as in the normal distribution scheme.

3. Gamma Distribution:

The use of the Gamma distribution requires consideration of the skewness of the historic flow data. The required historic flow statistics are the same as for the normal distribution, plus the coefficient of skewness for each season.

The random numbers obtained from the RANDØM subroutine are normally distributed, that is centered about the mean (zero), and without skew. The coefficient of skewness is used to adjust the random numbers to the required skewed distribution. The calculation scheme is the same as for the normal distribution, except for the use of the skewed random number in place of the normally distributed random number.

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SYNFLØ DICTIONARY

Variable Name	Definition
AA	Random no., multiplier of UA, for random no. generation in RANDOM subroutine. (AA≥1).
AB	Random no., multiplier of UB, for random no. generation in RANDOM subroutine. (AB≥1).
ACØN	Array of 12 elements, computation device for log-normal distribution. Added to antilog of computed log of flow.
AM	Random no. for remaindering divisor in RANDOM subroutine. (AM>AA,CA, and UA).
ATERM	Computation device for normal and gamma distirubtion calculations.
BCØN	Computation device for log-normal distribution.
BM	Random no. for remaindering divisor in RANDOM subroutine. (BM>AB,CB, and UB).
BTERM	Array of 12 elements, computation device for normal and gamma distribution calculations.
CA	Random no., added to AA * UA product in RANDOM subroutine. (CA≥1).
CB	Random no., added to AB * UB product in RANDOM subroutine. (CB≥1).
CTERM	Computation device for log-normal calculation, analogous to ATERM.
DA	Divisor of calculated UA in RANDOM subroutine. Least power of 10 such that DA>AM.

Variable Name	Definition
DB	Divisor of calculated UB in RANDOM subroutine. Least power of 10 such that DB>BM.
DTERM	Array of 12 elements for log-normal calculations analogous to BTERM.
IR	Integer to set READ statements (=5, here).
ISTA	Integer station identification no., usually USGS no., maximum of 10 digits.
IW	Integer to set WRITE statements (=6, here).
KALL	Integer array of 12 elements for calling desired calculation form for each season: KALL = 1, Normal distribution; KALL = 2, Log-normal distribution; KALL = 3, Gamma distribution.
KYR	Integer for setting year type. KYR=1, calendar year (Jan-Dec); KYR=2, water year (oct-Sep). Calls appropriate headings for output.
N	Counter to number the years of output after the first 50 years are discarded.
NSEA	Number of seasons in each year, from 1 (annual flows) to 12 (monthly flows).
NYR	Number of years for which synthetic flows are to be generated, to 250. (The first 50 years are discarded to eliminate start-up effects).
QAV	Array of 12 elements for average historical flows for each season, in 1000 ac-ft units.
QAVL	Array of 12 elements for average flow logs calculated for each season to preserve historical flow statistics for Log-normal distribution calculation.

Variable Name	Definition
QLFLØ	Array of 12 elements for calculated logs of synthetic flows for each season.
RA	First of two random nos. calculated in RANDOM subroutine.
RAN	Array of random nos. calculated for each season one year at a time in RANDOM subroutine.
RAND	Name of COMMON storage for RANDOM subroutine.
RANDØM	Name of subprogram for generating random numbers.
RANSK	Value of RAN adjusted in Gamma distribution calculation to preserve skewness of historical flow data.
RB	Second of two random nos. calculated in RANDOM subroutine.
RLAG	Array of 12 elements for Lag-one serial correlation coefficients for each season from historical record.
RLAGL	Array of 12 elements for calculated Logs of Lag-one serial correlation coefficients of flow Logs, to preserve flow statistics of historical record.
SFLØ	Two-dimensional (12x250) array of calculated synthetic flow sequence of NSEA seasons (to 12) and NYR years (to 250), in 1000 ac-ft units.
SKEW	Array of 12 elements for skewness coefficients for each season from historical record.
STD	Array of 12 elements for standard deviations for each season from historical record, in 1000 ac-ft units.

Variable Name	Definition
STDL	Array of 12 elements for calculated Logs of standard deviations of flow Logs, to preserve flow statistics of historical record.
TERM3	Computation device in Log-normal calculation.
TERM4	Computation device in Log-normal calculation.
TERM5	Computation device in Log-normal calculation.
TERM6	Computation device in Log-normal calculation.
TFLØ	Array of 250 elements for annual totals of synthetic flows.
UA	First of two uniformly distributed random nos. calculated in RANDOM subroutine. Initiated by data entry such that UA≥1.
UB	Second of two uniformly distributed random nos. calculated in RANDOM subroutine. Initiated by data entry, UB≥1.
XSKEW	Computation device in Gamma calculation.

DATA

Input data for the SYNFLØ model consists of four groups. Integer data are used to identify the station under consideration (to 10 digits), to set the number of years of calculation, to set the number of seasons in each year, and to identify either a calendar year or water year sequence. Another set of integer data is used to specify the distribution form for each season for the calculation. Real number data are used to initiate and continue the random number calculation. Statistical data from the historic flow record are also entered as real numbers, one entry for each season for each of four parameters.

Data Sources

1. Integer Data: The required integer data are ISTA, NYR, NSEA, and KYR in one set, and the KALL array in a second set. (Definitions of the variable names are given in the program dictionary.) ISTA identifies the site or gaging station for which the synthetic flows are to be generated and from which the historic records are obtained. It is limited to 10 digits, and may be a USGS gaging station number or some other identifier.

NYR limits the number of years for which synthetic flows are to be generated. The program is set for an arbitrary maximum of 250 years, but fewer may be specified. The user should be aware that the first 50 years of synthetic flows are discarded in the model, so as to minimize any effects on the flow sequence from the steps initiating the calculations.

NSEA specifies the number of seasons to be considered in each year. A value of 1 produces annual flows, while the maximum value of 12 gives monthly flows. The choice of NSEA depends upon the purposes for which the synthetic flows are to be generated, and must be made before the seasonal statistics can be determined. The historic monthly flows must be grouped in the appropriate seasonal pattern for the external calculation of the flow statistics.

KYR is used to specify whether the generated synthetic flows pertain to a calendar year or a water year. A value of 1 specifies a calendar year, and a value of 2 specifies a water year. Input data must be prepared for the appropriate kind of year. The water year is assumed to run October-September, and output headings for the water year specification contain this information. This does not prevent the use of other water years in the calculation, provided appropriate records are kept as to the actual meaning of the seasonal columns in the output.

The KALL array specifies which one of the distribution calculation schemes is to be used for each season. A value of 1 calls the normal distribution scheme, 2 calls the log-normal scheme, and 3 calls the Gamma distribution scheme. The decision as to which distribution is to be called is based on an examination of the historic data and their flow statistics, including frequency graphs, for each season. The limited historic data may not provide a frequency distribution that allows a definite conclusion as to the type of distribution that it best fits, and the determination may be somewhat subjective.

2. <u>Random Number Data</u>: The model incorporates a subroutine for producing normally distributed random numbers with zero mean and unit standard deviation as they are needed in the calculation process. A set of 10 numbers is entered to initiate and maintain the random number generation. All but 2 of these numbers are obtained from uniformly distributed random numbers that are integers, but used in real form. An upper limit

as to the maximum number of digits in these numbers should be selected, say 3 or 4. The other two (DA and DB) are the least powers of 10 that are greater than the maximum values allowed for the other eight. DA and DB may, and usually will, be equal.

The eight uniformly distributed random numbers are in two sets, each set carrying an A or B identifier. UA, UB, AA, AB, CA, CB, AM, and BM are selected by some predetermined scheme from a source of uniformly distributed random integers. The only limitations on UA, UB, AA, AB, CA, and CB are that they are one or greater, and that the number of digits in each is less than the number of digits in DA or DB for the respective set. AM and BM are used in a remaindering scheme, and have the further limitation that they are greater than UA, AA, and CA, and UB, AB, and CB, respectively.

The numbers UA and UB are recalculated each time a random number (RAN) is generated, and carried forward to enter the next random number calculation. The others retain their initial value. A new set of these numbers should be obtained each time the model is run for a given station.

3. <u>Statistical Data</u>: Data for the historic flow record are entered in the form of statistics derived from the historic flow record. These statistics represent the available historic flows, and for the shorter historic records they may produce synthetic flows that are not truly representative of the stream. The statistics for the model must be for flows in 1,000 ac-ft for means and standard deviations. The other statistics required are the lag-one serial correlation coefficients and the skewness coefficients for each season.

Ideally, the historic record should be adjusted to represent virgin flows before the statistics are calculated, and then the synthetic virgin flows adjusted to the desired level of use. These adjustments would be made outside of the model.

Statistics for annual flows (one season) for the historic records of Wyoming streams may be obtained from the University of Wyoming Water Resources Research Institute (WRRI) where a Water Resource Data System (WRDS) is maintained. The necessary statistics for annual flows, and means and standard deviations for monthly flows, as well as a printout of the monthly and annual flow record (in ac-ft), may be obtained through their MADIS program for a nominal charge. For monthly flows, the lag-one serial correlation coefficients and skewness coefficients for each month can be readily calculated.

Season combinations other than annual or monthly would require the appropriate grouping of the historic monthly data into seasons. The statistics could then be calculated by hand, or by entering the grouped data into a computer for use in one of the "canned" statistical package programs.

Fiering and Jackson suggest that the statistics of the logs of the historical flows not be used in the log-normal calculations, as the synthetic flows reproduce the statistics of the logs. They provide relationships for statistics derived from the historic flow statistics that preserve the historic flow statistics in the log-normal synthetic flows. The calculations for these derived statistics are incorporated in the model for the log-normal distribution calculation sequence.

Flow records may be obtained from the WRRI WRDS system, from USGS published data, or from any other source of reliable data. Adjustments to obtain virgin flows could come from water rights data, and actual diversion or depletion records. A certain amount of estimation may be required to obtain virgin flows in some cases.

Statistical Data Calculations

The following calculation forms may be used to obtain the statistics from the historic data. Where it is necessary to perform these calculations outside of a computer the user should set up a tabulation and computation scheme compatible with whatever desk calculator is available, and that will permit the desired seasonal grouping of the data. As many significant figures as practical should be carried through the calculation, rounding off to about 4 for entering the coefficients as data.

1. Average Flow: The average flow statistic (QAV) for each season is the mean flow for each season from the historic record. It is obtained from

$$QAV(J) = \frac{1}{N} \sum_{I=1}^{N} X(I,J) \qquad (1)$$

where J is the season, N is the number of years of record for the season, and X(I,J) is the flow for season J in year I. QAV(J) must enter the model in 1,000 ac-ft units. The sum of the X(I,J) values should be retained for other calculations.

2. Standard Deviation: The standard deviation of a sample is defined as the square root of the sample variance. For computation purposes, it is usually easier to obtain the variance for each season first and then

take the positive square roots for the seasonal standard deviations (STD). A readily used variance formula is

$$V(J) = \frac{1}{N-1} \sum_{I=1}^{N} X(I,J)^2 - \frac{N}{N-1} \; QAV(J)^2 \qquad (2)$$

where I, J, N, and X(I,J) are as defined previously, V(J) is the variance of the X(I,J) values for season J, and QAV(J) is from equation (1). Retain the sum of the $X(I,J)^2$ values for each season for later calculations.

The standard deviation for season J for the historic data is then obtained from

$$STD(J) = \sqrt{V(J)} \qquad (3)$$

where STD(J) is the standard deviation of the historic flows in season J, and must be expressed in 1,000 ac-ft units when entered into the model.

3. Lag-one Serial Correlation Coefficient: A lag-one serial correlation coefficient, RLAG, is used in the model, on the assumption that a given season flow is influenced by at least the flow in the previous season. The calculation and later use of RLAG is somewhat complex for a lag-one correlation. For more than one lag, the calculation, and the incorporation into the model, involves a complexity that is ordinarily not justified in view of generally short records of historic data and their inexactness of agreement with one of the statistical distributions.

Defining I, J, N, X(I,J), and $X(I,J)^2$ as before, the following sub-calculations may be made preparatory to calculating RLAG(J):

$$A = \sum_{I=1}^{N} X(I,J)X(I,J-1) \qquad (4)$$

$$B = \sum_{I=1}^{N} X(I,J), \qquad (5)$$

$$C = \sum_{I=1}^{N} X(I,J-1) \tag{6}$$

$$D = \sum_{I=1}^{N} X(I,J)^2 \tag{7}$$

$$E = \sum_{I=1}^{N} X(I,J-1)^2 \tag{8}$$

Using equations (4) - (8), the expression for calculating RLAG for season J may then be written as

$$RLAG(J) = \frac{A - BC/N}{(D - B^2/N)^{0.5}(E - C^2/N)^{0.5}} \tag{9}$$

When season J is the first season of the year, season J-1 would be the last season of the previous year, or X(I-1,NSEA), in the expressions for A, equation (4), C, equation (6), and E, equation (8).

4. Skewness Coefficient: The skewness coefficients (SKEW) are required only for calculations with the Gamma distribution form. They should be checked, however, for each season as an indicator as to which distribution is appropriate and are normally entered as data for all seasons. Normally distributed flows should have a near-zero value of SKEW, with the absolute value increasing as the skewness increases. A flow distribution may have either positive or negative skewness.

The sub-calculation approach as used above is also useful for calculation of the seasonal coefficients for skewness. With I, J, N, $X(I,J)^2$ and QAV(J) as previously defined, calculate

$$F = \sum_{I=1}^{N} X(I,J)^3 \tag{10}$$

and, from the variance calculation in equation (2), let

$$G = \sum_{I=1}^{N} X(I,J)^2 \tag{11}$$

The calculation for the skewness coefficient for season J may be made from

$$SKEW(J) = \frac{F - 3(G)\{QAV(J)\} + 2(N)\ \{QAV(J)^3\}}{N\{(1/N)(G) - QAV(J)^2\}^{1.5}} \tag{12}$$

using F and G from equations (10) and (11), respectively, and QAV(J) as obtained from equation (1).

The data card for the seasonal skewness coefficients may be left blank if the Gamma distribution is not to be called for any season. However, if the coefficients are entered, a run using this distribution can be made for selected seasons by just changing KALL to 3 for those seasons.

Input Data Sequence

IR = 5)
IW = 6) For READ and WRITE statements, respectively, to facilitate interchange between computer systems. Entered in program ahead of first READ statement.

Data Card Ident.	Data Name & Notes
	READ (IR,1000) ISTA, NYR, NSEA, KYR 1000 FØRMAT (I12, 10 I6)
INT 001	ISTA is station identification number, usually USGS number, to a maximum of 10 digits.

NYR is the number of years for which flows are to be synthesized, up to 250. (The first 50 years are discarded by the program to eliminate the start-up influence, leaving up to 200 years for output).

NSEA is the number of seasons to be calculated for each year, any number from 1 (annual flows) to 12 (monthly flows). The seasons need not be of equal length - i.e., there could be 2 seasons, say 8 months "dry" and 4 months "wet".

KYR is the identifier for either a calendar year (1), or a water year (2). Output identifies the water year as Oct-Sep, but others may be used if output is hand-identified accordingly.

```
(READ (IR,1010) UA, AA, CA, AM, DA, UB, AB, CB, BM, DB)
 1010 FØRMAT(12 F 6.0)
```

(Provides data to begin random no. calculation)

RAN 002

UA is a random no. ≥ 1

AA is a random no. ≥ 1

CA is a random no. ≥ 1

AM is a random no. such that AM > UA, AA, & CA

DA is the least power of 10 that is > AM

UB is a random no. ≥ 1

AB is a random no. ≥ 1

CB is a random no. ≥ 1

BM is a random no. such that BM>UB, AB, & CB

DB is the least power of 10 that is > BM

```
READ (IR,1020) (KALL(J), J = 1,NSEA)
1020 FØRMAT (12 I 6)
```

KALL 003 — KALL(J) is the identifier for the distribution calculation to be used for season J. KALL(J) = 1 for normal distribution, KALL(J) = 2 for log-normal distribution, KALL(J) = 3 for Gamma distribution.

```
READ (IR,1010)(QAV(J), J=1, NSEA)
```

QAV 004 — QAV(J) is the average historic flow at the station for season J in 1000 ac-ft units.

```
READ (IR,1010)(STD(J), J=1, NSEA)
```

STD 005 — STD(J) is the standard deviation of the historic flow at the station for season J in 1000 ac-ft units.

```
READ (IR,1010)(RLAG(J), J=1, NSEA)
```

LAG 006 — RLAG(J) is the lag-one serial correlation coefficient for the historic flows at the station between season J and season J-1.

```
READ (IR,1010)(SKEW(J), J=1, NSEA)
```

SKEW 007 — SKEW(J) is the coefficient of skewness for the historic flow at the station for season J.

PROGRAM CALCULATIONS

The complexity of the equations used in the model for the various calculations justifies explanations of the adaptation of the equations to the model, and in certain cases, an outline of derivation steps. The four sets of calculations are for: (1) random numbers; (2) the normal distribution; (3) the log-normal distribution; and (4) the Gamma distribution.

Random Number Calculations

The generation of normally distributed random numbers with zero mean and unit standard deviation is accomplished in a subroutine named RANDØM. This subroutine is called by each of the distribution calculation schemes once for each year of calculation, and produces an array of random numbers, one element for each season of that year.

The subroutine call includes the number of seasons (NSEA) and the data sets for calculating two random numbers uniformly distributed over (0,1), RA and RB. The first set consists of UA, AA, CA, AM, and DA and is used to calculate RA. The second set, UB, AB, CB, BM, and DB is used to obtain RB. The values of UA and UB change during each calculation for a seasonal value. The others in the sets remain as entered on the data card.

The calculation scheme for a season, K, is as follows, where UA and UB are from the previous calculation for season K-1. Note that if K = 1, the first season, UA and UB were calculated for the last season of the previous year, or for the initial calculation, were entered as data. The calculation of a new UA and UB,

$$UA = UA * AA + CA \qquad (13)$$

and

$$UB = UB * AB + CB, \qquad (14)$$

is the first step. The remaindering function is then applied to these values,

UA = AMØD (UA,AM) (15)

and

UB = AMØD (UB,BM), (16)

revising UA and UB to integers smaller than DA and DB, respectively. The value of UA from equation (15) cannot be zero, as this would cause a division by zero in a later step. This is avoided by the statement

IF(UA.LE.0.) UA = 1. (17)

following equation (15) in the subprogram. It is permissible for UB to have a zero value.

The uniformly distributed random numbers RA and RB are calculated by

RA = UA/DA (18)

and

RB = UB/DB (19)

The above considerations establish RA such that $0 \leq RA \leq 1$ and RB such that $0 \leq RB \leq 1$.

With RA and RB determined, the random number for the season, RAN(K), is generated from:

RAN(K) = SQRT(ALØG(1./RA))* CØS(6.2832*RB) (20)

where the constant 6.2832 approximates 2π. Alternatively, the SIN function could be used in place of the CØS function. The number RAN(K) belongs to a population that is normally distributed with mean zero and unit standard deviation.

After calculation of a RAN array for the year, control returns to the point in the main program from which the subroutine was called. The most recent values of UA and UB are retained to start the calculation process when RANDØM is next called.

Distribution Calculations

The three distribution calculations are made with adaptations of a basic equation relating the statistics of the historic flows for each season plus a random number. The equation, in the form used for the normal distribution, is

```
SFLØ(I,J) = QAV(J) + (RLAG(J)*STD(J)/STD(J-1))*(SLFØ(I,J-1) - QAV(J-1)) +
RAN(J)*STD(J)*SQRT(1. - RLAG(J)**2.)                              (21)
```

where I and J denote the year and season, respectively, and the variable names are as defined in the model dictionary. Certain terms in equation (21) are constants for a given season for a particular distribution form. These seasonal constants are calculated prior to entering the annual and seasonal loops. The appropriate constants are then entered into the calculation according to the distribution called for the particular season.

Preliminary Steps: The arrays of seasonal constants, with intermediate calculation steps, are calculated in the DØ 100 loop. Reference to this loop will show the computations for: STDL(J), QAVL(J), RLAGL(J), ACØN(J), and DTERM(J) arrays of seasonal constants used in the log-normal distributions calculations, and the BTERM(J) array used in the normal and Gamma distribution calculations. Data required for this calculation loop are the statistics QAV(J), STD(J), RLAG(J), and SKEW(J).

Upon entering the annual loop, the value of TFLØ(I) is set to zero for year I. The subprogram RANDØM is then called to generate the random number array for year I, RAN(J). The program then moves to the seasonal loop for computation of the synthetic flows for each season of year I.

The first step in the seasonal loop is the calculation of three computation devices, XSKEW, ATERM, and CTERM. The calculation form for these depends upon the combination of I and J values for the particular year and season. For other than the first season (J>1) of any year after the first (I>1):

```
XSKEW = (SKEW(J) - (RLAG(J-1)**3.)*SKEW(J-1))/((1.-RLAG(J)**2.)
**1.5)                                                        (22)

ATERM = (RLAG(J)*STD(J)/STD(J-1))*(SFLØ(I,J-1) - QAV(J-1))
                                                              (23)
```

and

```
CTERM = (RLAGL(J)*STDL(J)/STDL(J-1))*(QLFLØ(J-1) - QAVL(J-1))
                                                              (24)
```

When the season is the first (J=1) of any year other than the first (I>1), the subscript J-1 in equations (22) - (24) would not be defined. It is necessary to refer to the last season (J=NSEA) of the previous year (I-1) for the calculations, thus:

```
XSKEW = (SKEW(J) - (RLAG(NSEA)**3.)*SKEW(NSEA))/((1.-RLAG(J)
**2.)**1.5)                                                   (25)

ATERM = (RLAG(J)*STD(J)/STD(NSEA))*(SFLØ(I-1,NSEA)-QAV(NSEA))
                                                              (26)
```

and

```
CTERM = (RLAGL(J)*STDL(J)/STDL(NSEA))*(QLFLØ(NSEA)-QAVL(NSEA))
                                                              (27)
```

Another special computation arises for the first season (J=1) of the first year (I=1). In this case XSKEW is calculated as in equation (25). ATERM and CTERM are each zero, as there is no previous year. The only approach is substitution of QAV(NSEA) for SLFØ (I-1,NSEA) in equation (26) for ATERM, and substitution of QAVL(NSEA) for QLFLØ(NSEA) in equation (27) for CTERM. Both substitutions result in a zero factor in their respective equations, so that

ATERM = 0. (28)

and

CTERM = 0. (29)

With XSKEW, ATERM, and CTERM determined from one of the above situations, the log form of the synthetic flow, QFLØ(J), is calculated in statement 230 from

QLFLØ(J)=QAVL(J)+CTERM+RAN(J)*DTERM(J) (30)

which is adapted from equation (21). It is necessary to calculate QLFLØ for each season so that a QLFLØ(J-1) value will be available for the calculation of CTERM in equations (24) or (27) in case the log-normal calculation is called for season J.

Normal Distribution: When the normal distribution is called for season J, or KALL(J)=1, the synthetic flow for season J of year I is obtained from equation (21) after substitution of the appropriate constants and parameters discussed above. Thus, in statement 241,

SLFØ(I,J)=QAV(J)+ATERM+RAN(J)*BTERM(J) (31)

Control then moves to 240, where SFLØ(I,J-1) is checked for a negative value and reset to zero if necessary.

Log-Normal Distribution: A value of KALL(J)=2 causes the calculation to be made with the log-normal distribution for season J of year I. The value of QLFLØ(J) from equation (30) is exponentiated and ACØN(J) is added in statement 242,

SFLØ(I,J)=EXP(QLFLØ(J))+ACØN(J) (32)

and control moves to 240 as before.

Gamma Distribution: When KALL(J)=3, the calculation for the Gamma distribution is called. Statement 243 calculates a skewed random number from XSKEW and RAN(J),

```
RANSK=(2./XSKEW)*((1.+XSKEW*RAN(J)/6.-(XSKEW**2.)/36.)
**3.)-2./XSKEW                                              (33)
```

The equation (31) form of the basic equation, with RANSK substituted for RAN(J), is used to obtain the synthetic flow for season J of year I,

```
SFLØ(I,J)=QAV(J)+ATERM+RANSK*BTERM(J)                       (34)
```

and control again moves to statement 240.

Negative Flows: The calculations for SFLØ(I,J) can produce a negative value at times. When this happens, it must be carried as negative until the next SFLØ(I,J) value is obtained (see equation (21)). The previous value is then SFLØ(I,J-1), and is reset to zero when negative from one of the following equations, depending upon the I and J combinations. When I is greater than 1 and J equals 1,

```
SFLØ(I-1,NSEA)=AMAX1(0.,SFLØ (I-1,NSEA))                    (35)
```

The usual case, when I is any year and J is greater than 1, uses the form

```
SFLØ(I,J-1)=AMAX1(0.,SFLØ(I,J-1))                           (36)
```

For the last season (J=NSEA) of the last year (I=NYR),the calculated SFLØ (NYR,NSEA) will not be used in any further calculations, and

```
SFLØ(NYR,NSEA)=AMAX1(0.,SFLØ(NYR,NSEA)                      (37)
```

The initial calculation, I=1, and J=1, does not involve a previous SFLØ(I,J) value. No resetting is required in this case.

Annual Totals: The final step in the seasonal loop, which is also the the final step in the annual loop, accumulates each seasonal value of SFLØ for year I to produce the year I total. The maximizing function is used on the current SFLØ value,

```
TFLØ(I)=TFLØ(I)+AMAX1(0.,SFLØ(I,J))                         (38)
```

to avoid any problem with possible negative SFLØ values.

Derivation Outline: In order to obtain the statistics for calculation with the log-normal distribution that will preserve the statistics of the historic flows, the solution of a set of 4 simultaneous equations is required for each season. Using a subscript x for the parameters of the historic flows and a subscript y for the parameters of the adjusted statistics for the log form, the 4 equations are:

$$\mu_x = a + \exp(\sigma_y^2/2 + \mu_y) \qquad (39)$$

$$\sigma_x^2 = \exp\{2(\sigma_y^2 + \mu_y)\} - \exp(\sigma_y^2 + 2\mu_y) \qquad (40)$$

$$\gamma_x = \frac{\exp(3\sigma_y^2) - 3\exp(\sigma_y^2) + 2}{\{\exp(\sigma_y^2) - 1\}^{3/2}} \qquad (41)$$

$$\rho_x = \{\exp(\sigma^2\rho_y) - 1\}/\{\exp(\sigma_y^2) - 1\} \qquad (42)$$

The number a is assumed as a lower bound on the historic flows (x) such that a synthetic flow log (y) may be defined by y = log (x - a). The parameters μ, σ^2, γ, and ρ denote the mean, variance, skewness coefficient, and lag-one serial correlation coefficient, respectively. By replacing μ_x, σ_x^2, γ_x and ρ_x with their sample estimates from the historic data, $\bar{x}$, s_x^2, g_x, and r_x, or in the model notation, QAV, STD^2, SKEW, and RLAG, respectively, for the season, the Equations (39) - (42) may be solved for the y, or log, parameters for that season.

Equation (41) contains only one unknown, σ_y^2, after substituting SKEW (or g) for the season for γ_x. Algebraic manipulation of Equation (41) results in a cubic form,

$$e^{3\sigma_y^2} + 3e^{2\sigma_y^2} - (g^2 + 4) = 0 \qquad (43)$$

Equation (43) was then solved for σ_y^2 after a technique by Hart[1]. The result is

[1]Hart, William L., College Algebra, 4th ed., D.C. Heath and Co., Boston, Mass., 1953 (pp 254-256)

$$\sigma_y^2 = \ln \frac{\left[\frac{(g^2+2)+g(g^2+4)^{1/2}}{2}\right]^{2/3} \left[\frac{(g^2+2)+g(g^2+4)^{1/2}}{2}\right]^{1/3} + 1}{\left[\frac{(g^2+2)+g(g^2+4)^{1/2}}{2}\right]^{1/3}} \quad (44)$$

from which

$$\sigma_y = \text{STDL} = (\sigma_y^2)^{1/2} \quad (45)$$

STDL, for the appropriate season, is used as the estimate of the standard deviation log for the log-normal calculation form.

With σ_y^2, or STDL^2, available from Equation (44), and s^2 (or STD^2) from the historic record for the season, the solution of Equation (40) for μ_y (or QAVL) is readily accomplished. The first step is to solve for $\exp(2\mu_y)$:

$$\exp(2\mu_y) = \frac{s^2}{\exp(\sigma_y^2)\ \{\exp(\sigma_y^2) - 1\}} \quad (46)$$

from which

$$\mu_y = \text{QAVL} = \frac{1}{2} \ln \{\exp(2\mu_y)\}. \quad (47)$$

QAVL for each season is the estimate of the average flow log for that season for the log-normal calculation.

Again, using σ_y^2, or STDL^2, from Equation (44) and the historic sample value of ρ_x (RLAG) for each season, the seasonal values of ρ_y(RLAGL) can be obtained by solution of Equation (42):

$$\rho_y = \text{RLAGL} = \frac{\ln\{\rho_x\{\exp(\sigma_y^2)-1\}+1\}}{\sigma_y^2} \quad (48)$$

RLAGL is the estimate of the lag-one serial correlation log to be used in the synthetic flow log-normal calculation.

The remaining solution is for $\underline{a}$ from Equation (39) for each season. With $\bar{x}$ (or QAV) from the historic record, and σ_y^2 (STDL^2) and μ_y (QAVL) from Equations (44) and (47), $\underline{a}$ or ACØN, is found from

$$a = AC\emptyset N = \bar{x} - \exp(\sigma_y^2/2 + \mu_y) \qquad (49)$$

ACØN is a lower bound for the log-normal distribution synthetic flows for each season.

The above solutions appear complicated, but are readily adapted to computer calculation. Each parameter is a constant for a given season, and a DØ loop (DØ100) is used to calculate them from the historic record statistics prior to entering the yearly loop.

OUTPUT

Model output is straightforward, basically a table of synthetic flows by season, with a row for each year. Headings are printed to give the basic information as to site identification, number of seasons, kind of year, and column headings. The first 50 years of synthetic flows are ignored, so as to essentially eliminate any influence from the start-up conditions. The remaining years of synthetic flows are numbered sequentially from one to NYR-50.

The basic printout outline is:

(1) "synthetic flows for (NSEA) seasons each year for station number (ISTA), (units of 1000 ac-ft)";

(2) Depending upon the value of KYR, a statement of the type of year (calendar or water) for which data were entered, calculated, and are to be printed;

(3) Tabulation headings for year number, 12 season numbers, and the annual total;

(4) A DØ loop for writing all but the first 50 years of the synthetic flows, consisting of:

(a) the loop instruction for I = 51 to NYR,

(b) a year counter, N, is established such that N = I-50,

(c) writing the output for year I, which is the year number (N) the seasonal synthetic flows for NSEA seasons plus zero entries for any season columns not used, then the annual total of the synthetic flows for year I;

(5) Following the tabulation of the synthetic flows, the distribution information for each season is printed;

(6) Finally, the historic statistics used in the calculations are printed for each season.

ADDITIONAL DISTRIBUTIONS

Other distribution forms may be added to the model, once the calculation scheme is devised for each distribution. Any additional array storages required must, of course, be included in a DIMENSIØN statement. An integer identifier for the distribution must be assigned, sequential with those previously used (1,2, and 3 in the initial model). This identifier would be entered in the KALL array for the seasons for which it would be required. Any new input data required may be entered with the "READ" statements ahead of the DØ100 loop.

Depending upon the calculation forms required for the added distribution, the programming could be interwoven with the existing program, added as a separate section, or added as a subroutine. Appropriate routing statements would be required. The calculation results must be such that they go into the SFLØ(I,J) array ahead of the TFLØ(I) summing, statement 200.

Following the above outline, any number of calculation sequences may be added, provided that they can be programmed to be compatible with the other aspects of the model.

CODING OUTLINE

```
      CØMMØN/RAND/RAN(12)
C
      DIMENSIØN SFLØ(250,12), TFLØ(250), QAV(12), STD(12),
                RLAG(12), SKEW(12), QAVL(12), STDL(12),
                RLAGL(12), QLFLØ(12), ACØN(12), BTERM(12),
                DTERM(12), KALL(12)

C
C     MØDEL FØR SYNTHETIC FLØW SEQUENCES FØR MULTIPLE
C     SEASØNS          EACH YEAR          FRØM STATISTICS
C     ØF HISTØRIC FLØW SEQUENCE -- BASIS MAY BE CALENDAR
C     YEAR ØR WATER YEAR (ØCT-SEP) -- DISTRIBUTED EITHER
C     NØRMAL, LØG-NØRMAL, ØR GAMMA, FRØM HISTØRIC FLØWS. --
C     DATA AND RESULTS ARE FØR 1000 AC-FT UNITS.
C     VERSIØN MAY 1977.
C
C     FLØW STATISTICS MUST BE ØBTAINED ØUTSIDE ØF MODEL.
C

      IR=5
      IW=6
      READ (IR,1000) ISTA, NYR, NSEA, KYR
 1000 FØRMAT(I12,10I6)
C
C     ISTA IS STATIØN NØ. ~~TØ 10 DIGITS~~ -- NYR IS NØ. ØF YEARS TØ
C     BE GENERATED TØ 250 -- NSEA IS NØ. SEASØNS IN YEAR
C     TØ 12 -- KYR IS KIND ØF YEAR (1= CALENDAR, 2= WATER).
C
      READ (IR,1010) UA, AA, CA, AM, DA, UB, AB, CB, BM, DB
 1010 FØRMAT(12F6.0)
C                                                  ARE          .GT. 1
C     INPUT FØR RANDØM NØ. SUBRØUTINE -- ALL ^ RANDØM NØS ^ BUT DA
C     AND DB -- AM .GT. UA, AA, CA -- BM .GT. UB, AB, CB -- DA AND
C     DB LEAST PWR ØF 10 .GT. AM AND BM, RESPECTIVELY.
C
      DØ 50 I=1, NYR
      DØ 50 J=1, 12
   50 SFLØ(I,J)=0.
C
```

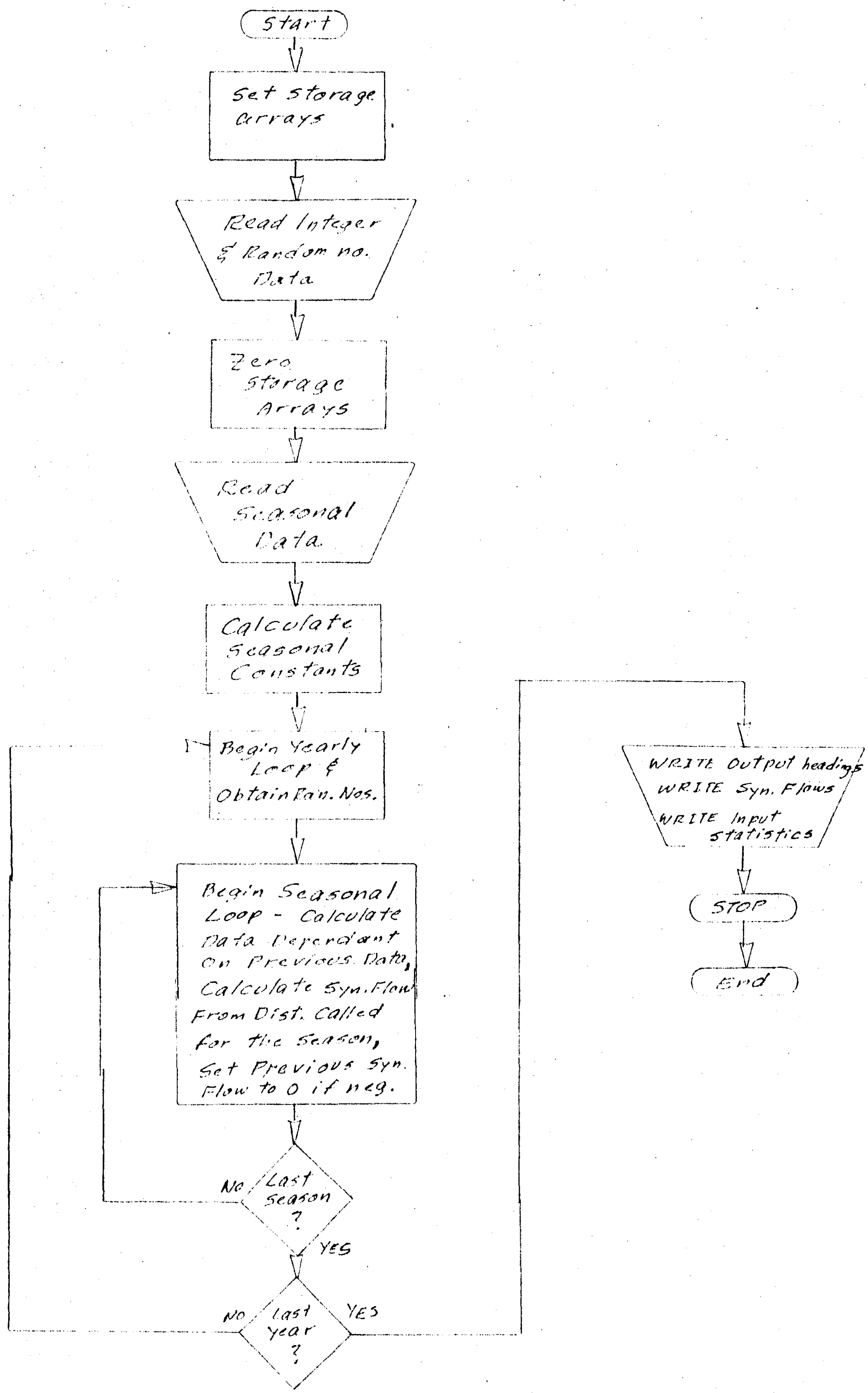
```
      DØ 60  J=1,12
      KALL (J) = 0.
      QAV (J) = 0.
      STD (J) = 0.
      RLAG(J) = 0.
      SKEW(J) = 0.
      QLFLØ(J) = 0.
      QAVL(J) = 0.
      STDL (J) = 0.
      RLAGL(J) = 0.
      ACØN (J) = 0.
      BTERM (J) = 0.
   60 DTERM (J) = 0.

      READ(IR, 1020) (KALL(J), J = 1, NSEA)
 1020 FØRMAT (12I6)
C
C     KALL IDENTIFIES DISTRIBUTION FØR ~~CALCULATION~~ EACH
C     SEASØN -- 1 = NØRMAL -- 2 = LØG-NØRMAL -- 3 = GAMMA.
C
      READ (IR, 1010) (QAV(J), J = 1, NSEA)
      READ (IR, 1010) (STD(J), J = 1, NSEA)
      READ (IR, 1010) (RLAG(J), J = 1, NSEA)
      READ (IR, 1010) (SKEW(J), J = 1, NSEA)
C
C     HISTØRIC FLØW STATISTICS BY SEASØN -- QAV IS AVG
C     FLØW, 1000 AC-FT -- STD IS STANDARD DEVIATIØN, 1000
C     AC-FT -- RLAG IS LAG-ØNE SERIAL CØRRELATIØN
C     CØEFFICIENT -- SKEW IS CØEFFICIENT ØF SKEWNESS.
C
C     CALCULATE SEASØNAL CØNSTANTS FRØM HISTØRIC STATISTICS--
C
      DØ 100  J = 1, NSEA
      TERM3 = ((SKEW (J) ** 2.  +  2. * SQRT (SKEW(J) ** 2. + 4.)) /
     &         2.) ** .33333
      TERM4 = (TERM3 ** 2.  -  TERM3  + 1.) / TERM3
      STDL (J) =  SQRT (ALØG (TERM4))
      TERM5  =  (STD(J) ** 2.) / (TERM4 * (TERM4 - 1.))
      QAVL (J) = ALØG (TERM5) / 2.
      TERM6 = RLAG(J) * (TERM4 - 1.) + 1.
      RLAGL (J) = ALØG (TERM6) / (STDL(J) ** 2.)
      BCØN =  (STDL (J) ** 2.) / 2.   +  QAVL (J)
      ACØN (J) =  QAV(J)  - EXP (BCØN)
      BTERM (J) =  STD (J)  * SQRT (1. - RLAG (J) ** 2.)
  100 DTERM (J) =  STDL (J) * SQRT (1. - RLAGL (J) ** 2.)
C
C     BEGIN ANNUAL LØØP FØR SYNTHETIC FLØWS --
C
```

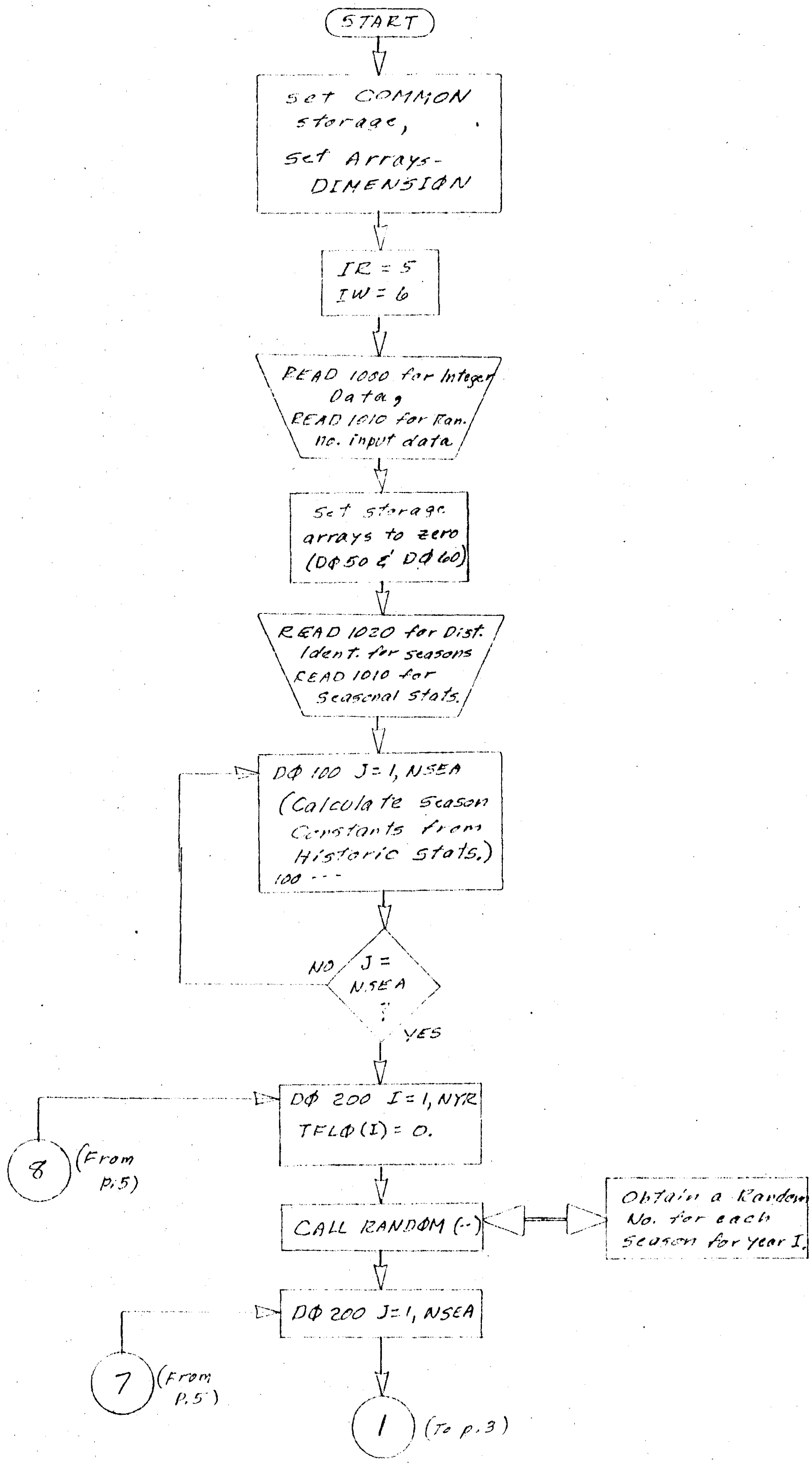
```
      DØ 200 I = 1, NYR
      TFLØ (I) = 0.
      CALL RANDØM (NSEA, UA, AA, CA, AM, DA, UB, AB, CB, BM, DB)
C
C     RANDØM GENERATES RANDØM NØ. FØR EACH SEASØN--
C                                                        NEW SET
C     ØBTAINED EACH YEAR.
C
C     BEGIN SEASØNAL LØØP FØR SYNTHETIC FLØWS EACH SEASØN
C     ØF YEAR I --
C
      DØ 200 J = 1, NSEA
      IF (I .EQ. 1 .AND. J .EQ. 1) GØ TØ 210
      IF (J .GT. 1) GØ TØ 220
C
C     FØR I .GT. 1 AND J = 1 --
C
      XSKEW = (SKEW(J) - (RLAG (NSEA) ** 3.) * SKEW(NSEA))/
              ((1. - RLAG(J) ** 2.) ** 1.5)
      ATERM = (RLAG(J) * STD(J)/STD(NSEA)) * (SFLØ(I-1,NSEA) - QAV(NSEA))
      CTERM = (RLAGL(J) * STDL(J)/STDL(NSEA)) * (QLFLØ( NSEA ) - QAVL(NSEA))
      GØ TØ 230
C
C     FØR I .GE. 1 AND J .GT. 1 --
C
  220 XSKEW = (SKEW(J) -(RLAG(J-1) ** 3.) * SKEW(J-1)) /
              ((1. - RLAG (J) ** 2.) ** 1.5)
      ATERM = (RLAG(J) * STD(J)/STD(J-1)) * (SFLØ(I, J-1) - QAV(J-1))
      CTERM = (RLAGL(J) * STDL (J)/STDL(J-1)) * (QLFLØ (.J-1) - QAVL (J-1))
      GØ TØ 230
C
C     FØR I = 1 AND J = 1 --
C
  210 XSKEW = (SKEW(J) - (RLAG (NSEA) ** 3.) * SKEW(NSEA)) /
              ((1. - RLAG (J) ** 2.) ** 1.5)
      ATERM = 0.
      CTERM = 0.
  230 QLFLØ (J) = QAVL (J) + CTERM + RAN(J) * DTERM (J)
C
C     CALCULATE SYNTHETIC FLØW FØR SEASØN BY CALLED DISTRIBUTIØN-
C
      GØ TØ (241, 242, 243), KALL (J)
C
C     NØRMAL DISTRIBUTIØN --
C
  241 SFLØ (I, J) = QAV(J) + ATERM + RAN(J) * BTERM (J)
      GØ TØ 240
```

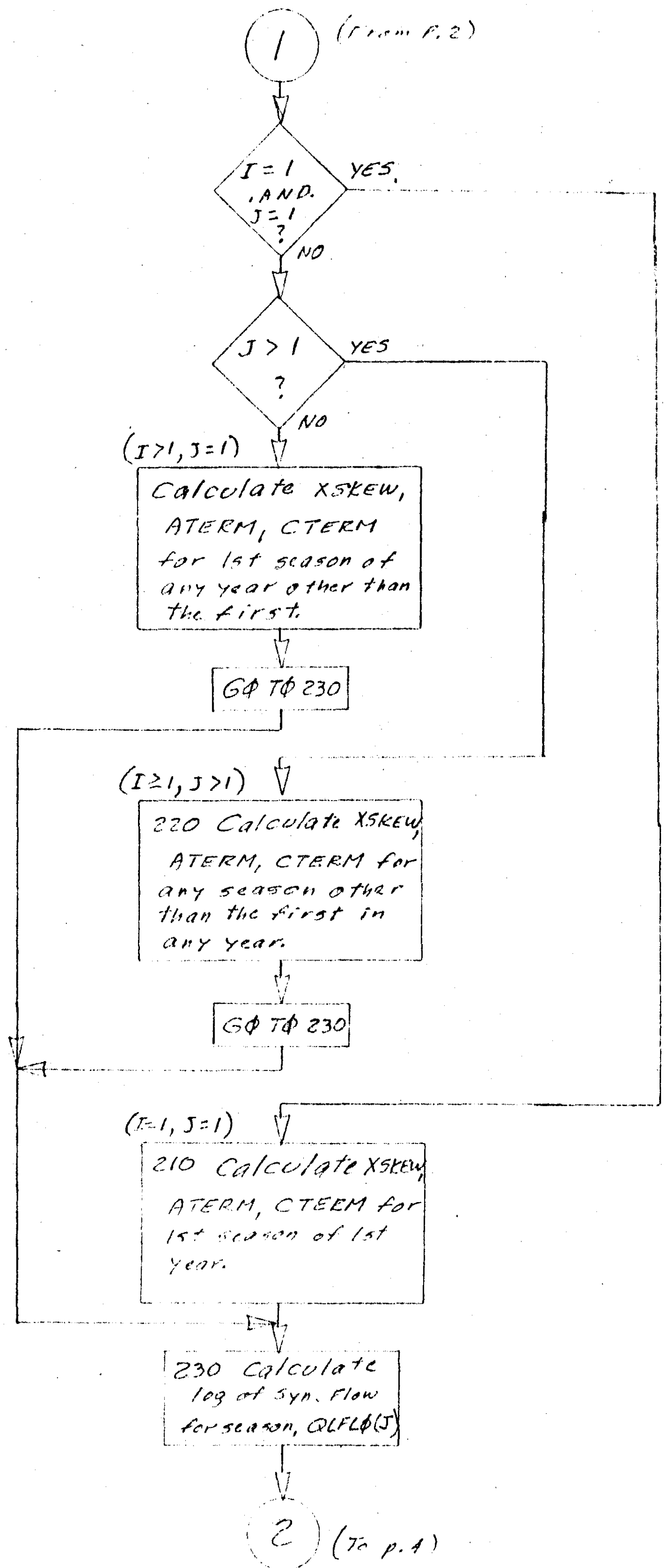
```
C
C        LØG-NØRMAL DISTRIBUTIØN --
C
  242   SFLØ(I,J) = EXP(QLFLØ(J)) + ACØN(J)
        GØ TØ 240
C
C        GAMMA DISTRIBUTIØN --
C
  243   RANSK = (2./XSKEW) * ((1. + XSKEW * RAN(J)/6. - (XSKEW ** 2.)/36.)
       ** 3.)  - 2./XSKEW
        SFLØ(I,J) = QAV(J) + ATERM + RANSK * BTERM(J)
C
C        IF PREVIØUS SFLØ .LT. 0, RESET TØ 0 --
C
  240   IF(I .EQ. NYR .AND. J .EQ. NSEA) GØ TØ 250
        IF(I .EQ. 1 .AND. J .EQ. 1) GØ TØ 200
        IF(J .GT. 1) GØ TØ 260
C
C        FØR I .GT. 1 AND J =1 --
C
        SFLØ(I-1, NSEA) = AMAX1(0., SFLØ(I-1,NSEA))
        GØ TØ 200
C
C        FØR I .GE. 1 AND J .GT. 1 --
C
  260   SFLØ(I, J-1) = AMAX1(0., SFLØ(I, J-1))
        GØ TØ 200
C
C        FØR I = NYR AND J = NSEA --
C
  250   SFLØ(NYR, NSEA) = AMAX1(0., SFLØ(NYR, NSEA))
  200   TFLØ(I) = TFLØ(I) + AMAX1(0., SFLØ(I, J))
C
C        WRITE ØUT HEADINGS--SYNTHETIC FLØWS -- HISTØRIC
C        SEASØNAL DISTRIBUTIØNS AND STATISTICS --
C
        WRITE (IW, 2000) NSEA, ISTA
 2000   FØRMAT(1H1, T10, 'SYNTHETIC FLØWS FØR', I3, 'b SEASØNS
             EACH YEAR FØR STATIØN NUMBER', I10, 'b (UNITS
             ØF 1000 AC-FT)')
        GØ TØ (910, 920), KYR
  910   WRITE(IW, 2010) NSEA
 2010   FØRMAT(1H0, T10, 'SEASØN SEQUENCE IS FØR CALENDAR
             YEAR DIVIDED INTØ', I3, 'b SEASØNS -- SEASØN 1
             BEGINS WITH JANUARY')
        GØ TØ 930
  920   WRITE (IW, 2020) NSEA
 2020   FØRMAT(1H0, T10, 'SEASØN SEQUENCE IS FØR WATER YEAR
             DIVIDED INTØ', I3, 'b SEASØNS -- SEASØN 1
             BEGINS WITH ØCTØBER')
```

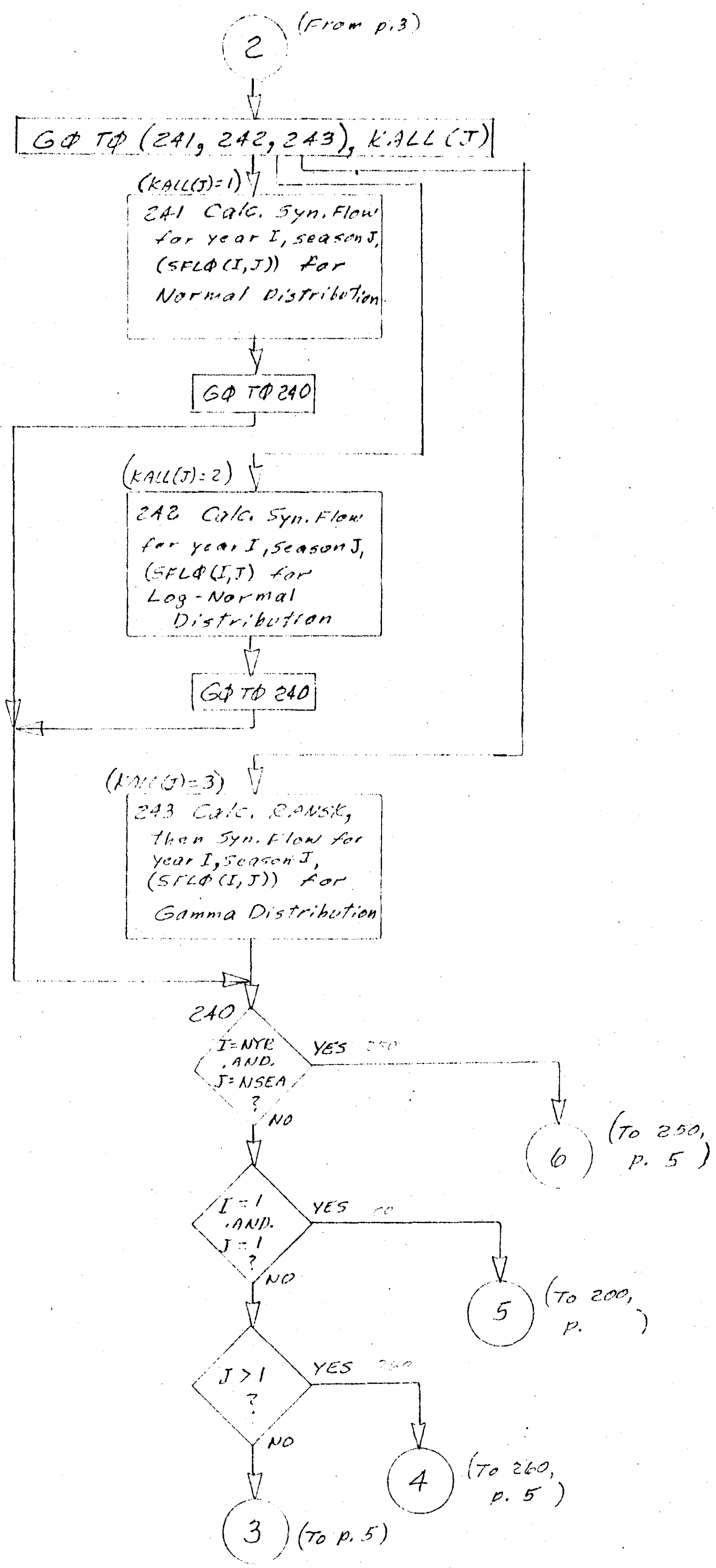
```
  930 WRITE(IW, 2030)
 2030 FØRMAT (1H0, T3, 'YEAR', T56, '--- SEASØN NUMBER ---',
     .        T120, 'ANNUAL')
      WRITE (IW, 2040)
 2040 FØRMAT (1Hb, T4, 'NØ.', T13, '1', T22, '2', T31, '3', T40, '4', T49,
     .        '5', T58, '6', T67, '7', T76, '8', T85, '9', T93, '10', T102,
     .        '11', T111, '12', T121, 'TØTAL')
      WRITE (IW, 2050)
 2050 FØRMAT (1Hb)
C
C     DISCARD FIRST 50 YEARS ØF SYNTHETIC FLØWS --
C     WRITE ØUT REMAINING YEARS BY SEASØNS --
C
      DØ 940 I= 51, NYR
      N = I - 50
      WRITE (IW, 2060) N, (SFLØ (I, J), J=1,12), TFLØ(I)
 2060 FØRMAT (1Hb, T3, I4, 12F9.2, F12.2)
  940 CØNTINUE

      WRITE (IW, 2070)
 2070 FØRMAT (1H0, T10, '*** DISTRIBUTIØN TYPE ** 1 -- NØRMAL **
     .        2 -- LØG-NØRMAL ** 3 -- GAMMA *** ')
      WRITE (IW, 2080) (KALL(J), J=1, NSEA)
 2080 FØRMAT (1H0, T7, 12I9)
      WRITE (IW, 2090)
 2090 FØRMAT (1H0, T10, '*** HISTØRIC RECØRD STATISTICS ***')
      WRITE (IW, 2100)
 2100 FØRMAT(1H0, T5, '** AVERAGE FLØWS -- 1000 AC-FT **')
      WRITE (IW, 2110) (QAV(J), J=1, NSEA)
 2110 FØRMAT(1H0, T7, 12F9.2)
      WRITE (IW, 2120)
 2120 FØRMAT (1H0, T5, '** STANDARD DEVIATIØNS -- 1000 AC-FT **')
      WRITE (IW, 2110) (STD(J), J=1, NSEA)
      WRITE (IW, 2130)
 2130 FØRMAT (1H0, T5, '** LAG-ØNE SERIAL CØRRELATIØN
     .        CØEFFICIENTS **')
      WRITE (IW, 2140) (RLAG(J), J=1, NSEA)
 2140 FØRMAT (1H0, T7, 12F9.5)
      WRITE(IW, 2150)
 2150 FØRMAT (1H0, T5, '** CØEFFICIENTS ØF SKEWNESS **')
      WRITE (IW, 2140) (SKEW(J), J=1, NSEA)

      STØP
      END
```

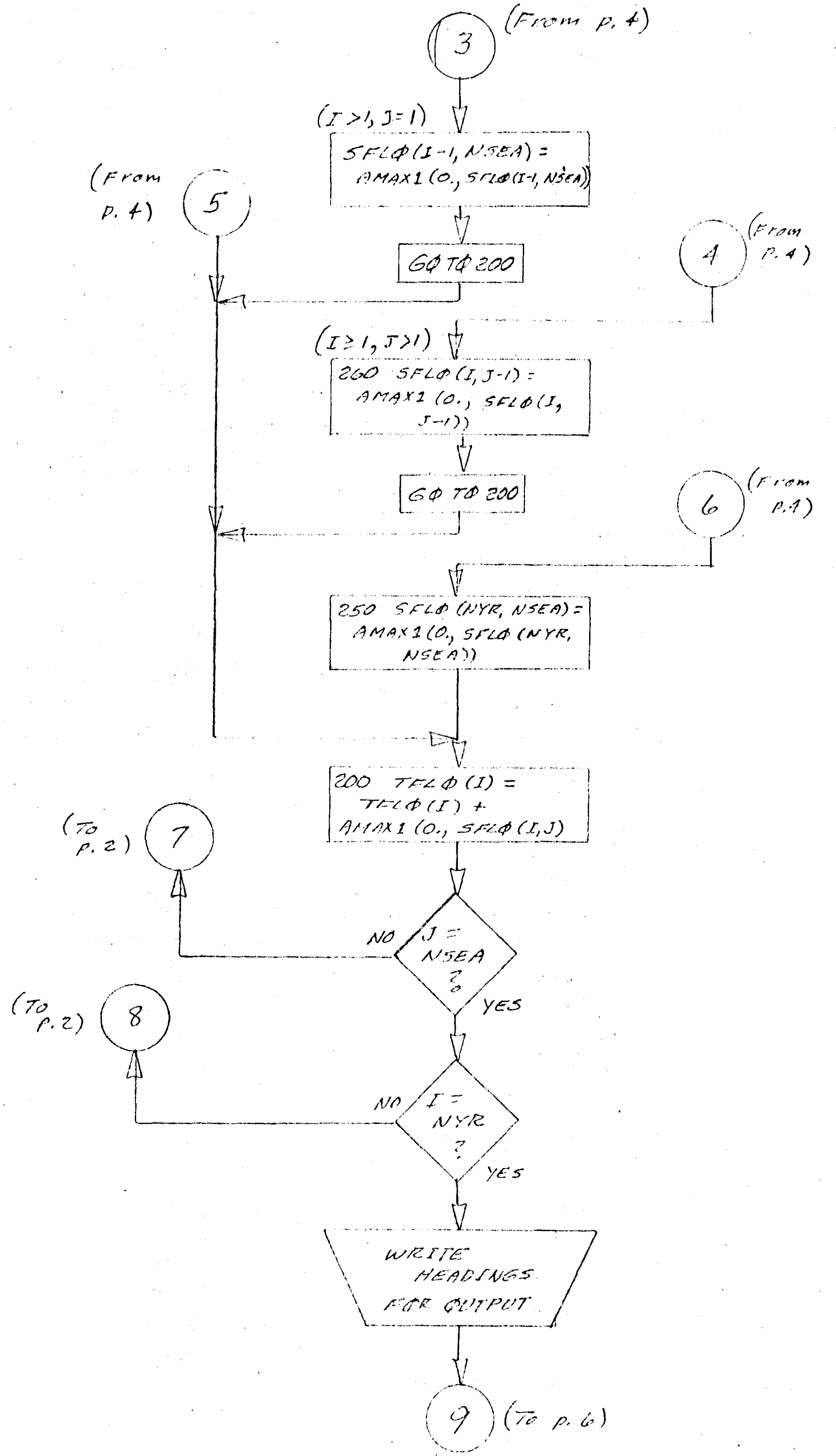
```
      SUBRØUTINE RANDØM (NSEA, UA, AA, CA, AM, DA, UB, AB, CB,
                         BM, DB)
      CØMMØN/RAND/RAN(12)
C
C     CALCULATE 2 UNIFORM DIST. OVER 0-1 RANDØM NØS,
C     RA AND RB -- THEN NØRMAL DIST RANDØM NØ., RAN,
C     WITH MEAN = 0 AND VARIANCE = 1 FØR EACH SEASØN--
C
      DØ 10 K = 1, NSEA
      UA = UA * AA + CA
      UA = AMØD(UA, AM)
      IF (UA .LE. 0.) UA = 1.
      RA = UA/DA
      UB = UB * AB + CB
      UB = AMØD (UB, BM)
      RB = UB/DB
   10 RAN(K) = SQRT(ALØG (1./RA)) * CØS (6.2832 * RB)

      RETURN
      END
```

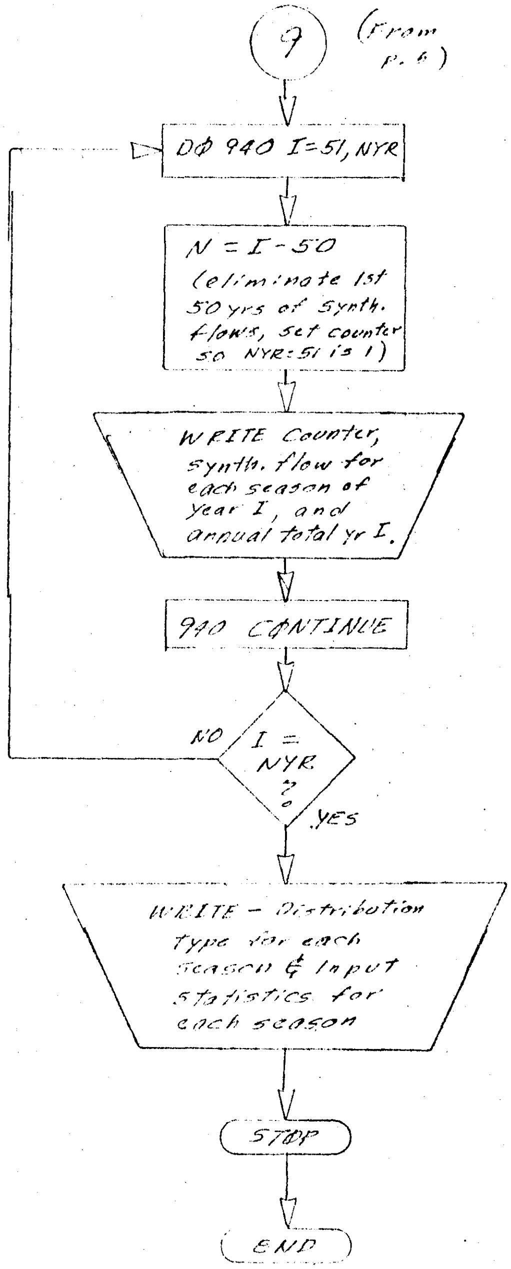

Start
Set storage arrays
Read Integer & Random no. Data
Zero Storage Arrays
Read Seasonal Data
Calculate Seasonal Constants
Begin Yearly Loop & Obtain Ran. Nos.
Begin Seasonal Loop - Calculate Data Dependant On Previous Data, Calculate Syn. Flow From Dist. Called for the Season, Set Previous Syn. Flow to 0 if neg.
Last Season ?
No
YES
Last Year ?
No
YES
WRITE Output headings
WRITE Syn. Flows
WRITE Input statistics
STOP
End


START
set COMMON storage,
Set Arrays-DIMENSIØN
IR = 5
IW = 6
READ 1000 for Integer Data,
READ 1010 for Ran. no. input data
Set storage arrays to zero (DØ 50 & DØ 60)
READ 1020 for Dist. Ident. for seasons
READ 1010 for Seasonal stats.
DØ 100 J = 1, NSEA
(Calculate Season Constants from Historic stats.)
100 - - -
J = NSEA ?
NO
YES
DØ 200 I = 1, NYR
TFLØ(I) = 0.
8
(From p.5)
CALL RANDØM (--)
Obtain a Random No. for each Season for Year I.
DØ 200 J = 1, NSEA
7
(From p.5)
1
(To p.3)

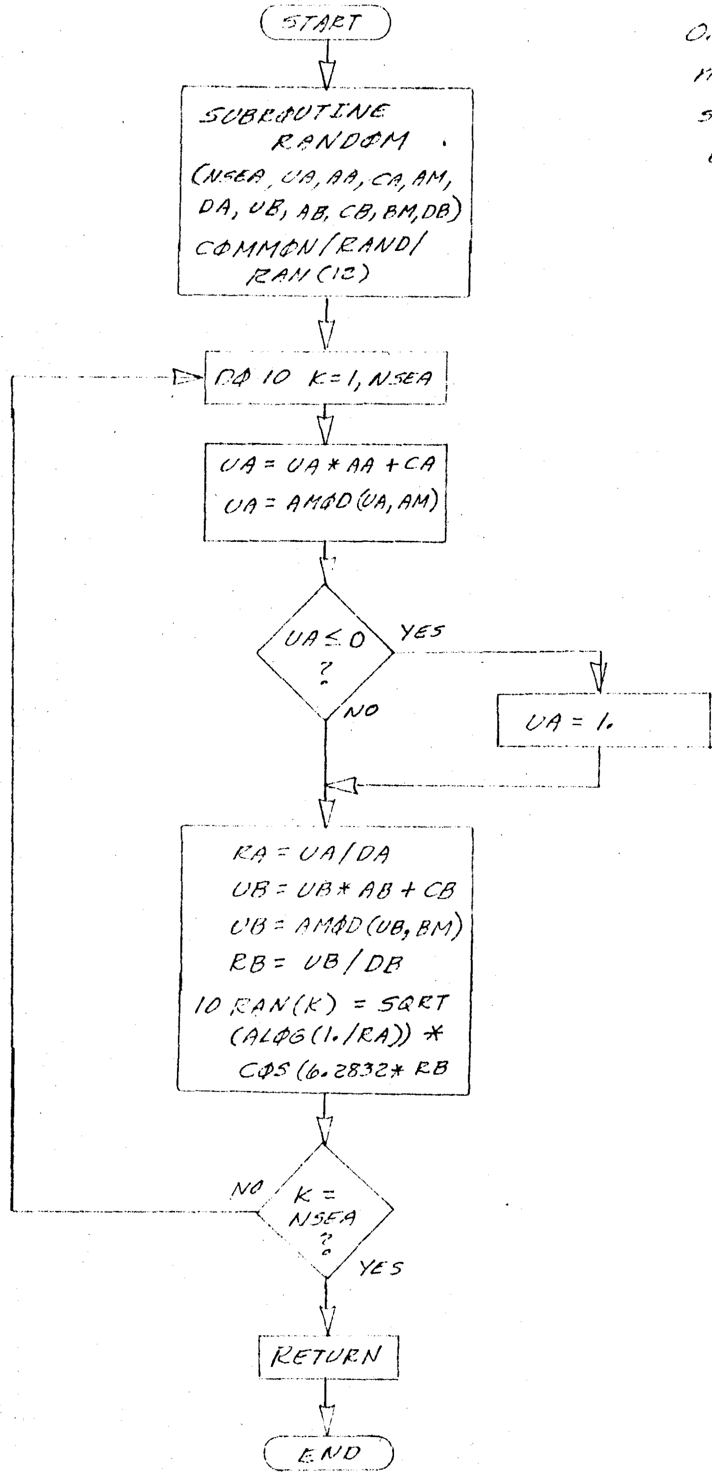

1
(from p. 2)
I = 1 .AND. J = 1 ?
YES
NO
J > 1 ?
YES
NO
(I>1, J=1)
Calculate XSKEW, ATERM, CTERM for 1st season of any year other than the first.
GØ TØ 230
(I≥1, J>1)
220 Calculate XSKEW, ATERM, CTERM for any season other than the first in any year.
GØ TØ 230
(I=1, J=1)
210 Calculate XSKEW, ATERM, CTERM for 1st season of 1st year.
230 Calculate log of Syn. Flow for season, QLFLØ(J)
2
(To p. 4)


2
(From p.3)
GØ TØ (241, 242, 243), KALL(J)
(KALL(J)=1)
241 Calc. Syn. Flow for year I, season J, (SFLØ(I,J)) for Normal Distribution
GØ TØ 240
(KALL(J)=2)
242 Calc. Syn. Flow for year I, Season J, (SFLØ(I,J) for Log-Normal Distribution
GØ TØ 240
(KALL(J)=3)
243 Calc. RANSK, then Syn. Flow for year I, Season J, (SFLØ(I,J)) for Gamma Distribution
240
I=NYR .AND. J=NSEA ?
YES
NO
6
(To 250, p. 5)
I=1 .AND. J=1 ?
YES
NO
5
(To 200, p.)
J > 1 ?
YES
NO
4
(To 260, p. 5)
3
(To p. 5)


3
(From p. 4)
(I>1, J=1)
SFLØ(I-1, NSEA) = AMAX1 (0., SFLØ(I-1, NSEA))
(From p. 4)
5
GØ TØ 200
4
(From p. 4)
(I≥1, J>1)
260 SFLØ(I, J-1) = AMAX1 (0., SFLØ(I, J-1))
GØ TØ 200
6
(From p. 4)
250 SFLØ (NYR, NSEA) = AMAX1(0., SFLØ (NYR, NSEA))
200 TFLØ (I) = TFLØ (I) + AMAX1 (0., SFLØ (I,J)
(To p. 2)
7
NO
J = NSEA ?
YES
(To p. 2)
8
NO
I = NYR ?
YES
WRITE HEADINGS FØR ØUTPUT
9
(To p. 6)


9
(From p. 6)
DØ 940 I=51, NYR
N = I - 50
(eliminate 1st 50 yrs of synth. flows, set counter so NYR=51 is 1)
WRITE Counter, synth. flow for each season of year I, and annual total yr I.
940 CØNTINUE
NO
I = NYR ?
YES
WRITE - Distribution type for each season & Input statistics for each season
STØP
END

(see p. 2 for call)



OBTAINS a random number for each season. Called once for each year.