水文學之進展及序率水文學之解釋與應用

The Development of Hydrology and The Application of Stochastic Hydrology

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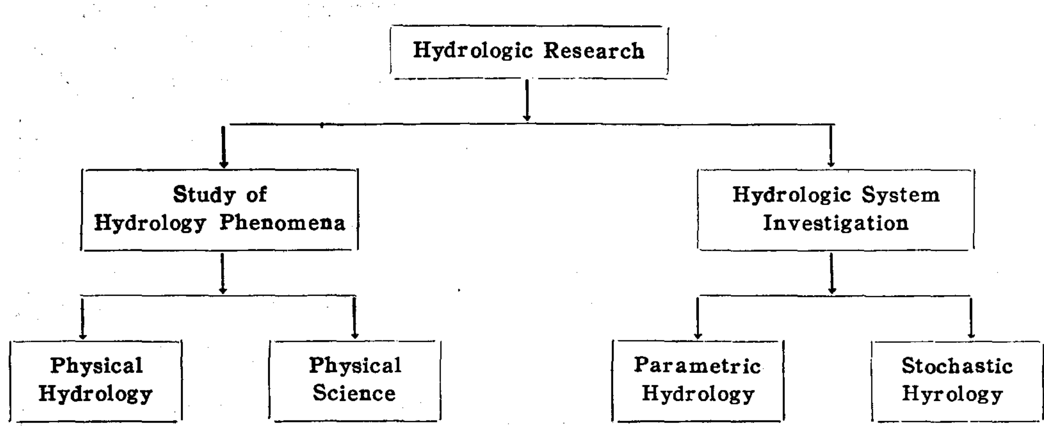
近年來常有友人及學生詢及目前水文學進展之情形，以及參數水文學（Parametric Hydrology）與序率水文學（Stochastic Hydrology）之意義及其主要區別。此種問題表面上似甚簡單，但實不易由言簡意賅之數語，給予圓滿具體之答復；而各個水文學家之見解與觀念亦略有不同，故筆者對詢問諸君，實難有滿意之回答。因此乃扼要摘錄若干水文名家所下之定義與觀點列述如後，以便參閱而共同研討，更為保持各家觀念之原意，不予翻譯為中文，而仍以原文表示。最後並以筆者近年來所作之研究——長期距乾旱頻率分析研究——為例，摘要舉例說明之。

一、水文學之進展與研究範圍

㈠ 美國加州大學 Davis 校區水利學工程系教授 Dr. J. Amorocho 之觀點：



又 Dr. J. Amorocho 對參數水文學及序率水文學之解釋為：

1. Parametric Hydrology
   (1) Correlation and regression analysis
   (2) Synthesis
   (3) Combination of partial synthesis and linear analysis
   (4) General non-linear analysis
2. Stochastic Hydrology
   (1) Analysis of frequency
   (2) Use of Markov chain for simulation } Monte Carlo techniques
   (3) Bilinear model } Monte Carlo techniques

㈡ 美國伊利諾大學水力工程學教授周文德博士（Dr. Ven Te Chow）之觀點：

1. Hydrologic processes
   (1) Deterministic process (chance-independent)

(2) Stochastic or probabilistic process (chance-dependent)

a. Probablistic process (time-independent or sequence ignored)-pure random process.

b. Stochastic process (time-dependent or sequence considered)

(a) Pure random process

(b) Nonpure random process

(c) Stationary process (time independent distribution)

(d) Nonstationary process (time-dependent distribution)

2. Stochastic analysis

(1) Sequential generation of hydrologic information

(2) Generating techniques-Markov chain and Monte Carlo methods.

3. Water Resources Systems Design by Operations Research

(1) Design by simulation

Ⅰ. Simulation analysis

Ⅱ. Sampling techniques

a. Random sampling

b. Systematic sampling

Ⅲ. Operating procedures

Ⅳ. Sequential generation of hydrologic data

(2) Design by mathematical models

Ⅰ. Nature of models

Ⅱ. Deterministic models

a. Linear programming

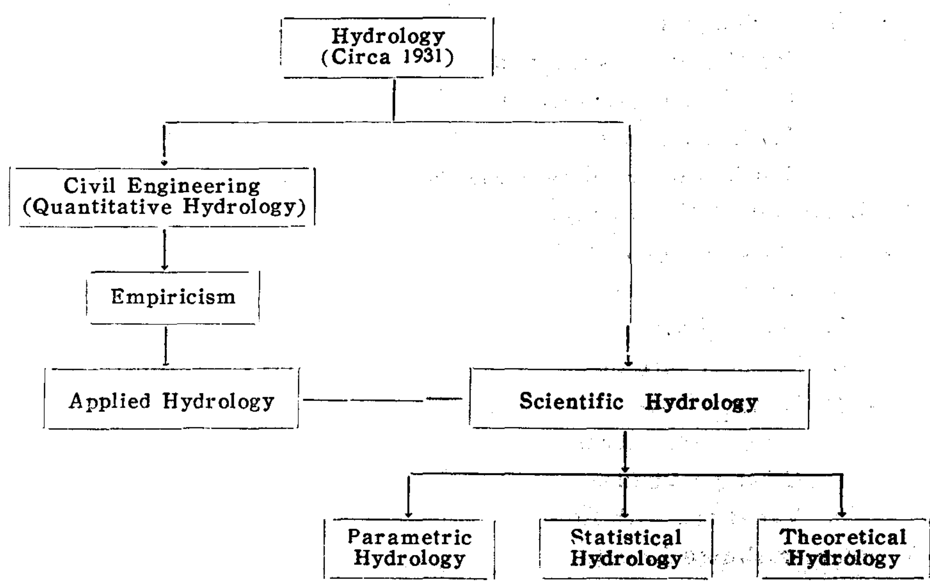
b. Dynamic programming

Ⅲ. Stochastic models

a. Stochastic models

b. Stochastic dynamic programming

㈢ 美國科羅拉多州立大學土木系教授 Dr. E. F. Schulz 之觀點（認爲水文之科學研究應自 1931 年開始）：



二、參數水文學，序率水文學及序率模式 (Stochastic Models) 之解釋與應用

(一) Dr. J. Amorocho：序率程序爲參數水文學中應用之方法。

Parametric Hydrology and the Stochastic Processes

1. Stochastic processes in hydrology
2. Application of Markovian analysis to hydrologic time series ; Markov chains and random walks; Monte Carlo methods.
3. Problems of predictive reliability
   (1) Characterization of distributions
   (2) Data reliability
   (3) Use of reconstructed data from parametric hydrology
   (4) Confidence bands in pred ction

(二) 美國陸軍工程師團水文工程中心主任（已退休），現任美國德州 Austin 水資源研究中心主持人 L. R. Beard.

Stochastic Models and Applications

1. Need for Synthetic Sequences
   (1) Present techniques do not extract all information from data
   (2) Complexity of water resources problems requires detailed sequential operation studies
   (3) Uncertainties in the order of a factor of 2 exist in soms design problems
2. Nature of Random Processes
   (1) Concept and characteristics of parent populations
      a. Continuous distributions
      b. Gaussian normal dictribution
      c. A symmetrical distributions
      d. Transforms
   (2) Random selection
      a. Definition–every possible sample has a calculable chance of selection
      b. Techniques
         (a) Uniform distribution
         (b) Normal distribution
         (c) Transforms
      c. Considerations of time invariance
3. Serial Correlation Effects
   (1) Nature and importance
      a. Storage effects
      b. Other effects
      c. Seasonal variations
   (2) Model techniques
      a. Linear correlation
      b. Other possibilites
      c. Variations with flow
4. Intercorrelation Effects

(1) Nature and importance
  a. Causes
  b. General magnitudes
  c. Effects
(2) Measuremant
  a. Multiple correlation
  b. Serial correlation complications
  c. Negative partial correlations
  d. Seasonal variations
  e. Variations with flow

5. Use of Linear Regression and Random Component
  (1) Basic equation

$$X_1 = a + b_2 x_2 \cdots\cdots\cdots\cdots\cdots + b_n x_n + \sqrt{1-R^2}\ X_r$$

  (2) Error distributions
  (3) Implications of logarithmic transform
  (4) Accuracy requirement
  (5) Frequancy statistics and standardized variate
6. Problems of Non-linearity and Remedial Techniques
  (1) Correlation bias
  (2) Transform to normal
7. Some Questions of Validity
  (1) Sampling error effects
  (2) Model assumptions
  (3) Computer accuracy
8. Completion of Data Sets
  (1) Purpose
  (2) Technique
  (3) Mathematical inconsistencies
  (4) Remedial technique
9. Application in Water Resources Planning
  (1) Facility of application
  (2) Basic application technique
  (3) Computation of expected benefits
  (4) Examination of rare consequences
  (5) Frequency applications
  (6) Effects on optimization computations
  (7) Over-all checks
10. Application in Project Operation
  (1) Uncertainties in forecasting
  (2) Present techniques
  (3) A suggested technique
  (4) Expected results of operation decision
  (5) Automatic selection of operation decision

㈢ 周文德博士：

Analysis of Stochastic Hydrologic System

Mathematical Techniques

Mathematical Models for Time Series.

The hydrologic time series is denoted by $(u_t;\ t,\ T)$, where u_t is the hydrologic variable attributed to the t-th time interval and T is the length of hydrologic record.

1. Moving Average Model. may be express as

$$u_t = a_1\epsilon_t + a_2\epsilon_{t-1} + \cdots\cdots a_m\ \epsilon_{t-m+1} \cdots\cdots (1)$$

where ϵ_t is a random variable

$a_1, a_2 \cdots\cdots a_m$ are the weights

m is the extent of the moving average

2. Sum of Harmonic Model. may be express as

$$u_t = \sum_j^n (A_j \cos\frac{2\pi jt}{T} + B_j \sin\frac{2\pi jt}{T}) + \epsilon_t \cdots\cdots (2)$$

where A_j and B_j are the amplitudes

$\frac{2\pi jt}{T}$ is the period of cyclicity with $j=1,2$—N is the number of record intervals in months, years or other units used in analysis.

ϵ_t is a random variable

3. Autoregression Model. may be express as

$$u_t = f\ (u_{t-1},\ u_{t-2}, \cdots\cdots u_{t-k}) + \epsilon_t \cdots\cdots (3)$$

where f( ) is a mathematical function

k is an integer

ϵ_t is a random variable

4. CORRELEGRAM: The correlegram is a graphical representation of a serial correlation coefficient r_k as a function of lag k wher the value r_k are plotted as ordinate against their respective values of k as abcissa.

$$r_k = \frac{\mathrm{cov}\ (u_t,\ u_{t+k})}{\mathrm{var}(u_t)\mathrm{var}(u_{t+k})^{1/2}}$$

where cov $(u_t,\ u_{t+k})$ is the sample autocovariance

var (u_t) and var (u_{t+k}) are sample variances.

$$\mathrm{cov}\ (u_t, u_{t+k}) = \frac{1}{T-k}\sum_{t=1}^{T-k} u_t\ u_{t+k} - \frac{1}{(T-k)^2}\ (\sum_{t=1}^{T-k} u_t)\ (\sum_{t=1}^{T-k} u_{t+k})^2 \cdots\cdots (4)$$

$$\mathrm{var}\ (u_t) = \frac{1}{T-k}\sum_{t=1}^{T-k} u_t^2 - \frac{1}{(T-k)^2}\ (\sum_{t=1}^{T-k} u_t)^2 \cdots\cdots (5)$$

$$\mathrm{var}\ (u_{t+k}) = \frac{1}{T-k}\sum_{t=1}^{T-k} u^2_{t+k} - \frac{1}{(T-k)^2}\ (\sum_{t=1}^{T-k} u_{t+k})^2 \cdots\cdots (6)$$

5 SPECTRUM ANLYSIS; This method is another diagnostic tool for the analysis of time series in the frequency domain that can help develop an appropriate time series model for the hydrologic process.

All stationary stochastic process can be represented in the form

$$u_t = \int_{-\pi}^{\pi} e^{itw} dz(w) \cdots\cdots (7)$$

where $i=(-1)^{1/2}$

and z(w) is a complex, random function

The autocovariace $r_k=\int_{-\pi}^{\pi} e^{ikw} dF(w)$ ··(8)

$i=(-1)^{1/2}$, k is time lag

w is the angular frequency

$\frac{F(w)}{r_o}$ is a distribution function monotonically increasing and bounded between $F(-\pi)=o$ and $F(\pi)=r_o=\sigma^2$

where σ is the standard diviation

and F(w) is called the "power spectral distribution function"

$$\text{if } k=o,\ r_o=\sigma^2=\int_{-\pi}^{\pi} dF(w) \quad \cdots\cdots(9)$$

which shows that dF(w) represents the variance attributed to the frequency band (w, w+dw). Thus

$$dF(w) = f(w)dw$$

f(w) is called the "power spectrum" of the process.

From (8)

$$r_k = 2\int_0^{\pi} \cos kw\ f(w)\ dw \quad \cdots\cdots(10)$$

The mathematical inversion of the above equation gives the power spectrum as

$$f(w) = (r_o+\sum_{k=1}^{\infty} r_k \cos kw) \quad \cdots\cdots(11)$$

For the finite amount of data the estimate of the power spectrum is

$$f'(w) = \frac{1}{2\pi}(C_o+2\sum_{k=1}^{T-k} C_k \cos kw) \quad \cdots\cdots(12)$$

where C_k is autocovariance for the time lag k

To adjust the smoothness

$$f'(w) = \frac{1}{2\pi}(\lambda_o(w)C_o+2\sum_{k=1}^{m} \lambda_k(w)\ C_k \cos kw) \quad \cdots\cdots(13)$$

$\lambda_k(w)$ are selected weighting factors

四 美國地質調查所水文研究員 D. R. Dawdy:

Hydrologic Model Evaluation

1. Why use A Hydrologic Model?
   (1) Stochastic
      a. Extend records in time at a site.
      b. Regionalization of parameters
   (2) Parametric
      a. Extend records in time at a site
      b. Regionalization of parameters
      c. Effect of man-made changes on parameter values.
2. Measure of Model Respose
   (1) Standard statistical linear theory

(2) Analogous simulation error measures

3. Sources of Error in Simulation and Their Effects

(1) Model errors—non-equivalence

a. Approximations

b. Indices as apparent parameters

(2) Data errors

a. Input errors

(a) Bias vs. random components

(b) Time vs. volume distribution errors

b. Discharge measurement errors

c. Curve-fitting errors.

4. Sensitivity Analysis

(1) Stability of parameter values

(2) Improvement of model structure

(五) 美國陸軍工程師團水文工程中心：

Introduction to Stochastic Hydrology

1. Purposes of Streamflow Generation

(1) *Operation studies.* A useful feature of a streamflow generation model is the ability to estimate missing values so that a longer set of "period-of-record" flows can be routed through the reservoir system to test various operational plans. Also, the establishment of operational criteria for a reservoir system by analysis of only the recorded flows is naturally biased by the small sample of flows. Therefore, the testing of a set of operational criteria on several generated streamflow sequences that are just as likely to occur in the future as the recorded flows should provide an indication of the adequacy of a set of criteria.

(2) *Planning studies.* For planning studies, it is necessary to evaluate the yield potential of various basins. The correlation of streamflows for short record stations with streamflows for long record stations can provide streamflows which will assist in the evaluation of potential reservoir sites.

(3) *Data for ungaged areas.* By analyzing the statistics at surrounding stations and relating these statistics to basin and hydrologic characteristics, a set of statistics can be derived for an ungaged area. These statistics can then be used to generate several sequences of synthetic streamflow for use in yield analyses.

2. Definitions

It is important to define the terms that are used in discussions of stochastic hydrology as there are several terms that can be used to define the same thing and, worse yet, some terms mean one thing to some people and something quite different to others.

(1) *Deterministic* - A deterministic process is one that defines a variable by the use of determined values of other variables and constants, but the process is chance-independent. A common example of a deterministic process is the classical unit hydrograph method.

(2) *Probabilistic* - A probabilistic process considers the probability, or chance, that some event will occur. The analysis of damages based on a flood-frequency curve

considers the probabilistic nature of floods, but the time sequence of the flood events is ignored.

(3) *Stochastic* - A stochastic process considers the probabilistic nature of the events and, in addition, can consider the time sequence of the events. A streamflow generation model which takes into account the previously generated events in estimating the current event is a stochastic process.

(4) *Other terms* - In the literature one will find several terms which essentially define the same process. The monthly streamflow generation model as used by the Corps of Engineers has called: 1) autoregressive, 2) Markovian, 3) synthesis, 4) simulation, 5) stochastic, and 6) operational hydrology. Other terms used in the literature that pertain to stochastic processes are *stationary* and *non-stationary*. A stationary process assumes that the parameters defining the probability distribution remain unchanged during the time span of interest, while a non-stationary process would allow the parameters defining the probability distribution to change with time.

3. General Procedure

(1) *A simple stochastic generation model can be composed of a deterministic portion developed by multiple regression techniques and a random component.*

$$X_1 = \overbrace{a + b_2X_2 + b_3X_3 + \cdots\cdots + b_nX_n}^{\text{deterministic}} + \overbrace{ZS\sqrt{1-R^2}}^{\text{random}}$$

where:

X_1 = dependent variable

a = regression constant

b_n = regression coefficients

X_n = independent variable

Z = random number from (0,1) population

S = standard deviation of dependent variable

R = multiple correlation coefficient

(2) *The random component can be expressed in different terms:*

$$RC = SE \cdot Z = S \cdot \sqrt{1-R^2} \cdot Z$$

because:

$$R = \sqrt{1 - SE^2/S^2}$$

$$\therefore SE = S \cdot \sqrt{1-R^2}$$

where:

RC = random component

SE = standard error of estimate

Z = random number, (0,1) zero mean and unit standard deviation

S = standard deviation of dependent variable

R = multiple linear correlation coefficient

(3) *The random component is necessary to:*

a. Preserve the range of values

b. Preserve the variance

c. Preserve the correlation

4. **Monthly Streamflow Simulation**

(1) *The monthly streamflow simulation model used in HEC-4 has the following form*:

$$K_{i,j}=\beta_1K_{i,1}+\beta_2K_{i,2}+\cdots\cdots+\beta_{j-1}K_{i,j-1}+\beta_jK_{i-1,j}+$$
$$\beta_{j+1}K_{i-1,j+1}+\cdots\cdots+\beta_nK_{i-1,n}+\sqrt{1-R^2_{i,j}}\cdot Z_{i,j}$$

where:

K = log of monthly streamflow transformed to normal deviate

β = beta coefficient

R = multiple correlation coefficient

Z = random normal standard deviate

i = month number

j = station number

(2) *Serial correlation, or persistence, is maintained by includiug the previous value (subscripted as i-1) in the model*

5. Daily Streamflow Generation

(1) *The daily model is similar to the monthly*:

$$K_i=\beta_1K_{i-1}+\beta_2K_{i-2}+\sqrt{1-R^2}\cdot Z_i$$

Where:

K = log of daily streamflow transformed to normal deviate

β = beta coefficient

R = multiple correlation coefficient

Z = random normal standard deviate

i = day number

(2) *Note that two previous days are used*

(3) *Volumes of the generated daily flows are adjusted to equal the input monthly flow*:

6. Analysis of Generated Flows

The generated output should be reviewed carefully to ensure that the generated data are consistent with the recorded data. The maximum and minimum values of the generated sequences should be compared with those of the recorded data to see if any unreasonable values have been generated. If the generated flows are to be used in analyzing the water yield capabilities of a reservoir system, the minimum 1, 6, and 54-month volumes should be compared for reasonableness with those of the recorded data. It is quite possible that the minimum volumes, especially for the long periods, of the generated sequences will not be as severe as those for some extremely severe recorded drought. Markov models are occasionally unable to simulate the extreme long-term drought, and several researchers are trying new generation processes to alleviate this problem.

(六) 筆者近年來應用序率程序 (Stochastic process) 簡易原理所作研究之一例——長期距乾旱頻率分析研究——扼要陳述如後，以便參閱。

超過一年期距總流量體積機率分佈之推演

1. 對數常態分佈分析法

期距超過一年以上頻率曲線之繪製，可應用樣本平均值之標準差與樣本大小平方根成反比例之統計關係研求之。如設年流量體積之對數值組成某一母羣體，則自此母羣體中抽樣時，樣本平均值之母羣體將有

一標準差 $S_{L\bar{x}}$，其與原始母羣體 (Original Population) 之標準差 S_L 之關係，可以下式表之，即

$$S_{L\bar{x}}=S_L/N^{1/2} \qquad (1)$$

式中 N＝樣本數，在此情況下 N 卽表示期距，亦卽連續之年數，在連續 N 年中自原始母羣體中之對數流量體積係隨機出現。樣本平均值之母羣體可視爲常態分佈，其平均值等於原始母羣體之平均值 M_L，代表 N 年內可望出現之平均流量值，N 年期距之總流量應爲平均流量乘以 N。

如考慮序列之相關性 (Serial Correlation)，則年流量體積對數值之標準差應依 Chow 氏提示之方程式，作序列相關性影響之修正，其式如下：

$$S^2_{Ls}=S^2_L\frac{n-1}{n}\left[1-\frac{1-R^2_L}{n(1-R_L)^2}+\frac{2R_L(1-R_L{}^n)}{n^2(1-R_L)^2}\right]^{-1} \qquad (2)$$

式中 S_{Ls}＝序列相關性修正之標準差 (年流量體積對數之標準差)

n ＝記錄年數＝16

R_L＝序列相關係數 (Serial Correlation Coefficient)＝0.929.6

S_{Ls}＝0.21634 其與對數皮爾生氏第三型分析法中所求得之 S_L＝0.121706 相較，則相差較大，亦卽 Chow 氏所謂當 n 值交小與 R_L 值較大時，S_{Ls} 與 S_L 之相差亦大之結論相符合。

通常樣本平均值之標準差 $S_{L\bar{x}}$ 可由下式求之：

$$S_{L\bar{x}}=S_{Ls}/N^{1/2} \qquad (3)$$

基於上述之觀念，依據對數常態分佈理論，當 N＝3,，N＝6 及 N＝10 年等於與小於某一流量發生之機率由電子計算機所得之結果列入第一表，由表中數字繪製之長期距理論對數常態曲線，亦併繪圖示之，以資比較。應用之計算機程式爲 PRGRAM YIH4 (流程圖 3 及 4) (略)。

第一表：應用理論之「對數～正規」分佈求長期距流量發生之機率

Table 1: Probability of Occurrence for Long Duration Flows Using a Theoretical Log-Normal Distribution

期　　距 (年) N	1	3	6	10
M_L	4.100989	4.100989	4.100989	4.100989
平均年期流量 (m³/sec/yr)	12618	12618	12618	12618
總年期流量 (m³/sec)	12618	37854	75708	126180
機率 (%，等於或小於)	50	50	50	50
$S_{L\bar{X}}$	0.21634	0.12490	0.08832	0.06841
($M_L-S_{L\bar{X}}$)	3 884639	3.976089	4.012669	4.032579
平均年期流量 (m³/sec/yr)	7767.5	9464.3	10296	10779
總年期流量 (m³/sec)	7767.5	28393	61776	107790
機率 (%，等於或小於)	15.9	15.9	15.9	15.9
2・$S_{L\bar{X}}$	0.43268	0.24980	0.17664	0.13682
($M_L-2S_{L\bar{X}}$)	3.668309	3.851189	3.924349	3.964169
平均年期流量 (m³/sec/yr)	4659	7099	8401	9208
總年期流量 (m³/sec)	4659	21297	50408	92080
機率 (%，等於或小於)	2.3	2.3	2.3	2.3
3・$S_{L\bar{X}}$	0.64902	0.37470	0.26496	0.20523
($M_L-3S_{L\bar{X}}$)	3.451969	3.726289	3.836029	3.895759
平均年期流量 (m³/sec/yr)	2831	5324.6	6855.3	7866
總年期流量 (m³/sec)	2831	15973.8	41320	78660
機率 (%，等於或小於)	0.135	0.135	0.135	0.135

2. 對數皮爾生氏第三型分析法

推演期距超過一年以上之流量爲應用模擬方程式 (Simulation Equation) 導衍出常態樣準差 (Generate Normal Standard Deviates)，然後將其變形 (Transform) 使與 Log-Pearson Ⅲ 分佈相符。此模擬方程式首由 Beard 氏採用，其式如下：

$$X_K = R_L \times X_P + X_r (1 - R^2_L)^{1/2} \quad \cdots\cdots (4)$$

式中 X_K ＝發生當年 (Current Year) 流量之對數，以一常態標準差表之。

X_P ＝前一年 (Previous Year) 流量之對數，亦以一常態標準差表之。

X_r ＝隨機常態標準差。

R_L ＝序列相關係數，由某一年流量對數值與其前一年流量對數值之相關性求得。

應用原有之資料，以電子計算機作相關性之分析計算求得 $R_L = 0.92956$ 亦係由程式 PROGRAM YIH3 (略) 計算者。X_r 由隨機常態標準差導衍之，其平均值爲 0 0，變異數爲 1.0，範圍爲 -6.0 至 + 6.0。

X_K 可變形爲 Log-Pearson Ⅲ 偏差 (應用下列之關係式求之)

$$K = \frac{2}{g}\left\{\left[\frac{g}{6}\left(X - \frac{g}{6}\right) + 1\right]^3 - 1\right\} \quad \cdots\cdots (5)$$

式中 K＝Pearson Type Ⅲ 偏差

g＝偏態係數 (Skew Coefficient)

推衍年流量體積應用之 g 值亦爲 −0.40，

推衍年流量體積應用之方程式亦爲：

$$\text{Log } Q = M_L + K \cdot S_L$$

式中 M_L 及 S_L 值與原研究報告中(1)－2 節中 (略) 之 M_L 及 S_L 相同。推衍 500 年流量體積之 3 年，6 年及 10 年累積值及發生之機率由電子計算機之程式 PROGRAM YIH3 (流程圖 2 及 4) (略) 求得之，並自動以大小順序排列，算出發生之頻率。

3. Weibull-Gumbel 分析法

超過一年以上之流量體積，亦可依據 Weibull-Gumbel 年頻率分佈理論推衍模擬得之，此模擬之流量，包含自回歸相關 (Regression Relationship) 式之一序列相關成份 (Serially Correlated Component) 及一隨機成份 (Random Component)，通常表示之方式如下：

$$Y = (bX + c) + E \quad \cdots\cdots (6)$$

式中 Y＝某一年之流量

X＝前一年之流量

b＝回歸係數

c＝常數

E＝隨機不相關成份，其平均值爲零。

在序列相關成份中之常數 c，可由下式求之：

$$c = \bar{Y} - b\bar{X} \quad \cdots\cdots (7)$$

式中 $\bar{X}$ ＝記錄資料之平均流量

$\bar{Y}$ ＝自開始期記錄資料 (Original Period of Record) 延後一年 (Lagged by One Year) 之平均流量。

將 (7) 式之 c 值代入 Y 式中，得

$$Y = b(X - \bar{X}) + \bar{Y} + E \quad \cdots\cdots (8)$$

應用適當之記錄期間長度，則 b 可視爲相當於相關係數 R，復由序列分析之統計關係，得

$$b = \frac{RS'}{S} \quad \cdots\cdots (9)$$

式中 S＝記錄資料之標準差

S'＝爲延後一年之標準差

取 S' 相當於 S，取 $\bar{Y}$ 相當於 $\bar{X}$，並分別將 R 及 $\bar{X}$ 代入式中，則

$$Y=R(X-\bar{X})+(\bar{X}+E) \quad \cdots\cdots (10)$$

應用原始之資料求得平均流量及相關係數分別爲 13120.0450 及 0.93736、此序列相關係數 R 係由電子計算機求出，亦即每一年之流量與其前一年流量之相關性，現記錄年期爲 16 年，則相關分析資料可有 15 項資料備用。

$(\bar{X}+E)$ 表示隨機流量，應用隨機抽樣程序，上述 Y 之方程式可用以求出 N 年期間之總流量。第一年僅有隨機流量部份可用，隨機流量加入相關係數乘以（前一年之流量減平均流量），即得次一年之流量，如此連續計算，並按 N＝3,6 及 10 年連續累加之，即可得長期距之流量體積，亦必須用電子計算機計算之，並依大小順序排列且計算相當累積流量發生之機率，以便繪製圖表。本計算所用之計算機程式編排爲 PROGRAM YIH1 及 YIH2（流程圖 1 及 4）（略）。

以上第(2)式，(4)式，(6)式及(10)式即爲序率模式之應用。讀者諸君如欲了解該文之全部研究過程，請參閱 64 年 5 月出版之土木水利季刊第二卷第一期 1-20 頁刊載之"長期距乾旱頻率分析研究"一文。

本會第廿一屆第三次理監事聯席會議審查通過會員名錄

入會會員

姓名	編號	級位	籍貫	服務機關	通訊處
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黃水河	2002	〃	〃	臺糖烏樹林糖廠	臺南縣後壁鄉後廍村 49 之 1 號
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李清柳	2005	〃	〃	臺灣省茶業改良場	宜蘭縣礁溪鄉林美村 26 號
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郭俊開	2012	初會員	廣東省	嘉南農田水利會	臺南縣佳里鎮溪州里學甲旱作灌溉試驗站

提升會員

江顯位	1179	提升仲會員	臺灣省	臺北市政府	雲林縣西螺鎮文昌路 148 號

歡迎本會會員踴躍惠賜稿件