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SUITABILITY OF BASINS TO WEATHER
MODIFICATION AND STATISTICAL
EVALUATION OF ATTAINMENT

Final Report for FY 1966 and 1967

Prepared for:
Bureau of Reclamation
Office of Atmospheric Water Resources
Denver, Colorado

PROJECT SKYWATER

Under Contract No. 14-06-D-6007

by Dr. H. J. Morel-Seytoux
Associate Professor of Civil Engineering

July 1, 1968

HYDROLOGY PROGRAM
COLORADO STATE UNIVERSITY
Fort Collins, Colorado

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Part 4



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INTRODUCTION

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This part, the fourth part, documents the computer programs in the form of subroutines that were used to carry the calculations reported in Part 1. These subroutines will be used repeatedly in the future in conjunction with the development and exploitation of the Hydrologic Data System. FORTRAN listings and source decks of the subroutines can be obtained by writing to the following address:

Professor H. J. Morel-Seytoux
Engineering Research Center
Foothills Campus
Colorado State University
Fort Collins, Colorado 80521

The subroutines belong to two main categories. One category consists of subroutines that calculate simple statistics (e.g., MEAVAR) or perform statistical tests (e.g., TACKI). The other category consists of subroutines that are convenient for use of the data tapes (e.g., RAWTAP).

INTRODUCTION

PART 4

For convenience the Final Report to the Bureau of Reclamation was divided into four parts. The first part is of general interest. It is a summary of the work done and contains the conclusions of the research.

This part, the fourth part, documents the computer programs in the form of subroutines that were used to carry the calculations reported in Part 1. These subroutines will be used repeatedly in the future in conjunction with the development and exploitation of the Hydrologic Data System. FORTRAN listings and source decks of the subroutines can be obtained by writing to the following address:

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LIST OF SUBROUTINES

PART 4

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MEAVAR

A FORTRAN IV Subroutine

Purpose: Calculation of simple statistics, given a sample. The statistics which are calculated are: mean, variance, unbiased variance, standard deviation and unbiased standard deviation.

Call Statement:

CALL MEAVAR (NDATA, X, XBAR, VARIAN, UNBIVA, SDX, UNBSDX, IREAD, IPRINT)

FORTRAN Variables Definition:

NDATA: number of elements x_i in the sample

X: array of elements x_i of the sample

XBAR: mean value of the x_i , usually denoted \bar{x}

VARIAN: variance of sample, often denoted S_x^2

UNBIVA: unbiased variance of sample, \hat{S}_x^2

SDX: standard deviation of sample, S_x

UNBSDX: unbiased standard deviation of sample, \hat{S}_x

IREAD: index of reading option. If IREAD is negative (or zero) the subroutine does not read data from cards (this implies that the data are already available in storage). If IREAD is positive the subroutine reads the data from cards, according to the following format:

1st card: NDATA in the field of 1-10 (integer mode), then 7 values of x_i in the fields 11-20, 21-30, ...etc.... in floating point mode.

other cards (number of cards depend on value of NDATA): 1 value of x_i per field of 10 columns in floating point mode.

IPRINT: index of printing output option. If IPRINT is negative (or zero) no output is expected from the subroutine.

If IPRINT is positive the subroutine prints out the results of the calculations it has just performed before returning control to the main program.

Note: IREAD and IPRINT are control parameters that must be set to the proper value, corresponding to the desired option, in the main program, prior to calling the subroutine.

Mathematical Symbols and Formulae:

Given the sample of N elements x_i then,

$$\bar{x} = \frac{\sum x_i}{N} \quad (1)$$

$$\Delta x_i = x_i - \bar{x}$$

$$S_x^2 = \frac{\sum (\Delta x_i)^2}{N} \quad (2)$$

$$S_x^2 = \frac{\sum (\Delta x_i)^2}{N - 1} = \frac{N}{N - 1} S_x^2 \quad (3)$$

Signature:

Subroutine written by H. J. Morel-Seytoux, May 2, 1967,
Department of Civil Engineering, Colorado State University.
Documentation written by H. J. Morel-Seytoux, June 16,
1967.

SIGNI	Interpretation
0	no significance
1	significance at the 95% level
2	significance at the 98% level
3	significance at the 99% level

UTEST

A ~~F~~ORTRAN IV Subroutine

Purpose: Test on the means of hypothesis that 2 samples come from the same population, assuming (1) that the two sample variances are not significantly different, and (2) that the common population variance is known or can be estimated accurately.

Call Statement:

CALL UTEST (N1, XBAR1, VAR1, N2, XBAR2, VAR2,
U~~Φ~~BSER, ISIGNI, IREAD, IPRINT)

~~F~~ORTRAN Variables Definition:

N1: size of first sample, N_1

XBAR1: mean of first sample, \bar{x}_1

VAR1: variance of first sample, S_1^2

N2: size of second sample, N_2

XBAR2: mean of second sample, \bar{x}_2

VAR2: variance of second sample, S_2^2

U~~Φ~~BSER: value of statistic $(\bar{x}_2 - \bar{x}_1) / \hat{S}_m$

where \hat{S}_m is the unbiased standard error of the mean

ISIGNI: index of significance, according to following code:

ISIGNI	Interpretation
0	no significance
1	significance at the 95% level
2	significance at the 98% level
3	significance at the 99% level

IREAD: index of reading option (at present IREAD must be set to -1)

IPRINT: index of printing output option (see MEAVAR)

Statistical Basis, Mathematical Symbols and Formulae:

Given two samples, one calculates the unbiased pooled variance \hat{S}_p^2 ,

$$\hat{S}_p^2 = \frac{N_1 S_1^2 + N_2 S_2^2}{(N_1 + N_2 - 2)} \quad (1)$$

and the unbiased standard error of the mean,

$$\hat{S}_m = \hat{S}_p \sqrt{\frac{1}{N_1} + \frac{1}{N_2}} \quad (2)$$

One then compares the statistic $(\bar{x}_2 - \bar{x}_1) / \hat{S}_m$ to the values of the standard normal variate u at the 95, 98 and 99 % levels.

Note: This test of significance should not be used for values of $(N_1 + N_2 - 2)$ less than 60.

Note: This is a two-tailed test.

Signature:

Subroutine written by H. J. Morel-Seytoux, May 3, 1967,
Department of Civil Engineering, Colorado State University.
Documentation written by H. J. Morel-Seytoux, June 19,
1967.

TTEST

A ~~F~~ORTRAN IV Subroutine

Purpose: Performance of test of significance of difference in means from two samples (large or small). The null hypothesis is: the samples come from the same population. It is assumed that the variances of the 2 samples are not significantly different.

Call Statement:

CALL TTEST (N1, XBAR1, VAR1, N2, XBAR2, VAR2,
T~~O~~BSER, ISIGNI, IREAD, IPRINT)

~~F~~ORTRAN Variables Definition:

N1: size of first sample, N_1

XBAR1: mean of first sample, \bar{x}_1

VAR1: variance of first sample, S_1^2

N2: size of second sample, N_2

XBAR2: mean of second sample, \bar{x}_2

VAR2: variance of second sample, S_2^2

T~~O~~BSER: value of statistic $(\bar{x}_2 - \bar{x}_1) / \hat{S}_m$ where \hat{S}_m
is the unbiased standard error of the mean.

ISIGNI: index of significance, according to following code:

ISIGNI	Interpretation
0	no significance
1	significance at the 95% level
2	significance at the 98% level
3	significance at the 99% level

IREAD: index of reading option (at present IREAD must be set equal to -1)

IPRINT: index of printing output option (see MEAVAR)

Statistical Basis, Mathematical Symbols and Formulae:

The unbiased pooled variance of the two samples is calculated:

$$\hat{S}_p^2 = \frac{N_1 S_1^2 + N_2 S_2^2}{N_1 + N_2 - 2} \quad (1)$$

and the unbiased standard error of the mean is deduced:

$$\hat{S}_m = \hat{S}_p \sqrt{\frac{1}{N_1} + \frac{1}{N_2}} \quad (2)$$

One compares the statistic $(\bar{x}_2 - \bar{x}_1) / \hat{S}_m$ to the values of Student's *t* distribution at the 95, 98 and 99 % levels and at the proper value of the degree of freedom $\nu = N_1 + N_2 - 2$.

Note: this is a two-tailed test.

Signature:

Subroutine written by H. J. Morel-Seytoux, May 8, 1967,

Department of Civil Engineering, Colorado State University.

Documentation written by H. J. Morel-Seytoux, June 19, 1967.

REGRES

A FØRTRAN IV Subroutine

Purpose: Calculation of (1): the parameters of the regression line of y on x given N pairs of values (x_i, y_i) , (2): the coefficients of correlation and of determination, and (3): the standard error of estimate

Call Statement:

CALL REGRES (NDATA, X, Y, ASLØPE, YZERØ, CORCØF, DETCOF, SESTY, IREAD, IPRINT)

FØRTRAN Variables Definition:

NDATA: number of pairs of values x_i, y_i

X: array of values x_i

Y: array of values y_i

ASLØPE: slope of the regression line i.e., coefficient of x in Equation (1): $y = mx + y_0$

YZERØ: ordinate at origin i.e., value of y_0 in Eq. (1)

CØRCØF: coefficient of correlation (decimal) usually denoted r in the literature

DETCØF: coefficient of determination (decimal) i.e., the square of the coefficient of correlation: r^2 .

SESTY: standard error of estimate of y using the regression line

IREAD: index of reading option. If IREAD is negative the subroutine does not read data from cards (this implies that the data are already available in storage). If IREAD is positive the subroutine reads the data from cards. At present this option is not programmed and IREAD is ignored by the subroutine.

IPRINT: index of printing output option. If IPRINT is negative no output is expected from the subroutine. If IPRINT is positive the subroutine prints out the results of the calculations it has just performed, before returning control to the main program.

Note: IREAD and IPRINT are control parameters that must be set to the proper value, corresponding to the desired option, in the main program, prior to calling the subroutine.

Mathematical Symbols and Formulae:

Given the set of N data pairs (x_i, y_i) , the coefficients of the regression line, $y = mx + y_0$, are calculated by the formulae:

$$m = \frac{\sum \Delta y_i \Delta x_i}{\sum \Delta x_i^2} \quad (2) \quad y_0 = \bar{y} - m \bar{x} \quad (3)$$

where $\Delta y_i = y_i - \bar{y}$, $\Delta x_i = x_i - \bar{x}$

$$r = \frac{\sum \Delta y_i \Delta x_i}{\sqrt{\sum (\Delta x_i)^2} \cdot \sqrt{\sum (\Delta y_i)^2}} \quad (4)$$

$$\text{S. E. of estimate } y = \sqrt{(1 - r^2)} \cdot S_y \quad (5)$$

where S_y is the S. D. of y_i , given by the formula:

$$S_y^2 = \frac{\sum (\Delta y_i)^2}{N} \quad (6)$$

Signature:

Subroutine written by H. J. Morel-Seytoux, April 13, 1967,
Department of Civil Engineering, Colorado State University.
Documentation written by H. J. Morel-Seytoux, April 26,
1967.

FIMEAN

A FORTRAN IV Subroutine

Purpose: Evaluation of the limits of confidence for the population mean, given the sample size, mean and variance. It is valid for large or small sample size. The limits of confidence are calculated at the 95, 98 and 99 % levels.

Call Statement:

CALL FIMEAN (NDATA, XBARS, VARSAM, MEANMA,
MEANMI, IREAD, IPRINT)

FORTRAN Variables Definition:

NDATA: size of sample, N

XBARS: mean of sample, \bar{x}

VARSAM: variance of sample, S^2

MEANMA: array of maximum values of the unknown
population mean at the 95, 98 and 99 %
levels of confidence

MEANMI: similar array for the minimum values

IREAD: at present this index is ignored (see REGRES)

IPRINT: index of printing option (see MEAVAR)

Note: see MEAVAR

Note: arrays MEANMA and MEANMI are defined in Floating point mode
Mathematical Symbols and Formulae:

Let $k = 1, 2, 3$ correspond respectively to the 95, 98 and 99 % levels of confidence.

It is a result due to Student (see Weatherburn C. E., "A first course in mathematical statistics," page 188) that the statistic

$$\frac{(\bar{x} - \mu)\sqrt{N}}{\hat{S}}, \quad \text{where } \mu \text{ is the unknown population mean and}$$

\hat{S} the unbiased standard deviation of the sample, is distributed like $t(\nu)$, where $\nu = N - 1$ is the number of degrees of freedom of the t -distribution. The maximum value of μ at the level k is:

$$\text{MEANMA}(K) = \bar{x} + \frac{\hat{S} t_k(\nu)}{\sqrt{N}} \quad (1)$$

$$\text{Similarly, } \text{MEANMI}(K) = \bar{x} - \frac{S t_k(\nu)}{\sqrt{N}} \quad (2)$$

Tables of $t_k(\nu)$ are stored in the subroutine.

Note: for large values of ν (i.e. $\nu > 60$) there is no appreciable difference between the t -distribution and the standard normal distribution.

Signature:

Subroutine written by H. J. Morel-Seytoux, May 22, 1967,
Department of Civil Engineering, Colorado State University.
Documentation written by H. J. Morel-Seytoux, June 16, 1967.

Statistical Basis, Mathematical Symbols and Formulae:

Fisher (C. E. Weatherburn, "A First Course in Mathematical Statistics," page 200) has shown that the random variable

$x = \frac{1}{2} \ln \left(\frac{1+r}{1-r} \right)$ is approximately normal with mean

$\xi = \frac{1}{2} \ln \left(\frac{1+p}{1-p} \right)$ and variance $\frac{1}{(N-3)}$, where r

is the sample coefficient of correlation, p is the unknown population coefficient of correlation and N is the common

FIDCØR

A FØRTRAN IV Subroutine

Purpose: Evaluation of the limits of confidence for the coefficient of correlation between two samples, at the 95, 98 and 99% levels.

Call Statement:

CALL FIDCØR (NDATA, CØRCØF, RHØMAX, RHØMIN, IREAD, IPRINT)

FØRTRAN Variables Definition:

NDATA: common size of two samples

CØRCØF: coefficient of correlation as obtained by linear regression, denoted usually as r

RHØMAX: array of maximum values of the unknown population coefficient of correlation at the 95, 98 and 99% levels

RHØMIN: similar array for the minimum values.

IREAD: at present this index is ignored (see REGRES)

IPRINT: index of printing option (see MEAVAR)

Note: see MEAVAR

Statistical Basis, Mathematical Symbols and Formulae:

Fisher (C. E. Weatherburn, "A First Course in Mathematical Statistics, " page 200) has shown that the random variable

$z = \frac{1}{2} \ln \left(\frac{1 + r}{1 - r} \right)$ is approximately normal with mean

$\zeta = \frac{1}{2} \ln \left(\frac{1 + \rho}{1 - \rho} \right)$ and variance $\frac{1}{(N - 3)}$, where r is the sample coefficient of correlation, ρ is the unknown population coefficient of correlation and N is the common

size of the two samples. Given r , one calculates z . Then one deduces the limits for ξ (which is particularly easy because z is normally distributed) and from the inverse formula, $r = \tanh z$, one calculates the corresponding limits of confidence for ρ . Let $u(k)$, ($k = 1, 2, 3$), be the absolute value of the standard normal variate corresponding respectively to the 95, 98 and 99 % levels of confidence (specifically $u(1) = 1.96$, $u(2) = 2.33$ and $u(3) = 2.58$).

Then:

$$\max(Z) \text{ at level } k = \frac{1}{2} \ln\left(\frac{1+r}{1-r}\right) + u(k) \cdot \frac{1}{\sqrt{N-3}} \quad (1)$$

$$\text{and } \max(\rho) \text{ at level } k = \tanh \left\{ \frac{1}{2} \ln\left(\frac{1+r}{1-r}\right) + \frac{u(k)}{\sqrt{N-3}} \right\} \quad (2)$$

Similar formulae hold for $\min(\rho)$ by changing in the above formulae $+u(k)$ into $-u(k)$

Signature:

Subroutine written by H. J. Morel-Seytoux, May 17, 1967,
Department of Civil Engineering, Colorado State University.
Documentation written by H. J. Morel-Seytoux, June 16,
1967.

Statistical Tests, Mathematical Symbols and Formulas

The population parameters $\mu_1, \mu_2, \dots, \mu_k, \sigma_1, \sigma_2, \dots, \sigma_k$ and ρ being known,

TAC~~Ø~~KI

A F~~Ø~~RTTRAN IV Subroutine

Purpose: Given two correlated populations (target and control) and a joint sample, test the hypothesis: the sample belongs to the correlated populations. Parameters of the correlated populations are assumed known.

Call Statement:

CALL TAC~~Ø~~KI (AMU1, VARP~~Ø~~1, AMU2, VARP~~Ø~~2, XBAR1, XBAR2, C~~Ø~~R~~Ø~~C~~Ø~~F, NSAM, CHISQ~~Ø~~, ISIGNI, IREAD, IPRINT)

F~~Ø~~RTTRAN Variables Definition:

AMU1: mean of population 1 (target), μ_1

VARP~~Ø~~1: variance of population 1, σ_1^2

AMU2: mean of population 2 (control), μ_2

VARP~~Ø~~2: variance of population 2, σ_2^2

XBAR1: mean of sample 1, \bar{x}_1

XBAR2: mean of sample 2, \bar{x}_2

C~~Ø~~R~~Ø~~C~~Ø~~F: coefficient of correlation between populations 1 and 2, ρ

NSAM: size of sample, N_s

CHISQ~~Ø~~: observed value of statistic, χ_o^2

ISIGNI: see TTEST

IREAD: see TTEST

IPRINT: see MEAVAR

Statistical Basis, Mathematical Symbols and Formulae:

The population parameters μ_1 , μ_2 , σ_1 , σ_2 and ρ being known,

then it has been shown that the statistic $\chi^2_o = \frac{N_s}{1 - \rho^2}$

$$\left\{ \frac{(\bar{x}_1 - \mu_1)^2}{\sigma_1^2} - 2\rho \frac{(\bar{x}_1 - \mu_1)(\bar{x}_2 - \mu_2)}{\sigma_1 \sigma_2} + \frac{(\bar{x}_2 - \mu_2)^2}{\sigma_2^2} \right\}$$

is distributed like χ^2 with 2 degrees of freedom.*

The statistic χ^2_o is calculated and compared to the values of the χ^2 distribution with 2 degrees of freedom at the 95, 98 and 99 % levels (namely 5.99, 7.82, 9.21).

Signature:

Subroutine written by H. J. Morel-Seytoux, May 11, 1967,
Department of Civil Engineering, Colorado State University.
Documentation written by H. J. Morel-Seytoux, June 19,
1967.

- *References: Mood, A. M. and Graybill, F. A. "Introduction to the Theory of Statistics," McGraw-Hill, 1963.
Marcovic, R. D., "Statistical Evaluation of Weather Modification Attainments," Colorado S. U. Hydrology Paper No. 16, November 1966.

TARC ϕ TA F ϕ RTAN IV Subroutine

Purpose: Given two correlated populations (target and control) and a joint sample, test the hypothesis: the sample belongs to the correlated populations. Parameters of the correlated populations are not known and therefore are estimated.

Call Statement:

CALL TARC ϕ T (N, NU, HETAR, YTAR, XC ϕ N, XIC ϕ N, T ϕ BSER, ISIGNI, IREAD, IPRINT, IMAP, ITYPE)

F ϕ RTAN Variables Definition:

N: size of sample that defines the correlated populations (or number of years of record of annual or seasonal runoff prior to seeding)

NU: size of sample to be tested (or number of years during which seeding took place)

HETAR: array of target data during seeding period

YTAR: array of target data prior to seeding

XC ϕ N: array of control data prior to seeding

XIC ϕ N: array of control data during seeding period

T ϕ BSER: observed value of statistic, t_o

ISIGNI: see TTEST

IREAD: presently ignored, see MEAVAR

IPRINT: index of printing option (see MEAVAR)

IMAP: index of mapping option. If IMAP is negative or zero the test is performed on the data as they came to the subroutine.

If IMAP is positive the subroutine TARC ϕ T calls the subroutine MAP ϕ FX which transforms the data according to desired option (see ITYPE). The test is performed on the transformed data.

ITYPE: if IMAP is negative or zero this index is ignored.

If IMAP is positive ITYPE indicates the desired transformation according to following code:

ITYPE	Interpretation
≤ 0	no transformation
1	data are squared
2	square root of data is calculated
3	data are raised to 4th power
4	natural logarithm of data is calculated

Statistical Basis, Mathematical Symbols and Formulae

Given the arrays x_i and ξ_j for the control, respectively prior to and after seeding, and similar arrays y_i and η_j for the target, then it can be shown by the likelihood-ratio method that the statistic:

$$t_0 = \frac{\left\{ (\bar{\eta} - \bar{y}) - \frac{(\bar{\xi} - \bar{x})}{\Delta} \left[\sum_{i=1}^n a_i \Delta y_i + \sum_{j=1}^v \alpha_j \Delta \eta_j \right] \right\} \sqrt{n + v - 3}}{\left[\frac{1}{n} + \frac{1}{v} + \left(\frac{\bar{\xi} - \bar{x}}{\Delta} \right)^2 \right]^{1/2} \left[\sum_{i=1}^n \Delta y_i^2 + \sum_{j=1}^v \Delta \eta_j^2 - \left(\sum_{i=1}^n a_i \Delta y_i + \sum_{j=1}^v \alpha_j \Delta \eta_j \right)^2 \right]^{1/2}}$$

$$\text{where: } a_i = \frac{\Delta x_i}{\Delta} = \frac{x_i - \bar{x}}{\Delta} ; \alpha_j = \frac{\Delta \xi_j}{\Delta} = \frac{\xi_j - \bar{\xi}}{\Delta}$$

$$\Delta^2 = \sum_{i=1}^n (\Delta x_i)^2 + \sum_{j=1}^v (\Delta \xi_j)^2$$

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i ; \bar{\xi} = \frac{1}{v} \sum_{j=1}^v \xi_j$$

$$\bar{y} = \frac{1}{n} \sum_{i=1}^n y_i ; \bar{\eta} = \frac{1}{v} \sum_{j=1}^v \eta_j$$

is distributed like Student's t with $n + v - 3$ degrees of freedom.

Signature:

Subroutine written by H. J. Morel-Seytoux, April 15, 1968,
Department of Civil Engineering, Colorado State University.

Documentation written by H. J. Morel-Seytoux, May 20, 1968.

References: Mood, A. M. and Graybill, F. A. "Introduction to
the Theory of Statistics" pages 298-306, 339, McGraw-Hill, 1963.

Note:

Even when the subroutine MAP~~Ø~~FX is not used because no mapping
is desired, it must nevertheless be included in the program deck.

X: array for which transformation is desired

XMAP: array of transformed data

ITYPE: index of mapping option. See TARCOT for code

Signature:

Subroutine written by H. J. Morel-Seytoux, April 15, 1968,

Department of Civil Engineering, Colorado State University

Documentation written by H. J. Morel-Seytoux, May 20, 1968.

MAPØFX

A FØRTRAN IV SubroutinePurpose:

To perform a desired transformation on a given array of data, while preserving the original array.

Call Statement:

CALL MAPØFX(NDATA, X, XMAP, ITYPE)

FØRTRAN Variables Definition:

NDATA: size of array X

X: array for which transformation is desired

XMAP: array of transformed data

ITYPE: index of mapping option. See TARCOØT for code

Signature:

Subroutine written by H. J. Morel-Seytoux, April 15, 1968,

Department of Civil Engineering, Colorado State University

Documentation written by H. J. Morel-Seytoux, May 20, 1968.

RAWTAP

Purpose: To read a record from monthly flow tape (A089) corresponding to a particular station. To print the record if desired.

Call Statement:

CALL RAWTAP (NCSULD, Q, IYEAR, NY, IRWIND, IP
RINT, IFILE)

FORTRAN Variables Definition:

NCSULD: CSU number of streamgage station for which monthly runoff data are desired.

Q: array of monthly runoff data over the available years of record Q(I,J) where I indicates the month and J indicates the year.

IYEAR: array of years of available record on tape.

Example IYEAR (3) may be 1921

IYEAR (4) may be 1925, etc.

NY: number of years of record.

IRWIND: index of tape rewind option. If IRWIND is positive the tape is rewound before it is scanned. If IRWIND is negative or zero the tape is scanned starting with station following last station read from tape.

IPRINT: index of printed output option. If IPRINT is positive the characteristics of the station and the array of data are printed.

IFILE: end and file tape option. Unless IFILE = - 1 it is assumed that the tape will no longer be used during the run. It therefore is filed and rewound.

Signature:

Subroutine written by H. J. Morel-Seytoux, July 10, 1968
 based on an earlier version by R. L. Brustkern. Department
 of Civil Engineering, Colorado State University. Documenta-
 tion written by H. J. Morel-Seytoux, July 20, 1968.

and seasonal flow over the same years of record. The ori-
 ginal data are preserved.

Call Statement:

CALL SEASON (NY, Q, QS, IB, IE, IREAD, IPRINT)

FORTRAN Variable Definition:

NY: number of years of record
 Q: array of monthly flow $Q(I, J)$ where index I
 corresponds to month of water year (i. e., 1 = 1
 corresponds to October, 1 = 2 corresponds to
 November, etc...) and J corresponds to year
 $1 \leq J$ varies from 1 to NY,
 QS: array of seasonal flow $QS(I)$ where I is defined
 as above,
 IB: month number at beginning of season, e. g., IB = 6
 corresponds to March,
 IE: month number at end of season, e. g., IE = 11
 corresponds to August,
 IREAD: mode of reading option,
 IPRINT: mode of printing output option.

Mathematical Symbols and Formulas:

$1 \leq I \leq NY$
 $Q(I, J)$
 $1 \leq J \leq NY$
 If $Q(I, J)$ is negative $QS(I)$ is set to -1.0

SEASON

A FØRTRAN IV Subroutine

Purpose: Transformation of monthly runoff over years of record into seasonal flow over the same years of record. The original data are preserved.

Call Statement:

CALL SEASON (NY, Q, QS, IB, IE, IREAD, IPRINT)

FØRTRAN Variables Definition:

- NY: number of years of record
- Q: array of monthly flow $Q(I, J)$ where index I corresponds to month of water year (i.e., I = 1 corresponds to October, I = 2 corresponds to November, etc...) and J corresponds to year i.e., J varies from 1 to NY.
- QS: array of seasonal flow $QS(J)$ where J is defined as above.
- IB: month number at beginning of season, e.g., IB = 6 corresponds to March.
- IE: month number at end of season, e.g., IE = 11 corresponds to August.
- IREAD: index of reading option.
- IPRINT: index of printing output option.

Mathematical Symbols and Formulae:

$$QS(J) = \sum_{I=IB}^{I=IE} Q(I, J)$$

If any of the values $Q(I, J)$ is negative $QS(J)$ is set to - 1.0 .

Signature:

Subroutine written by H. J. Morel-Seytoux, July 10, 1968,
 Department of Civil Engineering, Colorado State University.
 Documentation written by H. J. Morel-Seytoux, July 20, 1968.

Purpose: Reorder array of seasonal flow and develop a continuous record over 70 years starting with most recent year of record. The original array of seasonal flow is not preserved. (See example below).

Call Statement:

CALL ORDER (NY, QS, IYEAR, IREAD, IPRINT)

FORTTRAN Variables Definition:

NY: number of years of record
 QS: array of seasonal flow QS(J)
 IYEAR: array of years for which records are available
 IREAD: index of reading option
 IPRINT: index of output printing option

Example:

Input Arrays (NY = 4)			Output Arrays		
J	IYEAR (J)	QS (J)	J	IYEAR (J)	QS (J)
1	1959	2365	1	1964	2763
2	1961	1850	2	1963	750
3	1963	750	3	1962	-1
4	1964	2763	4	1961	1850
			5	1960	-1
			6	1959	2365
			7	1958	-1
			...	etc. ...	etc. ...
			70	1895	-1

\emptyset RDER

A F \emptyset RTRAN IV Subroutine

Purpose: Reorder array of seasonal flow and develop a continuous record over 70 years starting with most recent year of record. The original array of seasonal flow is not preserved. (See example below).

Call Statement:

CALL \emptyset RDER (NY, QS, IYEAR, IREAD, IPRINT)

F \emptyset RTRAN Variables Definition:

NY: number of years of record
 QS: array of seasonal flow QS(J)
 IYEAR: array of years for which records are available
 IREAD: index of reading option
 IPRINT: index of output printing option

Example:

Input Arrays (NY = 4)			Output Arrays		
J	IYEAR (J)	QS (J)	J	IYEAR (J)	QS (J)
1	1959	2365	1	1964	2763
2	1961	1850	2	1963	750
3	1963	750	3	1962	-1
4	1964	2763	4	1961	1850
			5	1960	-1
			6	1959	2365
			7	1958	-1
				etc...	etc...
			70	1895	-1

Signature:

Subroutine written by H. J. Morel-Seytoux, July 10, 1968.

Department of Civil Engineering, Colorado State University.

Purpose: Documentation written by H. J. Morel-Seytoux, July 20, 1968.

of data and count the number of positive entries.

Call Statement:

CALL NONZOR (QS, QT, NDATA, IREAD, IPRINT)

FORTRAN Variables Definition:

QS: continuous array including negative entries

(missing data)

QT: array obtained from QS by deleting all negative entries

NDATA: number of data in array QT

IREAD: index of reading option

IPRINT: index of output printing option

Signature:

Subroutine written by H. J. Morel-Seytoux, July 10, 1968.

Department of Civil Engineering, Colorado State University.

Documentation written by H. J. Morel-Seytoux, July 20, 1968.

NØNZØR

A FØRTRAN IV Subroutine

Purpose: To eliminate the negative entries in a continuous array of data and count the number of positive entries.

Call Statement:

CALL NØNZØR (QS, QT, NDATA, IREAD, IPRINT)

FØRTRAN Variables Definition:

QS: continuous array including negative entries
(missing data)

QT: array obtained from QS by deleting all negative entries

NDATA: number of data in array QT

IREAD: index of reading option

IPRINT: index of output printing option

Signature:

Subroutine written by H. J. Morel-Seytoux, July 10, 1968.
Department of Civil Engineering, Colorado State University.
Documentation written by H. J. Morel-Seytoux, July 20, 1968.

Example:

Input Arrays			Output Arrays (NDATA = 3)		
J	QTAR (J)	QCØN (J)	J	QT (J)	QS (J)
1	3112	2562	1	3112	2562
2	256	-1	2	725	364
3	-1	1253			
4	725	364			
5	-1	-1			
6					
7	-1	-1			

PAIR

A FØRTRAN IV Subroutine

Purpose: Given two continuous arrays of data with possibly negative values (indicating missing records), to develop a pair of arrays with common record and only non-negative values. (See example below).

Call Statement:

CALL PAIR (QTAR, QCØN, QT, QS, NDATA, IREAD, IPRINT)

FØRTRAN Variables Definition:

QTAR: input continuous array of data starting with most recent year of record on tape (1964).

QCØN: another input continuous array of data.

QT: output array selected from QTAR. It has no negative entries and entries only for years of common record of QTAR and QCØN.

QS: output array selected from QCØN.

NDATA: number of years of common record.

IREAD: index of reading option.

IPRINT: index of output printing option.

Example:

Input Arrays			Output Arrays (NDATA = 2)		
J	QTAR (J)	QCØN (J)	J	QT (J)	QS (J)
1	3112	2562	1	3112	2562
2	950	-1	2	725	864
3	-1	1653			
4	725	864			
5	-1	-1			
etc.					
70	-1	-1			

Signature:

Subroutine written by H. J. Morel-Seytoux, July 10, 1968.

Department of Civil Engineering, Colorado State University.

Documentation written by H. J. Morel-Seytoux, July 20, 1968.