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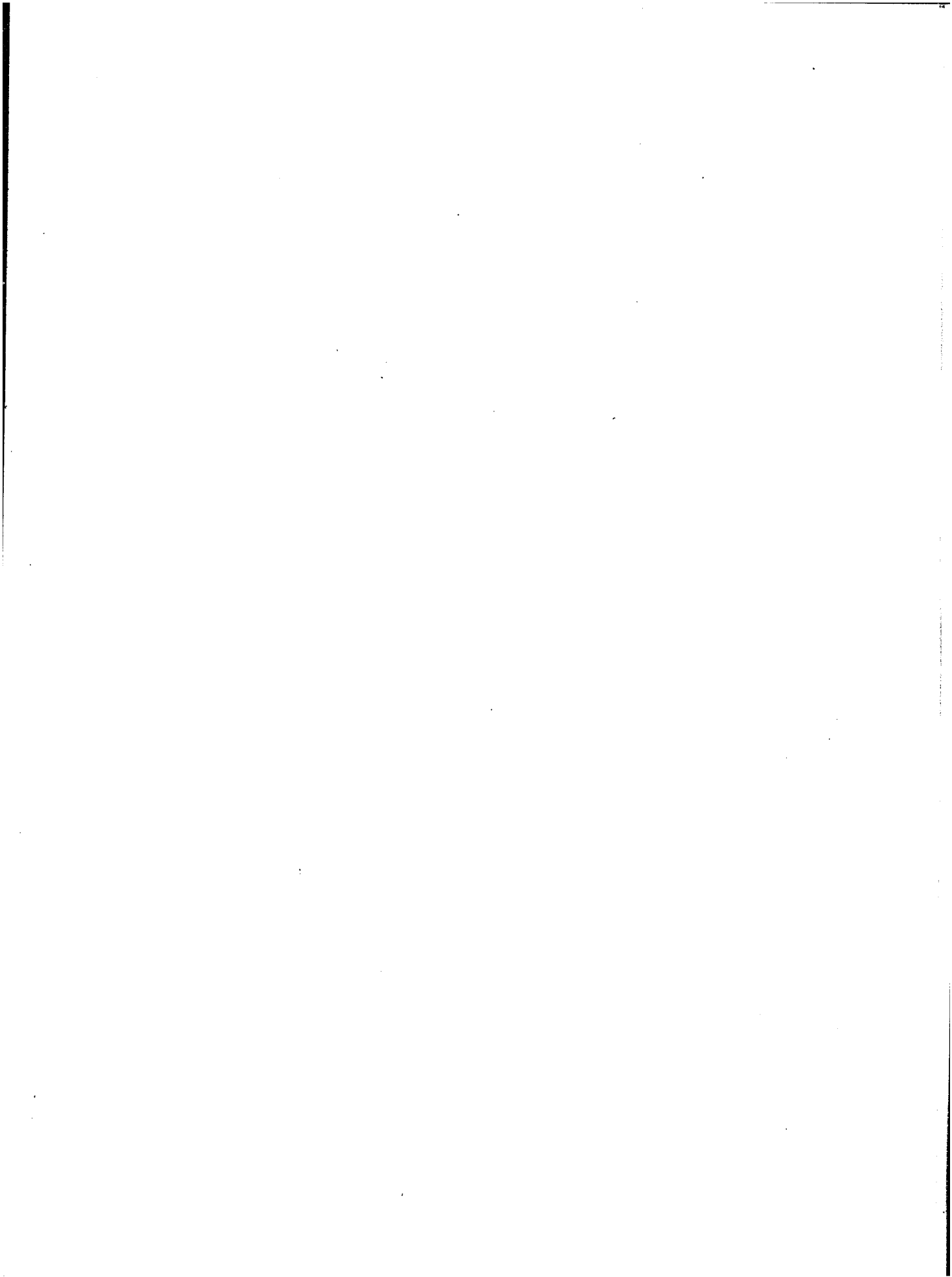
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STOCHASTIC DESIGN OF WASTEWATER FLOW
EQUALIZATION BASINS

by

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Submitted in partial fulfillment of the
requirements for the degree of
Master of Applied Science

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ABSTRACT

Wastewater flow equalization basin volume design has been an imprecise art in which the use of safety factors has been required to allow for the lack of sophistication. A design method is proposed which takes into account the time-dependent nature of flows, the brevity of the observed data record, the facility operation, and the expected performance.

Wastewater treatment plant raw inflow rates are modelled using combined deterministic-stochastic time series techniques. Long flowrate series samples generated by Monte Carlo simulation with a fitted time series model are routed through flow equalization basins to estimate their performance capabilities. The routing procedure includes forecasting of inflow rates and storage requirements and adjustment of basin outflow rates at discrete time intervals. With the inclusion of a plant effluent recycle option, the major performance variables are basin overflow occurrence, reduction of diurnal flowrate variance, and the effect of the recycle option on increasing the mean flowrate through the plant.

For the Ottawa, Ontario, Green Creek wastewater treatment plant, this study indicates highest expected performance is derived from basins with volumes close to those suggested by previous design methods. The uncertainty in the flows and the limitations inherent in basin operation contribute to a reduction in attainable performance from the ideal level.

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NOTATION

a	- independent shocks superimposed upon a process
$a(t)$	- time series of shocks, a
$\hat{a}, \hat{a}(t)$	- sample estimates of shocks $a, a(t)$, fitted time series model residuals
$AC(k)$	- sample autocovariance of time series at lag k
a_n, b_n	- Fourier series coefficients for the n^{th} harmonic of time series periodic component z_p
ARIMA	- autoregressive integrated moving average
B	- discrete series backward shift operator for ARIMA models
B^s	- discrete series seasonal backward shift operator, exponent s indicating extent of shift
B.O.D.	- 5 day - 20°C Biochemical Oxygen Demand
$C(j)$	- ARIMA model weighting coefficient for $z_s(t-j)$
$CF(i)$	- ARIMA model weighting coefficient for $a(t-i)$
chi	- Chi-square test statistic for autocorrelation coefficients and white noise hypothesis
C.L.[]	- confidence limits on quantity within brackets
C_n	- Fourier series amplitude for the n^{th} harmonic of time series periodic component z_p
C.O.D.	- Chemical Oxygen Demand
cov[x,y]	- population covariances of variables x and y
D_{K-S}	- Kolmogorov-Smirnov goodness-of-fit test statistic
DVF	- diurnal variation factor
$E[]$	- expected value of variable within brackets
$E(i)$	- theoretical frequency in the i^{th} class interval, for Chi-square goodness-of-fit test
f	- frequency

F	- cumulative probability density function
F^{-1}	- inverse of function F
g_1	- sample skewness coefficient
g_2	- sample kurtosis
G_1, G_2, G_3	- clustering, directional runs, signs test statistics, for randomness tests
$I(t)$	- reservoir inflow rate at time t
$m, m^3, m^3/d$	- metres, cubic metres, cubic metres per day
M_1, M_2, M_3	- theoretical mean, for clustering, directional runs, signs tests
\bar{a}_i	- the i^{th} central moment of the distribution of \hat{a} values
MG, MGD	- million imperial gallons, million imperial gallons per day
N	- discrete sample size
NFP	- number of consecutive fundamental periods in time series
$O(i)$	- observed frequency in the i^{th} class interval, for Chi-square goodness-of-fit test
$O(t)$	- reservoir outflow rate at time t
OUT	- sample result of simulated equalization basin performance tests
PERVAR(n)	- percent of time series variance attributable to n^{th} harmonic
$r(k)$	- sample autocorrelation coefficient at lag k
$r(x,y)$	- sample correlation coefficient for variables x and y
S.S.	- suspended solids
$S(t)$	- reservoir storage volume at time t
s_x	- sample standard deviation of variable x
s_x^2	- sample variance of variable x

- t - time of observation, or time with which time-averaged observations are associated
- T - length of observed series or fundamental period
- t_r - test statistic for independence of two variables
- v - raw variance spectrum estimate
- V - population variance (power) spectrum
- $w(t)$ - lag window filter
- w_B, w_H, w_P - Bartlett, Hanning, Parzen lag windows
- \bar{x} - sample mean of variable x
- X - Fourier transform
- X^2 - Chi-square goodness-of-fit test statistic
- $z(t)$ - time series of values of process z
- $z_{(DM)}(i)$ - raw daily mean flowrate series on day i
- $z_{(DF)}(i,j)$ - raw diurnal flowrate fluctuation about daily mean series, on day i , at time j
- $z_P(t)$ - deterministic periodic component of time series $z(t)$
- $z_S(t)$ - stochastic component of time series $z(t)$
- $z_{S(DM)}(i)$ - stochastic component of series $z_{(DM)}(i)$
- $z_{S(DF)}(i,j)$ - stochastic component of series $z_{(DF)}(i,j)$
- $z_T(t)$ - trend component of time series $z(t)$
- $\tilde{z}_S(t)$ - normalized series: $\tilde{z}_S(t) = z_S(t) - \bar{z}_S$ if $D = d = 0$
 $\tilde{z}_S(t) = z_S(t)$ if $D > 0$ and/or $d > 0$
- $z_{S1}(i,j)$ - flowrate time series stochastic component, on day i , at time j
- $ZAV(i)$ - periodic mean value of time series $z(t)$, at time i relative to start of fundamental period T
- $ZS(i)$ - periodic standard deviation of time series $z(t)$, at time i relative to start of fundamental period T
- $z'_\ell(t_0)$ - flowrate forecast error, for ℓ -step ahead forecast, made at time t_0

- α - significance level of confidence region or hypothesis tests
- $\gamma(\tau)$ - population autocovariance at lag τ
- $\Delta x(j,t)$ - diurnal flowrate fluctuation about daily mean flowrate, at time t , on day j
- ∇^d - discrete series backward difference operator for ARIMA models, d being the degree of regular differencing
- ∇_s^D - discrete series seasonal backward difference operator for ARIMA models, D being the degree of seasonal differencing on lag s
- θ_n - Fourier series phase angle for the n^{th} harmonic of time series periodic component $z_p(t)$
- θ_q - moving average coefficient of order q
- θ_Q - seasonal moving average coefficient of order Q
- λ - weights for ARIMA process: $\lambda(B) = \psi^{-1}(B)$
- μ_z - population mean of time series $z(t)$
- $\rho(\tau)$ - population autocorrelation coefficient at lag τ
- σ_z^2 - population variance of time series $z(t)$ about μ_z
- $\sigma_1, \sigma_2, \sigma_3$ - theoretical standard deviation for clustering, directional runs, signs tests
- ϕ_p - autoregressive coefficient of order p
- Φ_P - seasonal autoregressive coefficient of order P
- $\phi(\tau, i)$ - population partial autocorrelation coefficient for τ -order autoregressive process, at lag i
- $\hat{\phi}(\ell, j)$ - sample partial autocorrelation coefficient for ℓ -order autoregressive process, at lag j
- ρ - non-stationary autoregressive operator
- χ^2 - theoretical Chi-square value
- $\psi(B)$ - transfer function applied to shocks a , to produce stochastic time series $z_s(t)$
- ω - fundamental angular frequency

CHAPTER 1

INTRODUCTION

1.1 Motivation

A recent survey in Ontario (7)^{*} placed hydraulic overloading as the major problem area in water pollution control plants, regardless of plant size and age. Some of the hydraulically overloaded plants undoubtedly are forced, due to a combination of poor planning and politics, to receive mean daily flows which exceed the design flows of the installations. The survey information revealed, however, that 15 percent of the responding plants received maximum flows greater than twice their design flows. This suggests a large percentage of water pollution control plants must be hydraulically overloaded for at least part of each day. The flow variability, with accompanying waste load fluctuations, is a major cause of degradation of wastewater treatment plant performance. Effluent standards, meanwhile, grow more stringent.

Whether the form of treatment the plants provide is physical, biological, or chemical, the fluctuations in wastewater loads and flows only serve to reduce the plants' effectiveness in removal of the undesirable constituents. Clarification efficiency is reduced by varying flowrates. Loss of biological populations due to high flowrates or toxic slugs is always a risk. Variable flows and loads complicate

* Numerals in parentheses refer to corresponding references in the Bibliography.

design and controlled operation of advanced treatment methods requiring chemical feedings such as coagulation and precipitation processes or carbon adsorption. Any flow-bypassing used as an attempt to circumvent this problem allows untreated or partially treated wastes to enter a receiving water. Man is the ultimate loser.

Present efforts are directed toward reduction of the amount of wastes that reach the natural environment without having received the full impact of our treatment methods. With the realization that non-point sources are perhaps contributing orders of magnitude more to the pollution problem than are municipal and industrial wastes (55), one can only expect increased land areas to be serviced by sewerage in the future. Maintenance of high treatment efficiencies is a parallel goal.

With more demanded of them, treatment methods must be improved. For existing methods this requires a tighter control over performance, including, as one aspect, the management of flow and constituent fluctuations. That this is not easy to implement is evidenced in the causes of flow and load variability, which include non-uniformity in domestic water useage, industrial discharges, storm runoff, and the physical condition of the sewerage, each a product of a multitude of factors.

Possible solutions include flow smoothing in sanitary sewerage systems, separate treatment for wet weather sewer overflows, and flow and waste load equalization within the wastewater treatment plant.

In the first case peak flows can be stored in basins situated throughout the sewerage drainage basin, to be released later to supplement lower flows through the wastewater treatment plant (16,17). Land availability for the basins and pumping and other costs are the major drawbacks of this type of system. Others (25,32,49) make use of existing sewerage to store peak flows.

The second alternative has shown effectiveness (46), but the slug-like behaviour of storm runoff creates problems in both the biological and clarification stages of the treatment process.

So far, the most promise has been shown by equalization basins installed within the wastewater treatment plant.

Treatment plant equalization basins are generally of two types. The more elementary of the two utilizes a constant volume inline storage tank whose contents are continuously mixed in order to damp the fluctuations in the influent waste load concentrations. The actual wastewater flowrates are unaffected by such a basin, and any hydraulic problems, therefore, remain unresolved.

The basin type of most interest, then, is the second type, which temporarily stores part of the flow volume during peak flows and releases this stored volume during low flow periods. Any degree of flow smoothing is presently considered possible, depending on maximum installed storage capacity. An attendant waste load concentration smoothing is also achieved.

The benefits of the inclusion of flow equalization into a wastewater treatment plant are obvious. Treatment process performance

can be improved. Operation of downstream treatment stages is facilitated. Design of treatment facilities, traditionally the domain of average conditions and large safety factors, such as suggested by Eckenfelder and Adams (22), is aided by decreased expected flow variation. Older overloaded plants can be rehabilitated.

An economic gain is realized from all these factors. The debate continues, however, as to whether the equalization basin can pay for itself in benefits (24,26,39).

Design of flow equalization facilities ought to be based on maximization of benefits since an overall aim is to make best use of treatment facilities. Up to the present there has been only limited investigation in the area of benefit quantification. Given the present state-of-the-art of flow equalization, and recognizing that any facility requires an operational guiding hand, the motivation for this project was the need to define realistic criteria for, and develop an improved, yet easy-to-apply method for the design of wastewater flow equalization basins.

1.2 Literature Review

The consideration of continuing events as time series has proven to be a popular and useful vehicle for solutions of water-related engineering problems. Time series analysis as a statistical technique facilitates an understanding of the process being measured. As well, the power of statistics is placed at the disposal of the analyst. This technique has seen only limited use as a water pollution

engineering tool, but appears applicable to the equalization basin problem.

Solutions to (i.e. the effects of equalization on) certain equalization basin inputs have been developed. Performance of flow equalization techniques has been observed and measured in the field.

The chief design variable for equalization basins is the useable storage volume. Generally the design problem reduces to one of limiting the storage capacity while accepting a loss of performance. Storage volume requirements can be determined by simple means for a variety of flowrate series.

Other design variables for wastewater equalization basins have been investigated.

1.2.1 Time Series Approach

A time series is a set of observations, either continuous or discrete, recorded sequentially in time (41). Discrete series are more useful in practice, most often with the observations being associated with equally spaced points in time, or with intervals in time having constant length.

In an effort to understand observed processes, statistical techniques are often applied. A process that evolves in time according to probabilistic laws is called a stochastic process. Investigations of the characteristics of such a process are known as time series analysis.

A time series is usually conceptualized as being the linear sum of two principal components, the deterministic and stochastic components. The former is that part of the observed behaviour which can be predicted exactly, whether root causes are understood or not. Trends, periodicities, and jumps are usually included in the deterministic component. A trend is a gradual change of a variable over a relatively long time span. A trend in a pollution indicator time series, as an example, might be a steady worsening in a water quality parameter due to a continued discharge of a pollutant. Periodicities are repeated, constant fluctuations in a variable. Examples in natural time series can be attributed to periodic astronomic behaviour (41). Man-influenced time series are similarly affected as, for example, pollutional discharges may be regularly patterned according to time of day or time of year. Jumps, or discontinuities in the sequence of the variable, are due to sudden changes affecting the process that produces the variable. The aforementioned pollutional index time series could experience a jump due to a catastrophic natural event such as a landslide or man-made changes such as diversion or the abrupt commencement or cessation of discharge from an industry.

Added to the deterministic component to yield the complete time series is the stochastic component, that part of the time series which cannot be predicted exactly, and can be expressed only in statistical terms. The stochastic component is generally considered to be made up of serially dependent random "errors" upon the deterministic component, and can also include trends.

Whereas the value of the deterministic component of the variable depends only on time, the shock, or error, in the observation of that variable at any time depends somewhat on the shocks at some previous time. As illustration, the persistence in successive observations of the pollutional index variable shows up when an unusually high value is followed by a similar value.

The general procedure followed in an analysis of a time series involves detection and removal from the time series of any present deterministic components (41) and subsequent analysis of the remaining stochastic component. At each step use can be made of several alternative approaches. Characteristics of the various components of a time series can be observed through the use of the time-based autocorrelation function, or its transform, the frequency-based variance or power spectrum.

The removal of trends can be accomplished by regression analysis or by the moving average method. The shortcoming of the former technique is that while arbitrary polynomials can be developed to reproduce observed data with respect to time, there is no reason to believe they will adequately describe future data (11). On the other hand, the latter method, in which a series of overlapping means of successively weighted values are computed to eliminate trend, has been shown (65) to induce long-period oscillations into the new series, as well as to remove from the series periodicities having periods related to the effective length of the moving average scheme. This is the Slutsky-Yule effect.

Periodicity removal is most commonly effected by the subtraction from the time series of a number of Fourier components (sine waves) of pre-determined frequencies and amplitudes (54). This method is most suitable for those series containing obvious periodicities or where physical theory suggests presence of a certain frequency. Otherwise, building a model out of cyclical contributions of different frequencies and amplitudes is not justifiable unless the true behaviour can reasonably be expected to be based on such underlying characteristics. The result could easily be a periodic component containing a large, and therefore unwieldy, number of phase and amplitude parameters. It has been shown (34) that all the periodicities of a given fundamental frequency can be removed from a discrete time series by subtraction of the periodic mean values, each one the mean of the variable values at the corresponding times in each one of the fundamental periods in the record. All coefficients associated with the Fourier representation of the periodic component are avoided.

Treatment of jumps must be developed appropriate to each situation in which they are encountered.

After all predictable (deterministic) components have been removed from a time series, the remaining series is generally considered to be the stochastic component. In some cases, parts of the deterministic component too small or difficult to detect or remove are lumped with the stochastic component and therefore are assumed stochastic as well.

The degree of persistence in a stochastic time series is measured by the autocorrelation function of the series which quantifies the amount of linear association between two realizations of a variable separated in time (41). The remaining part of the stochastic component is assumed to be a series of independent random variables (usually assumed normally distributed) (41). These are due to non-systematic errors in obtaining and handling the observed data, as well as to other random fluctuations in the inputs to the stochastic process or in the ambient conditions affecting the process (10).

Various models for describing behaviour of stochastic time series have been grouped as the ARIMA (autoregressive integrated moving average) package of univariate stochastic time series models by Box and Jenkins (14).

1.2.1.1 Applications in Pollution Control Engineering

To the present only limited applications of time series analysis to water quality and wastewater treatment plant problems appear in the literature.

Gunnerson (27) illustrated the use of variance spectrum analysis on time series of a variety of water quality parameters for the Potomac River and Raritan Bay.

Wastler and Walter (61) found spectral analysis of chloride concentrations helpful in a study of sedimentation problems in Charleston harbour.

Thomann (56) examined temperature and dissolved oxygen time series records for the Delaware estuary using Fourier analysis and variance spectrum techniques at several points along the river to gain an understanding of the physical environment. In another paper (57) he used the same techniques to examine municipal wastewater treatment plant flow and B.O.D. to improve understanding of plant behaviour and to see the effect of plant effluent quality variations on the receiving water.

Wallace and Zollman (60) fitted fourth-order polynomial curves to series segments of hourly combined sewage C.O.D. data. A simple statistical analysis was performed on the deviations from these curves. In a discussion of this paper, McMichael and Vignani (43) demonstrated the flexibility and power of the ARIMA models of Box and Jenkins to characterize the variety of C.O.D. series used by Wallace and Zollman, and their use in forecasting.

McMichael and Hunter (42), in characterizing daily Ohio River flows and water temperatures, could explain a high proportion of the original time series variance using a model combining a simple deterministic function of time and a simple stochastic function of the ARIMA group. The percentage of variance explained was greater than that accounted for by either a deterministic or a stochastic ARIMA models alone, parsimony (state of having as few model parameters as possible) being equal.

Huck and Farquhar (31) found the ARIMA models alone could be used to describe time-behaviour of water quality parameters in the St. Clair River. The authors consider these models to be able to

outperform frequency-based models where the random variable lacks seasonality. In this case the information gleaned allowed inferences to be made about the causative processes behind the data values.

Mehta, Ahlert, and Yu (44) demonstrated ARIMA modelling of the stochastic components of daily Passaic River streamflows, water temperatures, B.O.D., and dissolved oxygen deficits after the removal of significant harmonic components from the original series of data.

Berthouex, Hunter, Pallesen, and Shih (11) modelled hourly wastewater treatment plant input B.O.D. data using only ARIMA models as a prelude to future work on operation of treatment processes.

Adams and Gemmel (1), in a study of municipal wastewater treatment plant influent and effluent variables as time series, attempted to assess the impact on receiving waters of centralized, as compared to regionally decentralized, treatment facilities. Linear regression and Fourier analysis were used to study the trend and periodicities, respectively, of the B.O.D., S.S., and discharge variables. In general, the series showed little determinism, so serial correlation and runs tests were used to test randomness. Simple and multiple correlation techniques provided the means of plant-to-plant comparison of single variables. Influent and effluent quality variables were found to be much more random than plant discharges which showed a significant periodic component. Among several plants only weak correlation of quality variables was observed, but some dependence was found among the discharges.

1.2.2 Equalization Basin Performance

Design procedures revolve around an assessment of alternatives, generally performance rated against cost. For equalization basin design, an adequate definition of basin performance must therefore be available. Prediction of the effects of equalization on basin input variables becomes a necessity.

1.2.2.1 Equalization with Constant Storage Volume

Previous investigations have concentrated on the reduction of fluctuations in the concentration vs. time curve by flow-through, fixed-volume storage tanks.

Assumptions normally applied in these works are (59):

- 1) the basin is completely mixed,
- 2) inflow and outflow rates are equal and constant,
- 3) the basin level remains constant,
- 4) the property under consideration is linear and additive, and
- 5) no chemical reaction takes place.

Beaudry (8) determined the ratio of output to input variance for mixing of batches of waste, referring to this as "blender efficiency".

Danckwerts and Sellers (19) developed expressions for outflow to inflow variance ratios for equalization of gas streams whose concentrations exhibited regular periodic or completely random fluctuations. The expression for periodic behaviour was also modified to include first-order decay of the constituent.

Gutoff (28) calculated the ratio of output concentration variation to maximum input concentration variation (as a fraction of average concentration) for equalization of streams having sinusoidal concentration fluctuations. For design this was related to the ratio of the retention time to the period of the fluctuations.

Walker and Cholette (58) derived equations relating concentration damping factors (ratio of output to input amplitudes) to hydraulic residence time (for a constant flowrate this is synonymous with basin volume) for theoretical sinusoidal, square-wave, and finite pulse feeds to completely mixed paper pulp "stock chests".

Reynolds, Gibbon, and Attwood (51), using a constituent mass balance on paper pulp stock chests at finite time increments, described the outflow concentration-time curves for various basin schemes involving different degrees of mixing, outflow recirculation, and feed-splitting. This time-increment method was evaluated by comparison with observed data, with mathematical solutions to sinusoidal and square-wave inflows, and with a statistical approach. Results showed random variations of inflow concentration are best smoothed by a completely mixed basin, while periodically varying inputs have their fluctuations reduced most by recirculation and split-feed systems.

Wallace (59), in summarizing previous work, also mentioned the potential of analytical solutions for deterministic basin inputs and the use of analog simulation for more complicated basin inputs. He evaluated the models of Danckwerts and Sellers (19), using numerical

integration and graphical comparison of results with those of Reynolds, Gibbon, and Attwood (51). Variations in degree of mixing were also discussed.

Novotny and Englande (47) began with the mass balance for a conservative substance through a completely mixed basin and determined Fourier response (transform) functions for a single basin and for two basins in series (a representation of the practical case of an equalization basin followed by the aeration basin of the treatment step). Their response functions relate the Fourier-transformed concentrations of output and input for a linear system such as the equalization process. These spectral analysis techniques enable use to be made of constituent variances as design criteria. Mass balance solutions in both time and frequency domains were given for the cases of finite pulse and unit step inputs. Design relationships were developed based on detention time vs. maximum effluent concentration for pulse inputs, and vs. maximum effluent concentration rate change for the unit step case. The frequency response solution for harmonic and purely random inputs provided the foundation for design techniques based on amplitude damping. The solution for purely random inputs was verified experimentally.

Novotny and Stein (48) expanded the preceding equalization basin models to include non-conservative constituents (first-order decay characteristics) for three basin types: completely mixed, dispersed flow, and plug flow. Comparison of inflow and outflow variance spectra were used to illustrate effectiveness of two observed dispersed

flow-type basins. A simplified formula for the ratio of output to input variance for completely mixed basins and purely random inflows was developed and verified experimentally. A similar formula was developed for a simple harmonic input.

DiToro (21) assumed three simple parameters (mean mass inflow rate, coefficient of variation of mass inflow rate, and a correlation time constant indicating the time lag for which mass inflow rates are essentially uncorrelated assuming exponentially decaying serial correlation coefficients) were sufficient to characterize the statistical nature of random basin (completely mixed, constant volume) inputs regardless of their probability distribution. Despite these liberal assumptions, his prediction of output variation was adequate for the case of constant fluid flowrates. Random flow fluctuations, characterized statistically in the same fashion, tended to increase predicted output concentration variations. Predicted performance deteriorated rapidly as serial correlation of flowrates increased relative to basin detention time. Introduction of a first-order decay term, while not complicating performance prediction, made possible the illustration of the trade-off between reduction of concentration variation, a function of equalization, and reduction of mean concentration, a function of the reaction rate.

Clearly, then, for fixed volume equalization, reduction of variance of constituent concentrations is the major performance indicator. With interest shifting from the deterministic to the stochastic approach, DiToro (21) has stated the problem facing all

analysts: that the probability density functions of outflow concentrations are very difficult to determine from input characteristics for all but the constant flow, simple Gaussian input situation, for which, in some cases as in DiToro's example, the output is also Gaussian.

1.2.2.2 Equalization with Variable Storage Volume

Prediction of the effects of equalization on time-variable waste loads is complicated by fluctuations in flowrates. DiToro (21) has addressed this problem using a simplified statistical analysis. For highly correlated variable flowrates poor performance is indicated and flow equalization is suggested as being necessary. This situation, with three variables (waste load, flowrate, basin volume) fluctuating, requires complicated analysis, an area not as yet investigated.

LaGrega (37), and with Keenan (38), reported on a full-scale study of the effects of equalization of municipal wastewater flows at Newark, New York. The flows were considered to be stochastic variables and were modelled using the ARIMA family of time series models. Diurnal flows were forecasted to enable a completely mixed equalization basin (actually an existing clarifier) to be operated efficiently. Thus, by varying the basin volume, a significant reduction in the variability of flowrates from inflow to outflow was achieved. Since the equalization basin was placed at the head of the wastewater treatment plant, the flowrate to all treatment processes was held fairly constant.

The physical flow smoothing over a 24-hour period effected

a reduction in the maximum concentration and a reduction in the coefficient of variation of on the order of 50 percent in the significant quality variables. Equalization of the wastewater under aerated conditions did not significantly reduce its B.O.D. The preaeration induced preflocculation of suspended solids. This preflocculation and the more uniform overflow rates markedly improved the sedimentation process. Even with a highly variable plant influent, the effluent strength of the primary sedimentation tank was found to be consistent and to have a frequency distribution resembling the normal distribution. Diurnal flow equalization had little effect on the day-to-day variability of the waste strength, except for suspended solids concentrations, whose day-to-day variability unaccountably increased with equalization. Primary effluent suspended solids concentrations and their variability were dramatically improved, however.

While these results appear in the form of frequency distributions, they are empirical for a specific municipal waste and treatment system. Similar data may or may not be obtained from other situations. Nevertheless, LaGrega's results show that flow equalization does have beneficial effects on the treating of waste loads.

Biological treatment performance can benefit both from the reduced risk of shock loadings provided by concentration smoothing and the improved final settling performance provided by the flow smoothing (50). The concentration damping effected by flow equalization can facilitate control of chemical coagulation and precipitation systems and improve process reliability. Advanced filtering operations would benefit from flow smoothing by smaller filter requirements and more uniform filtration cycling.

Whether there are effluent quality improvements due to flow equalization is, however, still an open debate because of the shortage of observations.

1.2.3 Determination of Storage Requirements for Flow Equalization

The major design variable for equalization basins is the maximum useable storage space, i.e. the effective basin volume. Its determination is a familiar water resources problem: the solution of the reservoir continuity equation,

$$I(t) - O(t) = \frac{dS(t)}{dt} \quad 1.1$$

where, at any time t , I is the inflow rate, O is the outflow rate, and S is the reservoir storage volume. All three are stochastic variables (62).

1.2.3.1 The Reservoir Storage Problem

Methods of reservoir design make extensive use of derivatives of the original mass curve concept first introduced by Rippl (52). The mass curve approach considers the time-behaviour of variables, so it may be a compatible companion to time series analysis. A mass curve describes the cumulative volumes of reservoir inflow and outflow. The similar "differential" mass curve illustrates the cumulative deviations of the inflow and outflow from the mean inflow. In general, determination of required storage volumes involves time studies of the maxima and minima characteristics of differential mass curves of flow, i.e. the study of surplus, deficit, and range, as discussed by Yevjevich (62).

Design procedures based on examination of observed records alone are now being replaced by those which take into consideration the stochastic nature of the involved variables. Asymptotic behaviour of the stochastic variables in the reservoir storage problem can be studied through the use of Monte Carlo simulation. This involves the generation of large samples of data having the same properties as an observed sample or a theoretical population. Some work has been done on mathematical derivations of asymptotic or exact properties of some of the storage problem variables.

Series of independent standard normal variables have been the focus of the theoretical work. For such series Feller (23), using the theory of Brownian motion, derived equations for the asymptotic values of the expected value and variance of the range and adjusted range (definitions of these terms can be found in (62)). He also found a general expression for the probability density function of the range and adjusted range.

Anis and Lloyd (5) determined the expression for the exact value of the expected range.

Anis (3) found an exact expression for the second moment about zero of the maximum of partial sums, and later (4) generalized that to include all moments.

Solari and Anis (6) derived the exact expressions for expected value and variance of the maximum of adjusted partial sums.

Data generation has aided the study of the asymptotic properties of unadjusted and adjusted surplus, deficit, and range of

linearly dependent normal variables and of other probability distributions (53,62,63). Unfortunately, theory on the exact moments of range and adjusted range is lacking as yet. At the present time, therefore, data generation appears to be the most useful technique that can be applied to the reservoir storage design problem.

1.2.3.2 Wastewater Flow Storage Requirement Determination

The problem of providing a volume of reservoir storage for runoff control in a natural drainage area is similar to the wastewater flow storage situation, in that prediction of expected flow volumes can be aided by an understanding of the meteorological and physical factors governing behaviour in the watershed. Since man, however, is the source of much of the wastewater flow many additional factors are involved in wastewater flow prediction.

Wastewater flow storage determination, on the other hand, is facilitated by the fact there are no maximum yield requirements as in water supply-flood control problems. Flow smoothing is the only objective. Assumption of the adequacy of downstream facilities to handle the "equalized" flow is mandatory, whereas in a water supply-flood control reservoir design, downstream capacity is critical.

Simple methods are presently available for the calculation of a design volume for flow equalization. All intend only to dampen diurnal flow variation.

Click and Mixon (17) in determining required volumes of local peak flow retention basins, have schematized the wastewater

hydrograph for one day as a square wave (Figure 1.1). The assumption of the equality of the peak-to-average and the average-to-minimum flow ratios allowed the development of a deterministic equation for the required storage volume.

The U.S. Environmental Protection Agency (50) has used a simple mass curve range analysis of a typical diurnal flow hydrograph as the method of determining the required storage volume (Figure 1.2). This is normally in the vicinity of 10 to 20 percent of the average daily dry weather flow. Once the required volume has been determined, the impact of the flow smoothing on constituent concentrations and mass loading can be determined assuming conservative materials and completely mixed conditions.

The value of these methods rests solely on the choice of the diurnal flow pattern. They must necessarily rely on safety factors to allow for the effects of uncertainty. LaGrega (37) attempted to avoid the effects of randomness in the flows by suggesting use of a mass curve analysis of each day of available flow records in order to determine empirically what maximum volume will deliver the desired degree of flow smoothing for the desired fraction of the time. Unfortunately, he could only guess at a definition of the desired degree of equalization: an arbitrary basin outflow diurnal fluctuation of 20 percent of the average flow.

Gorber, Halbert, and Scharer (26) have modified the above idea slightly by using a long record of daily mean flows to establish "Daily Peaking Factors" for various "exceedence" levels (Figure 1.3).

FIGURE 1.1

SCHEMATIZED WASTEWATER HYDROGRAPH AND PEAK FLOW RETENTION
BASIN VOLUME DETERMINATION - from Click and Mixon (17).

Assumption: $P : A = A : M = X$

$$A = M + (P - M)t$$

$$t = \frac{A - M}{P - M} = \frac{X - 1}{X^2 - 1}$$

$$\therefore, \text{ Required basin volume } V = (P - A)t = \frac{A(X - 1)^2}{X^2 - 1}$$

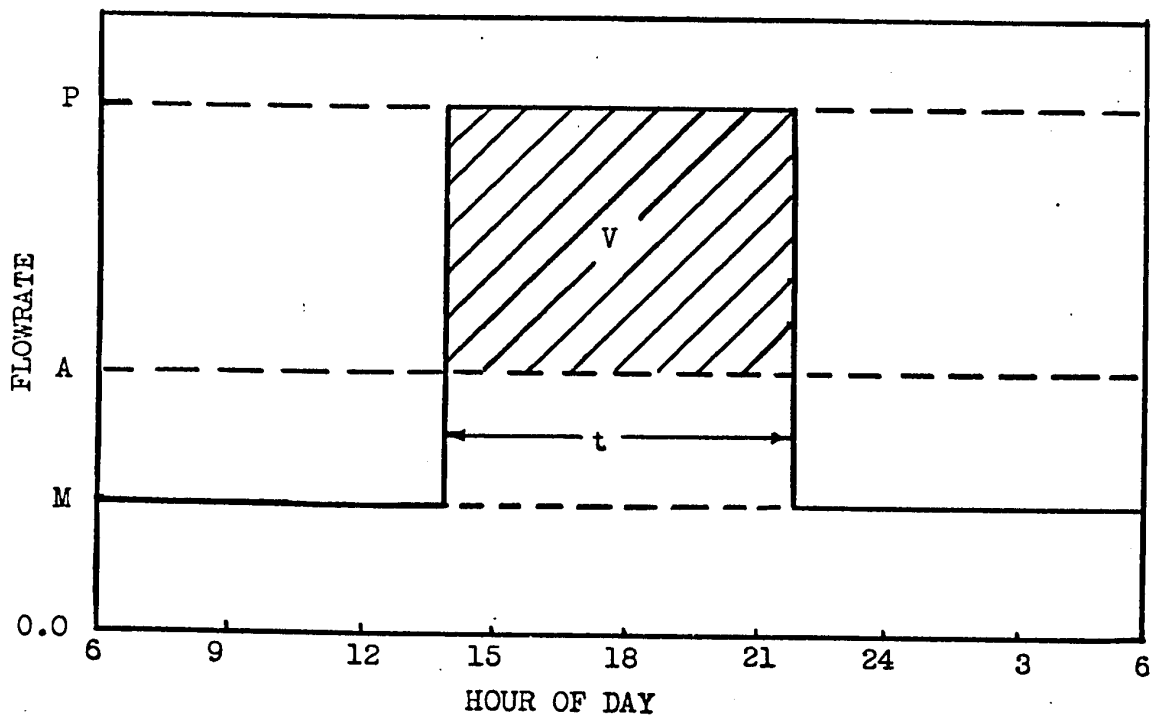


FIGURE 1.2
FLOW EQUALIZATION BASIN VOLUME DETERMINATION - from U.S.
Environmental Protection Agency Technology Transfer (50).

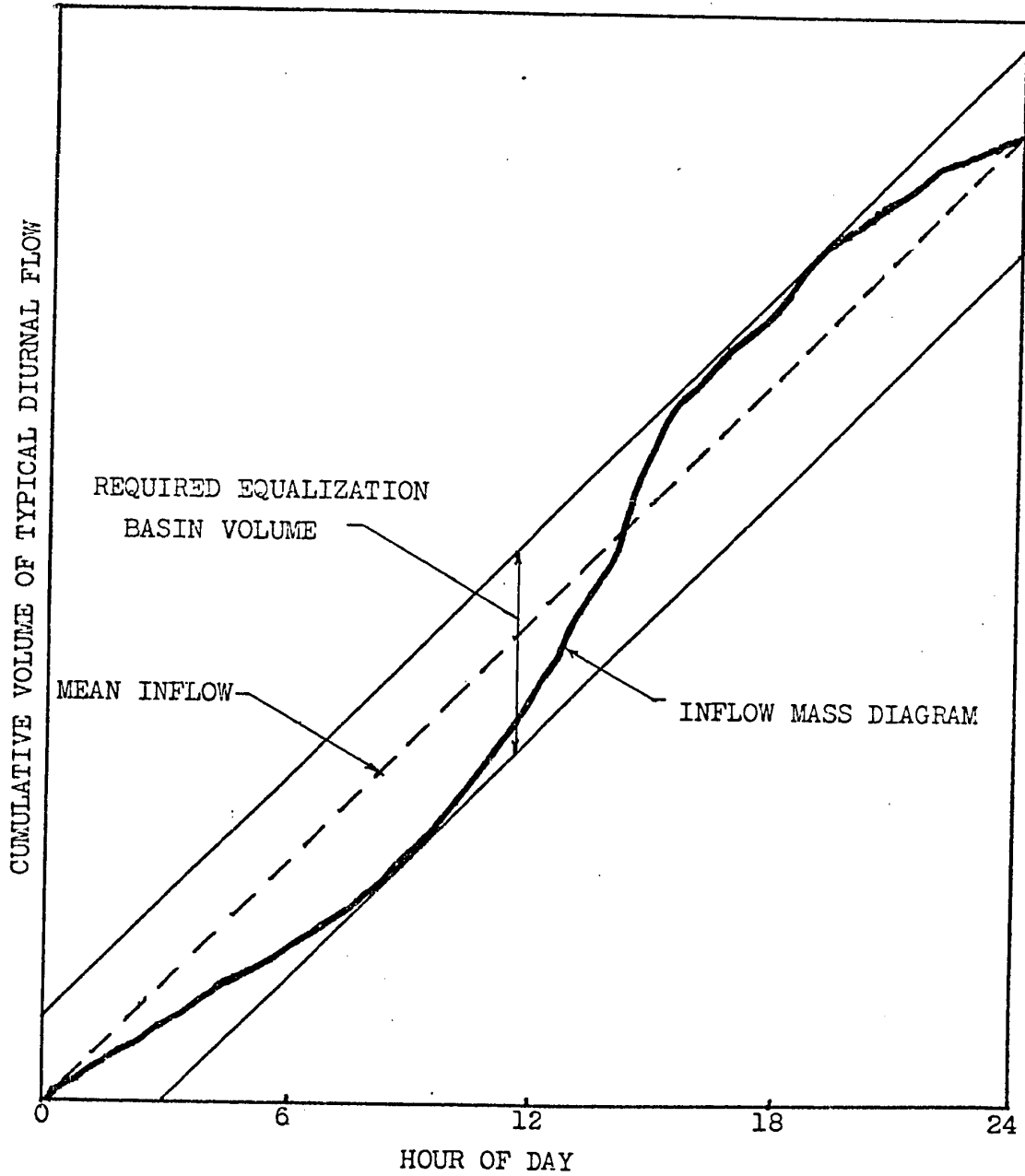
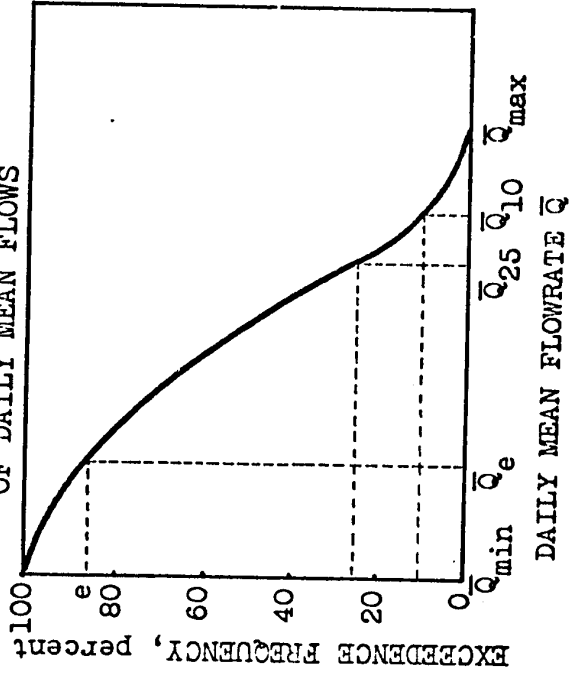


FIGURE 1.3
 STATISTICAL FLOW EQUALIZATION VOLUME DESIGN - from Gorber, Halbert, Scharer (26).

Annual mean daily flowrate = \bar{Q}_a

Daily Peaking Factor $F = \frac{\bar{Q}_e}{\bar{Q}_a}$

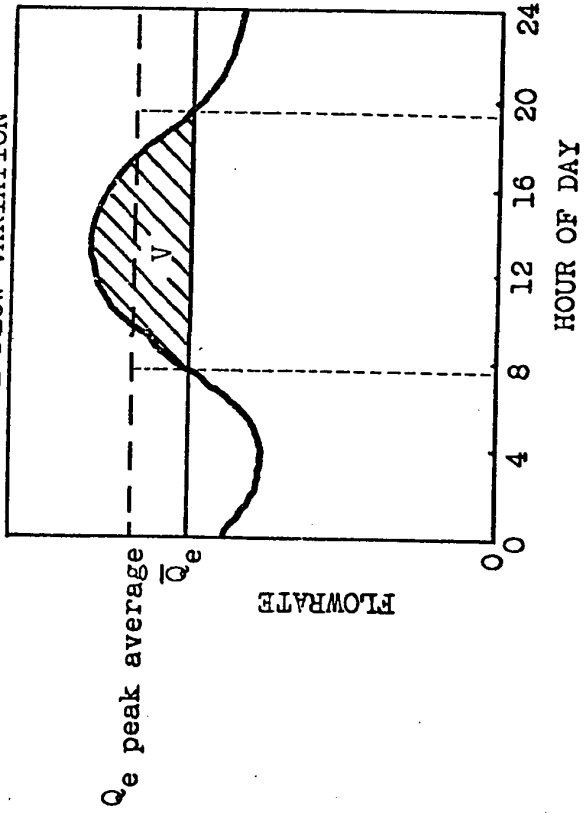
FREQUENCY OF EXCEEDENCE
 OF DAILY MEAN FLOWS



Diurnal Peaking Factor $F_d = \frac{Q_e \text{ peak average}}{\bar{Q}_e}$

Required Equalization Basin Volume
 $V = 0.5 F (F_d - 1) \bar{Q}_a$

DIURNAL FLOW VARIATION



Diurnal variations were quantified by studying the daily flow charts for days on which the mean wastewater flows corresponded to certain exceedence levels, for example, maximum, 10, and 25 percent exceedence. A "Diurnal Peaking Factor" was established for the 12 hour (approximately) peak period of the day. Combination of the above factors resulted in an equation for the required storage volume. Averaging of results from five Ontario plants produced a required volume of 11 percent of annual mean daily flow for "full" equalization, a figure comparable to others reported in their paper. A safety factor of 1.25 is suggested to be applied to volumes determined by their method.

While more complex than earlier procedures, the proposals of LaGrega (37) and Gorber et al (26) remain as empirical methods. They do not fully account for the stochastic nature of wastewater flows, as "full" equalization is theoretically impossible with a finite basin volume and stochastic inflows.

1.2.4 Other Design Considerations

While the maximum useable storage volume is the principal design variable for flow equalization basins, other factors influence the final configuration of the installed flow equalization system (37,38,50).

Click and Mixon (17) discuss basin location within the collection network. Within plant alternatives are in-line or side-line units, or the use of existing tankage (37,39,50). A wide variety of hardware and materials can be incorporated into the design, the choice depending upon the particular situation (37,50).

1.3 Objectives

The review of the literature has shown that design methods presently available for the determination of the useable storage capacity requirement for wastewater flow equalization facilities are crude, use only observed flows, presuming they represent long-term behaviour, and require the use of safety factors to account for uncertainty. The most important criterion for design is considered to be the amount of reduction in the fluctuations of the waste stream through the equalization tank.

Theoretical investigations have been carried out into the basin response to (production of outflows from) ideal basin inflows for the cases of constant volume-constant flowrate-varying concentration and constant volume-fluctuating flowrate-varying concentration. The varying basin volume problem has not been approached. Limited observation of full-scale flow equalization has shown beneficial effects are felt on downstream wastewater treatment processes due to the concentration and flow smoothing.

Time series analysis has been used successfully on water quality variables and flowrates, including wastewater flows. Data generation has proven useful where analytical solutions were difficult.

The objectives of this study are therefore (1) to make use of time series analysis to model the stochastic time-behaviour of incoming wastewater flows for the purposes of flow forecasting and data generation, (2) to use the resulting stochastic model of the

flows and Monte Carlo simulation to provide a proposed flow equalization basin with "experience", and (3) to develop a design relation which, while considering the uncertainty in the equalization process, compares basin size to simulated performance.

CHAPTER 2

THEORETICAL CONSIDERATIONS

Univariate time series techniques were used to analyse and model wastewater treatment plant raw inflow rates. The analysis consisted of the step-by-step identification and removal of the various components (Section 1.2.1), which was aided by the interpretation of the variance characteristics of the remaining portion of the series in both time and frequency domains. This involved the use of autocorrelation and variance spectrum analysis, respectively. The stochastic time series models of Box and Jenkins (14) were used to model the stochastic components of the series.

Once adequate time series models were determined for the wastewater flow time series they were used as a base for simulation of large data samples. As a means of assessing performance toward the choice of a design volume for a specific series, the simulated raw wastewater flows were routed through ideal equalization basins.

2.1 Modelling of Time Series

A process evolving in time may be observed continuously, or, more practically, at discrete points in time. The latter also includes time-averaged observations associated with discrete points in time. Most time series exhibit non-homogeneity, or time dependence, caused by changes through time in the factors affecting the outcomes of the processes. That part of an observed time series which

is time dependent and completely predictable is called the deterministic component. In addition there is the portion of the series which expresses the uncertainty of the process, the stochastic component. A stochastic process evolves in time according to probabilistic laws and may be pure-random or non-pure random, i.e. the probability law from which realizations of the process are samples may be time-independent or time-dependent, respectively (35).

In this study it was initially assumed a time series $z(t)$ can be described by a linear additive model of the type

$$z(t) = z_T(t) + z_P(t) + z_S(t) \quad 2.1$$

where $z_T(t)$ is a linear trend component, $z_P(t)$ is a periodic component, and $z_S(t)$ is a stochastic component composed of serially dependent random variables generated from independent random variables. If the probability law governing the stochastic component is invariant with respect to position in time, which will be assumed in this project, the stochastic process is said to be stationary.

The procedure followed in the identification and removal of the various components of the wastewater flow time series included an examination of the characteristics of the remaining series at each step by means of correlation and spectral analysis and a subsequent modelling of the phenomenon of interest by the appropriate technique.

2.1.1 Correlation and Spectral Analysis

Correlation and spectral analysis are useful tools for the

identification of the components of time series (9,12,33,35). Correlation analysis quantitatively illustrates the relation between two or more variables. In univariate time series analysis the relation between two variables of the same process, separated in time, is expressed by the autocorrelation function. Exactly the same information is conveyed by the variance spectrum of the process, with frequency as a base.

The mean or expected value of a time series of process z is written as

$$\mu_z = E[z(t)] = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T z(t) dt \quad 2.2$$

where T is the time length of record. The variance or measure of dispersion of the distribution of z about the mean μ_z is written as

$$\sigma_z^2 = E[(z(t) - \mu_z)^2] = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T (z(t) - \mu_z)^2 dt \quad 2.3$$

The expression for the covariance of two variables x and y ,

$$\begin{aligned} \text{cov}[x,y] &= E[(x(t) - \mu_x) * (y(t) - \mu_y)] \\ &= \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T (x(t) - \mu_x)(y(t) - \mu_y) dt \quad 2.4 \end{aligned}$$

in the context of the same time series, is modified to become the autocovariance function γ of two variables of the process z separated by an interval, or lag, τ :

$$\begin{aligned} \gamma(\tau) &= \text{cov}[z(t), z(t+\tau)] = E[(z(t) - \mu_z)(z(t+\tau) - \mu_z)] \\ &= \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T (z(t) - \mu_z)(z(t+\tau) - \mu_z) dt \end{aligned} \quad 2.5$$

The autocorrelation function ρ at lag τ is the ratio of the autocovariance at lag τ to the autocovariance at lag zero (the total variance, σ_z^2); that is

$$\rho(\tau) = \frac{\text{cov}[z(t), z(t+\tau)]}{\text{cov}[z(t), z(t+0)]} = \frac{\gamma(\tau)}{\gamma(0)} = \frac{\gamma(\tau)}{\sigma_z^2} \quad 2.6$$

A plot of the autocorrelation function ρ vs. lag τ is referred to as a correlogram.

An expression relating the autocorrelation function at various lags is given by (14):

$$\begin{aligned} \rho(j) &= \phi(\tau, 1)\rho(j-1) + \phi(\tau, 2)\rho(j-2) + \dots \\ &\dots + \phi(\tau, \tau-1)\rho(j-\tau+1) + \phi(\tau, \tau)\rho(j-\tau) \quad (j=1, 2, \dots, \tau) \end{aligned} \quad 2.7$$

where τ is the maximum lag considered and the ϕ are weighting coefficients called partial autocorrelation coefficients.

A time series can be assumed to be the sum of oscillations of different frequencies. Spectral analysis assumes the process population consists of a continuing spectrum of frequency of which the observed series is but a discrete sample. The variance spectrum analysis separates the continuous frequency spectrum into a number of adjoining intervals, or frequency bands, and apportions part of the

series variance into the appropriate band according to series characteristics.

The Fourier transform $X(f)$, a function of frequency, of any function of time $x(t)$ is given by

$$X(f) = \int_{-\infty}^{\infty} x(t)e^{-i2\pi ft} dt \quad 2.8$$

Physically this represents the distribution of process signal with frequency. Therefore the Fourier transform of the autocovariance function $\gamma(\tau)$,

$$V(f) = \int_{-\infty}^{\infty} \gamma(\tau)e^{-i2\pi f\tau} d\tau \quad 2.9$$

represents the distribution of series variance over frequency.

More practically, since γ and V are even functions,

$$V(f) = \int_{-\infty}^{\infty} \gamma(\tau)\cos(2\pi f\tau) d\tau \quad 2.10$$

and, since negative frequencies are a physical unreality,

$$V(f) = 2 \int_0^{\infty} \gamma(\tau)\cos(2\pi f\tau) d\tau \quad 2.11$$

In terms of $z(t)$,

$$V(f) = \lim_{T \rightarrow \infty} \frac{1}{T} \left| \int_{-T/2}^{T/2} z(t)e^{-2\pi ft} dt \right|^2 \quad 2.12$$

A plot of "power" V vs. frequency f is termed the variance, or power, spectrum. The variance attributable to a particular

frequency band $f_1 f_2$ is the area under V in the interval $f_1 f_2$.

Obviously, then,

$$\int_0^{\infty} V(f) df = \frac{\sigma^2}{2} \quad 2.13$$

These two methods of analysis contribute the same information. The difference is in the way it is displayed. Either method or both can aid in the identification of characteristics of components of time series.

2.1.2 Trend Component

Linear trends, considered in most analyses to be deterministic functions, in this study are dealt with in the analysis of the stochastic component (Section 2.1.4).

2.1.3 Periodic Component

Any periodic or quasi-periodic time series can be expanded into a Fourier series as

$$z(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos(2\pi nft) + b_n \sin(2\pi nft) \quad 2.14$$

in which

$$f = T^{-1} = \frac{\omega}{2\pi} \quad 2.15$$

where T is the fundamental period and ω is the fundamental angular frequency, n is an integer representing the order of the harmonic, a_n and b_n are the harmonic coefficients, and $\frac{a_0}{2}$ is equal to the

mean of the $z(t)$, \bar{z} (9,35). The harmonic coefficients are defined by

$$a_n = \frac{2}{T} \int_0^T z(t) \cos(2\pi nft) dt \quad (n=0,1,2,\dots) \quad 2.16$$

$$b_n = \frac{2}{T} \int_0^T z(t) \sin(2\pi nft) dt \quad (n=1,2,3,\dots) \quad 2.17$$

A periodic component $z_p(t)$ of time series $z(t)$ is assumed to be composed of a finite number k of Fourier harmonics such that

$$z_p(t) = \bar{z} + \sum_{n=1}^k a_n \cos(2\pi nft) + b_n \sin(2\pi nft) \quad 2.18$$

$$a_n = \frac{2}{T} \int_0^T z_p(t) \cos(2\pi nft) dt \quad 2.19$$

$$b_n = \frac{2}{T} \int_0^T z_p(t) \sin(2\pi nft) dt \quad 2.20$$

The amplitude C and phase angle θ of the n^{th} harmonic are expressed as, respectively,

$$C_n = (a_n^2 + b_n^2)^{\frac{1}{2}} \quad 2.21$$

$$\theta_n = \tan^{-1} \left(\frac{b_n}{a_n} \right) \quad 2.22$$

Choice of the fundamental period and the number of harmonics to be used in a periodic component rests on the examination of the particular characteristics of the series being studied. A Fourier analysis of the $\frac{T}{2}$ possible harmonics of the fundamental frequency $\frac{1}{T}$ of a series of length T makes possible the determination of the significant harmonics and their coefficients. Any number of

these up to the maximum may be subtracted from the series, or, as Jones (34) has shown, all the harmonics of fundamental period T may be removed by the subtraction, from each $z(t)$, of the periodic mean $\bar{z}_p(i)$ corresponding to that time t , i.e.,

$$\bar{z}_p(i) = \frac{1}{NFP} \sum_{j=1}^{NFP} z(i+(j-1)T) \quad (i=1,2,\dots,T) \quad 2.23$$

where NFP is the number of fundamental periods, each T data values in length, present in the data record, and i is the relative position of \bar{z}_p within the fundamental period.

2.1.4 Stochastic Component

After removal of all the components of the original time series that are considered to be deterministic and completely predictable (e.g. trends, jumps, periodicities, (Section 1.2.1)), whatever remains is assumed to be a stochastic component $z_s(t)$. Due to lack of information or understanding, or due to the presence of truly random phenomena it is not possible to develop a deterministic model to predict exactly the future of the stochastic process. It may be possible, however, to make a probability statement about the stochastic portion's future behaviour. In this study, it is assumed a time-invariant (i.e. stationary) probability law governs the evolution of the stochastic component of a time series. The collection of parametric stochastic time series models presented by Box and Jenkins (14) can be used to characterize the stochastic components.

The models are based on the concept that the serially dependent values in a stochastic time series can be considered to have been generated from a sequence of independent shocks $\{a\}$, which are drawn from a distribution governed by a time-invariant probability law. Usually the shocks $\{a\}$ are assumed normally distributed with mean zero and variance σ_a^2 .

A divergence is necessary here to introduce the discrete series backward shift operator B (14). It is defined by

$$Bz_S(t) = z_S(t-1) \quad 2.24$$

$$B^m z_S(t) = z_S(t-m) \quad 2.25$$

The backward difference operator ∇ is defined as

$$\nabla z_S(t) = z_S(t) - z_S(t-1) = (1-B)z_S(t) \quad 2.26$$

The shocks $\{a\}$ are assumed to be transformed to the process $z_S(t)$ by a linear filter with transfer function $\psi(B)$, where

$$\psi(B) = 1 + \psi_1 B + \psi_2 B^2 + \dots \quad 2.27$$

Therefore,

$$z_S(t) = \bar{z}_S + \psi(B)a(t) = \bar{z}_S + a(t) + \psi_1 a(t-1) + \psi_2 a(t-2) + \dots \quad 2.28$$

If $\psi(B)$ converges, the process z_S is considered to be stationary and \bar{z}_S is the mean of the process. Otherwise \bar{z}_S represents a reference point for the non-stationary process z_S .

A special case of the linear filter model of Equation 2.28, letting $\tilde{z}_S(t)$ represent $z_S(t) - \bar{z}_S$, is

$$\tilde{z}_S(t) = \psi(B)a(t) \quad 2.29$$

which is an infinite series of shocks, $a(t)$, or, where $\psi(B) = \phi^{-1}(B)$,

$$\phi(B)\tilde{z}_S(t) = a(t) \quad 2.30$$

which is a finite series of values $\tilde{z}_S(t)$, the so-called autoregressive (AR) model. In this model the current value of \tilde{z}_S is expressed as a finite weighted linear sum of p previous values of \tilde{z}_S , plus a random shock $\{a\}$. This is

$$\tilde{z}_S(t) = \phi_1 \tilde{z}_S(t-1) + \phi_2 \tilde{z}_S(t-2) + \dots + \phi_p \tilde{z}_S(t-p) + a(t) \quad 2.31$$

If $\tilde{z}_S(t)$ can be considered to be a finite linear sum of q previous shocks $\{a\}$, the expression

$$\tilde{z}_S(t) = a(t) - \theta_1 a(t-1) - \theta_2 a(t-2) - \dots - \theta_q a(t-q) = \theta(B)a(t) \quad 2.32$$

describes the moving average (MA) model of the stochastic process.

Autoregressive and moving average models may be combined for greater applicability as

$$\phi(B)\tilde{z}_S(t) = \theta(B)a(t) \quad 2.33$$

Non-stationary behaviour in the stochastic time series, such as trends, can be modelled with the introduction of a non-stationary autoregressive operator $\varphi(B)$, which is related to the

stationary autoregressive operator $\phi(B)$ by

$$\psi(B) = \phi(B)(1-B)^d = \phi(B)\nabla^d \quad 2.34$$

where d is the degree of differencing performed by the operator ∇ .

The general stochastic model is then

$$\phi(B)\nabla^d \tilde{z}_S(t) = \psi(B)\tilde{z}_S(t) = \theta(B)a(t) \quad 2.35$$

where $\tilde{z}_S(t)$ refers to $z_S(t) - \bar{z}_S$ for $d = 0$, and to $z_S(t)$ for $d > 0$. This general model treats the d^{th} difference of the series as a stationary, invertible (definition: if the series is expressed in terms of $\pi(B)\tilde{z}_S(t) = a(t)$, the π series of weights must converge on or within the unit circle, or, the roots B must lie outside the unit circle), autoregressive-moving average process. The ensemble of models for stationary and non-stationary time series discussed here are referred to as the autoregressive integrated moving average (ARIMA) stochastic time series models. In particular, one containing a p -order autoregressive operator and a q -order moving average operator, and acting on the d^{th} difference of a time series, is referred to as an ARIMA model of order (p,d,q) .

In different form this treatment of non-stationary behaviour is the same as the variate-difference technique used by Kite (36), but no attempt is made, in the ARIMA modelling procedure, to fit a polynomial function by regression. Uncertainty in the trends is considered to be generated as part of the stochastic process.

A further generalization of these models allows modelling of periodic or seasonal behaviour. Introduction of a seasonal backward shift operator B^S , where

$$B^S \tilde{z}_S(t) = \tilde{z}_S(t-s) \quad 2.36$$

and a seasonal backward difference operator ∇_s , where

$$\nabla_s \tilde{z}_S(t) = \tilde{z}_S(t) - \tilde{z}_S(t-s) = (1-B^S)\tilde{z}_S(t) \quad 2.37$$

simplifies the expression of the multiplicative ARIMA model of order $(p,d,q) * (P,D,Q)_s$, i.e.,

$$\phi_P(B^S)\phi_p(B)\nabla_s^D\nabla_s^d\tilde{z}_S(t) = \theta_Q(B^S)\theta_q(B)a(t) \quad 2.38$$

where ϕ_P and θ_Q are, respectively, the seasonal AR and MA operators of order P and Q , and D is the degree of seasonal differencing. In the interest of model parsimony, or simplicity, it is desirable to use as few parameters as practically possible, as further model refinements may not improve the fit significantly, and may in some cases be redundant. In actual fact, only a few of the above terms are usually required per model in practical applications.

2.2 Data Generation

Sometimes it may be desirable to possess a larger data set than is available in order to, for example, obtain a smoother estimate of sample properties or provide "experience" for a designed structure. If it is expensive or impossible to obtain further observations, an

alternative is the simulation of a large data sample from either a small sample or from a theoretical population. This technique is referred to as Monte Carlo simulation (62).

Data generation from empirical samples makes use of the empirical frequency density distribution and, if it is a property of the sample, the dependence relationship. The latter can be in the form of an empirical correlogram, a mathematical function fitted to the correlogram, or some other mathematical dependence model. The procedure usually involves the equating of the cumulative distribution of independent random numbers x , uniformly distributed between 0 and 1, to the cumulative empirical distribution of variable y (29). That is,

$$\int_0^x 1 dx = \int_0^y f(y) dy = F(y) = x \quad 2.39$$

Taking the inverse function of $F(y)$:

$$y = F^{-1}(F(y)) = F^{-1}(x) \quad 2.40$$

Thus, from generated x values, independent variables of the empirical distribution are produced. Serial or other dependency, if required, can be introduced by another transformation.

Instead of an empirical distribution being used, a theoretical probability distribution can be inferred from a small sample or assumed. Generation of a sample then proceeds as before, the simulated data adopting the characteristics of the assumed distribution.

The only limits to the size of the samples created by the Monte Carlo method are practical ones: the costs of producing and utilizing a large sample, and the degree of accuracy required in results. The most important concept is that the amount of information contained in the generated sample is no more than that in the observed sample, since its properties or inferred properties are merely reproduced by the simulation in arrangements different from the observed.

2.3 The Flow Equalization Basin

In order to determine the operational performance of a flow equalization basin of given volume, controlled operation was simulated.

In this study, a single "ideal" flow equalization basin is assumed, which is a completely mixed tank of given effective volume. This useable storage capacity is in addition to any "dead" storage volume that may be occupied by tank hardware or required for equipment safety (Section 1.2.4). It is therefore the total volume of wastewater that can be pumped into or out of the basin in the space between the minimum water level and the water level above which basin overflow occurs, assuming a horizontal liquid surface at all times.

The basin is assumed to be placed ahead of all treatment stages and to be of the in-line type. Basin inlet and outlet works and pumping capacities are assumed to be adequate to accept the same flows that the treatment plant without flow equalization would be expected to handle. Basin overflows and controlled outflows all pass directly to the next treatment stage.

Recycled flow can be used as an equalization tool. Properly controlled recycle flows can entirely eliminate the fluctuations in flowrates through the wastewater treatment plant at the expense of an increased mean flowrate. Implementation depends heavily on the design flows of other treatment stages and the average inflow rates expected over the life of the equalization facility. In this study the option of recycling plant effluent to the equalization basin is included, to be used to make up unexpected deficits in inflow. Where the option is specified, infinite recycling capacity is assumed.

2.3.1 Basin Operation

The objective adopted in this study for flow equalization is the smoothing of diurnal fluctuations only. The uncertainty in the future flowrates complicates the pre-selection of a smoothed flowrate. At each time interval the attempt is made to "equalize" the flowrate to the forecasted mean inflow rate of the next 24 hours.

The procedure for operation of the ideal basin involves the recording of the inflow rate for the interval and the current storage volume, the forecasting of future flowrates, and the resetting of basin pumping rates according to the forecasts and projected tank levels. The operational procedure is assumed to be carried out precisely at the end of each time interval, and theoretically to consume zero time, so that outflow rates are theoretically reset instantaneously, between successive time intervals.

Adjustments are made to the calculated outflow rate at any interval to avoid forecasted basin overflows, and to force the complete emptying of the basin as near as possible to the end of the low flow period. If recycling is included in the design, a predicted early storage depletion is avoided by recycling to the equalization tank.

In adherence with the definition of a discrete time series, all flowrates used in the simulated operation of equalization basins in this study are assumed constant over the time interval with which they are associated. At each interval boundary the change from one flowrate to the next is considered to occur instantaneously. While basin overflows are not constrained by the step-like flow hydrographs to begin at interval boundaries (overflow begins when a positive net inflow rate has filled a basin to its maximum), the volume of overflow in an interval is considered distributed uniformly over the interval for the purpose of determining the resulting downstream average flowrate. Deficit volumes from occurrences of basin depletions are treated the same way. Where the recycling option is specified and depletion of the storage within the next interval is forecasted, a constant recycle flowrate is determined for the entire interval.

CHAPTER 3

DATA COLLECTION

Discrete time series of raw wastewater inflows to two Ottawa wastewater treatment facilities were compiled from available flow data. Partial flowrate data were available for the years 1967 to 1975 for the 80 MGD ($364,000 \text{ m}^3/\text{d}$) primary treatment Green Creek plant. A time series of 9 years (1967 to 1975) of daily mean flowrates, and three complete series of 3-hourly average flowrates for the years 1970, 1974, and 1975 were constructed. For the 8 MGD ($36,000 \text{ m}^3/\text{d}$) activated sludge Watts Creek plant, continuous flow records for the period November 1, 1972 to January 16, 1976 were available from which a daily mean flowrate time series was obtained. Additionally, a series of hourly average flowrates for January 1, 1975 to January 16, 1976 was taken from the continuous record.

3.1 Selection of Flowrate Data

At both wastewater treatment plants flow data are collected on a continuous basis. At the Green Creek plant both a continuous strip chart recording of instantaneous flowrate and a digital cumulative flow recorder are in operation. As the plant is manned 24 hours per day, readings are taken from the flow "totalizer" every 3 hours. Unless discrepancies are noticed, the 3-hourly average flowrates thus obtained are considered to be the actual flowrates.

For this study the totalizer readings were used for the flowrate data time series, corrections performed by plant personnel included (these were determined by planimetered checks of strip recordings). Missing or incomplete flowrate values, amounting to approximately 0.7 percent of the total for the daily mean series, and 3.2 percent (1970), 0.0 percent (1974), and 0.1 percent (1975) for the 3-hourly flowrate series, were filled in by "engineering" judgment, a method considered adequate when so few data are missing. Any errors so introduced, while not measurable, were assumed to be insignificant compared with the randomness of these series, and therefore were lumped with the stochastic components for analysis.

The flowrate strip recorder and cumulative flow recorder at the Watts Creek plant show excellent agreement, but since this facility is manned only during the day the digital recorder is read only once daily. The effort required to planimeter years of strip charts to find hourly flowrates was avoided by a visual inspection of the charts for the determination of the average hourly flowrate time series. Only small discrepancies were obtained between the daily means of these flowrates and the cumulative daily flow readings which were used for the daily mean time series. The hourly flowrates were adjusted for agreement by means of the assumption that any discrepancy was uniformly distributed over the whole day's hourly flowrates. The downtime of the flow meter was the sole contributor to missing data for the Watts Creek plant flowrates. For the daily mean series this amounted to 3.6 percent of the values, and, for the hourly series,

3.2 percent. Missing data were filled as for the Green Creek time series.

For modelling purposes only the pre-1975 data for Green Creek and pre-1976 data for Watts Creek were used, with the remaining data in both cases being used for forecast checking.

3.2 Flowrate Series Analysis

While the ideal situation for the analysis of a time series is to have available the largest possible data record to enable statements of highest possible resolution to be made about the components, the wastewater flow series under investigation here pose a problem in that regard. Although the behaviour of most interest in this study is the hour-to-hour movements, much information is contained in the day-to-day behaviour throughout the year. It would be advantageous, then, in order to study the longer term series characteristics, to possess at least several years of record. Data handling problems and required computation time for tens of thousands of series values would then become excessive.

There is little that can be done to improve this situation without the loss of valuable information. Evidence for this lies in the case of the Green Creek plant where 3-hourly flowrate data for the years prior to 1970 were discarded due to data storage limitations. Some solution must be found in order to make analysis of long flow records practically applicable.

A possible compromise for the time series analysis of this project is to split the time series into two shorter, independent series, perform an analysis on each, and subsequently combine the information gained. The obvious division of the wastewater flowrate series into a daily mean flowrate series and several series of diurnal fluctuations about the daily means is complicated by the generally held concept (e.g., 45, p.39) that diurnal fluctuation of wastewater flows decreases with increasing daily mean flow. This dependence between the two series would necessitate a separate diurnal series one day in length for each daily mean value.

To test this dependency a variable was defined to characterize the magnitude of the diurnal fluctuation of each day. The variable DVF, is determined by

$$DVF(j) = \int_{j,0:00}^{j,24:00} \frac{\Delta x(j,t)}{\overline{\Delta x}(t)} dt \quad 3.1$$

where $\Delta x(j,t)$ is the diurnal fluctuation about the daily mean flowrate at time t for day j , and $\overline{\Delta x}(t)$ is the average diurnal fluctuation at time t over a large number of days. Using 699 days of Green Creek WWTP 3-hourly flowrate data from 1970 and 1974, the discrete approximation to the variable DVF and the daily mean flowrates were computed and compared for each day.

The scattergram (Figure 5.9) showed no discernable dependence, but the sample correlation coefficient, $r(z_{DM}, DVF)$, where

$$r(x,y) = \frac{\sum_{i=1}^N (x(i)-\bar{X}) (y(i)-\bar{Y})}{\left[\sum_{i=1}^N (x_i-\bar{X})^2 \sum_{i=1}^N (y_i-\bar{Y})^2 \right]^{\frac{1}{2}}} \quad 3.2$$

was, -0.188. To test the hypothesis that the sample correlation coefficient was not significantly different from zero, the statistic t_r was calculated where (64)

$$t_r = \frac{r(N-2)^{\frac{1}{2}}}{(1-r^2)^{\frac{1}{2}}} \quad 3.3$$

which follows the Student-t distribution with N-2 degrees of freedom. The result obtained indicated the sample correlation coefficient was significantly different from zero at the 1 percent level.

While dependence was indicated at the 1 percent level, it was considered small enough to allow the statement to be made that a time series of municipal wastewater treatment plant inflow rates can be considered to be the sum of two independent time series: one of daily mean flowrates, and one of diurnal fluctuations about the daily means.

CHAPTER 4

COMPUTATIONAL PROCEDURE

The raw wastewater flowrate time series (Section 3.2) were analysed according to the procedure outlined previously (Section 1.2.1), using both autocorrelation and variance spectrum analyses for identification purposes. Time series models of flowrate behaviour were constructed. The resulting flowrate models were used in Monte Carlo simulation of flowrate data series with parameters estimated from the observed series.

Computer routines for the operation of flow equalization basins were prepared, capable of accepting actual or simulated flowrate time series as input. A design program was developed for the determination of the required flow equalization basin storage capacity using as a base the simulation of basin operation.

4.1 Time Series Modelling

4.1.1 Autocorrelation and Spectral Analysis Estimation

For discrete series used in this analysis, the sample mean and sample variance were estimated from

$$\bar{z} = \frac{1}{N} \sum_{t=1}^N z(t) \quad 4.1$$

and

$$s_z^2 = \frac{1}{N} \sum_{t=1}^N (z(t) - \bar{z})^2 \quad 4.2$$

Regardless of the length of the interval between successive series values in absolute time, i.e. days or hours, the interval width is assumed, in calculations of this study, to be one time unit.

The sample autocorrelation coefficient r for time lag k was calculated from (19)

$$r(k) = \frac{\sum_{t=1}^{N-k} (z(t) - \bar{z})(z(t+k) - \bar{z})}{\sum_{t=1}^N (z(t) - \bar{z})^2} \quad (k=1, 2, \dots, k_{\max}) \quad 4.3$$

where k_{\max} is the highest order of r to be calculated.

Confidence limits for $r(1)$ on the null hypothesis of $\rho_1 = 0.0$ were calculated according to Anderson (2) as

$$\text{C.L.}[r(1)] = \frac{-1 \pm x_{\alpha} \frac{1}{2} (N-2)^{\frac{1}{2}}}{N-1} \quad 4.4$$

where x_{α} is the standard normal deviate corresponding to the significance level of α percent for a two-tail test.

The series were tested against white noise (definition: a time series having a uniform and equal distribution of variance over all frequencies, and mean equal to zero) by using the chi-square statistic (14)

$$\text{chi} = (N-d-s*D) \sum_{k=1}^{k_{\max}} r^2(k) \quad 4.5$$

where d , s , and D are defined as in Section 2.1.4. For white noise this statistic is Chi-square distributed with k_{\max} degrees of freedom.

In order to examine the correlation not accounted for by an autoregressive process of a certain order the partial autocorrelation coefficients were calculated. For a given lag ℓ , the partial autocorrelation coefficient $\hat{\phi}(\ell, \ell)$ measures the excess correlation in $r(\ell)$ not explained by a $(\ell-1)$ order autoregressive process fitted to the series. The sample partial autocorrelation coefficients $\hat{\phi}(\ell, \ell)$ for lag ℓ were calculated by (14)

$$\hat{\phi}(\ell, \ell) = r(\ell) \quad (\ell=1) \quad 4.6$$

$$\hat{\phi}(\ell, \ell) = \frac{r(\ell) - \sum_{j=1}^{\ell-1} \hat{\phi}(\ell-1, j) * r(\ell-j)}{1 - \sum_{j=1}^{\ell-1} \hat{\phi}(\ell-1, j) * r(j)} \quad (\ell=2, 3, \dots, \ell_{\max}(\leq k_{\max})) \quad 4.7$$

where

$$\hat{\phi}(\ell, j) = \hat{\phi}(\ell-1, j) - \hat{\phi}(\ell, \ell) * \hat{\phi}(\ell-1, \ell-j) \quad (j=1, 2, \dots, \ell-1) \quad 4.8$$

An expression for the sample autocovariance AC for lag k can be obtained by multiplying the sample autocorrelation coefficient (Equation 4.3) by the sample variance (Equation 4.2). Estimates of the sample spectrum v in frequency band j (average frequency in band j is $\frac{j}{k_{\max}}$), smoothed to reduce the variance of the raw spectrum estimator, were calculated using (9)

$$v\left(\frac{j}{k_{\max}}\right) = 2 * [AC(0) + 2 \sum_{k=1}^{k_{\max}-1} AC(k) w(k) \cos\left(\frac{2\pi j k}{k_{\max}}\right)] \quad (j=0, 1, 2, \dots, \frac{k_{\max}}{2}) \quad 4.9$$

where $w(k)$ is the smoothing function, or lag window. In this study three different lag windows were used as each has different smoothing properties:

the Bartlett window (12), $w_B(k) = 1 - \frac{k}{k_{\max}}$ 4.10

the Hanning window (12), $w_H(k) = \frac{1}{2}(1 + \cos(\frac{k}{k_{\max}}))$ 4.11

and, the Parzen window (35), $w_P(k) = 1 - 6(\frac{k}{k_{\max}})^2 + 6(\frac{k}{k_{\max}})^3$ ($\frac{k}{k_{\max}} \leq \frac{1}{2}$) 4.12

$$= 2 * (1 - \frac{k}{k_{\max}})^3$$
 ($\frac{k}{k_{\max}} > \frac{1}{2}$) 4.13

Comparison of smoothed spectral estimate calculations was accomplished by integrating, for each window, the spectrum over the frequency interval $0 \leq f \leq \frac{1}{2}$ and comparing with the sample variance.

Confidence limits on the null hypothesis of white noise for the sample spectrum v at frequency f ($0 \leq f \leq \frac{1}{2}$) were calculated according to

$$\text{Upper C.L.}[V(f)] = \bar{v} * \frac{\chi^2_{100-\alpha, 2N/k_{\max}}}{\frac{2N}{k_{\max}}} \quad 4.14$$

$$\text{Lower C.L.}[V(f)] = \bar{v} * \frac{\chi^2_{\alpha, 2N/k_{\max}}}{\frac{2N}{k_{\max}}} \quad 4.15$$

where $\chi^2_{\alpha, 2N/k_{\max}}$ is the value of the chi-square distribution at the α percent level and with $2N/k_{\max}$ degrees of freedom.

A logarithmic scale was used in plotting the sample spectral estimates because confidence limit factors become additive to the spectral estimates when logarithms are taken, and because a wide range of spectral estimates were found within individual series.

4.1.2 Periodic Component Estimation

Two wastewater flowrate time series were created from the original series based on the assumption of independence (Section 3.2). Both the resulting daily mean and diurnal fluctuation flowrate series were decomposed into their Fourier components as defined by Equations 2.18, 2.19, 2.20, 2.21, and 2.22, using one year and one day, respectively, as the fundamental period, T. The percentage of the series variance attributable to each harmonic n of the $\frac{T}{2}$ harmonics of the fundamental period was calculated as (33)

$$\text{PERVAR}(n) = \frac{C_n^2}{2s_z^2} \quad (n < \frac{T}{2}) \quad 4.16$$

$$= \frac{C_n^2}{s_z^2} \quad (n = \frac{T}{2}) \quad 4.17$$

In both series, the relatively even observed spread of variance among a large number of harmonics necessitated the use of a periodic component model containing an unwieldy number of Fourier terms. For simplicity, therefore, the method of Jones (34) was used to separate the periodic means component (all $\frac{T}{2}$ harmonics) from the original series. For each series the T periodic means and standard deviations of the fundamental period T were calculated, respectively, by

$$\text{ZAV}(i) = \frac{1}{\text{NFP}} \sum_{j=0}^{\text{NFP}-1} z(i+j*T) \quad (i=1,2,\dots,T) \quad 4.18$$

where NFP is the number of fundamental periods contained in the analysed series, and

$$ZS(i) = \left[\frac{1}{(NFP-1)} \left(\sum_{j=0}^{NFP-1} z^2(i+j*T) - NFP * ZAV^2(i) \right) \right]^{\frac{1}{2}} \quad 4.19$$

which includes a correction for the bias introduced by small values of NFP.

The total variance in the sample periodic series, s_z^2 , can be attributed to various components. That is,

$$s_z^2 = s_{ZAV}^2 + s_{ZS}^2 + s_S^2 \quad 4.20$$

where s_{ZAV}^2 is the variance due to periodicity in the means ZAV, s_{ZS}^2 is the variance due to periodicity in the standard deviations ZS, and s_S^2 is the residual variance, i.e., the variance of the stochastic component. The sample estimates of variance were calculated as

$$s_{ZAV}^2 = \frac{1}{T} \sum_{i=1}^T ZAV^2(i) - \overline{ZAV}^2, \quad 4.21$$

$$s_{ZS}^2 = \frac{1}{T} \sum_{i=1}^T ZS^2(i) - \overline{ZS}^2, \quad 4.22$$

and

$$s_S^2 = s_z^2 - s_{ZAV}^2 - s_{ZS}^2 \quad 4.23$$

where \overline{ZAV} and \overline{ZS} are the mean values of the periodic means and standard deviations, respectively.

The complete removal of periodicity in the fundamental period T for a series z(t), leaving the stochastic component $z_S(t)$

was therefore accomplished for the N values of $z(t)$ by the calculation

$$z_S(t) = \frac{z(t) - ZAV(t)}{ZS(t)} * s_S \quad 4.24$$

where ZAV and ZS are the periodic elements of the fundamental period that correspond to time t . The validity of this transformation to remove periodicity is currently under question since the transformation may change the series properties (20).

Discrete deterministic models for the periodic components in this study, therefore, consisted of one-dimensional vectors of periodic means and periodic standard deviations for the series of daily means and diurnal fluctuations, as given by

$$z_p(t) = ZAV(i) \quad \{ZS(i)\} \quad 4.25$$

where i is the number of the time interval in the periodic cycle of daily means or diurnal fluctuations corresponding to absolute time t . The periodic component of a shorter diurnal fluctuation series is, by definition, deterministic, and as such is considered to be the diurnal fluctuation periodic component for the period covered by the longer daily mean series for the same original series.

4.1.3 Stochastic Component Estimation and Modelling

After the removal of the periodic component $z_p(t)$ from the original series $z(t)$, what remains is considered separable into the trend component $z_T(t)$ and the stochastic component $z_S(t)$. For this study the trend component was assumed to be a stochastic variable and was therefore included with the stochastic component $z_S(t)$ in

subsequent analysis. The stochastic components of the two independent series were summed to produce one stochastic time series. To do this it was necessary to assume that the uncertainty expressed by the stochastic component of the daily mean series for any day was uniformly distributed throughout the entire day. The assumption of a governing time-invariant probability law having assured series stationarity except for trends, shorter segments of the resulting series were analysed and modelled according to the procedure outlined by Box and Jenkins (14).

The stochastic modelling procedure involved an initial inspection of the characteristics of the time series by means of the autocorrelation and spectral analysis techniques of Section 4.1.1. A tentative form of ARIMA model (Section 2.1.4) for the series having been suggested through the interpretation of correlograms and spectra, a model of the suggested type was fitted to the observed stochastic component and parameters estimated. The residuals of the fitting, the series of estimated shocks $\hat{a}(t)$, were tested for randomness and probability distribution. If the fitted model was deemed inadequate, a more complicated model was investigated, the process being repeated until satisfaction was achieved.

Parameter estimation for the ARIMA models followed an iterative procedure based on a non-linear least-squares method proposed by Marquardt (40), which combines the rapid convergence in the vicinity of the solution of the iterative Taylor series model expansion method, and the ability of the steepest descent (gradient)

method to converge from a poor initial estimate. Using the results of the previous iteration or the initial parameter estimates, the proposed models were manipulated into the form

$$a(t) = \tilde{z}_S(t) - C(1)\tilde{z}_S(t-1) - \dots - C(j)\tilde{z}_S(t-j) + CF(1)a(t-1) + \dots + CF(i)a(t-i) \quad 4.26$$

where the $C(1), C(2), \dots, C(j)$, and $CF(1), CF(2), \dots, CF(i)$ are numerical weighting coefficients. For example, if a first-order AR model of the form

$$\phi_1(B)\tilde{z}_S(t) = a(t) \quad 4.27$$

were proposed along with an estimate $\hat{\phi}_1$, of ϕ_1 , the model would be manipulated into the form

$$(1 - \hat{\phi}_1 B)\tilde{z}_S(t) = a(t) \quad 4.28$$

or

$$\tilde{z}_S(t) = \hat{\phi}_1 \tilde{z}_S(t-1) + a(t) \quad 4.29$$

Thus the coefficient $C(1)$ would receive the value $\hat{\phi}_1$ and all other values of C and CF in this case would be zero.

Using the observed stochastic time series and Equation 4.26, series of estimated residuals $\hat{a}(t)$ were calculated. At each step of the iteration the sum of squares of the estimated residuals and the parameter estimates were checked for improvement and change, respectively, from the previous iteration. At the end of the iteration, the residual series $\hat{a}(t)$ was tested for serial correlation and spectrum properties as in Section 4.1.1, the only exception being the number

of degrees of freedom for the statistic in Equation 4.5 which became (kmax-NP), where NP is the number of parameters used to fit the model.

Approximate 95 percent confidence limits on a parameter estimate $\hat{\phi}_i$ were computed according to

$$C.L._{.95}[\hat{\phi}_i] = \hat{\phi}_i \pm 2.0 * RSS^{\frac{1}{2}} * s_{\phi}(\hat{\phi}_i). \quad 4.30$$

where RSS is the final residual sum of squares and $s_{\phi}(\hat{\phi}_i)$ is the standard deviation of the parameter estimate, calculated from the covariance matrix of the parameters.

On the assumption of independence and randomness, the empirical frequency distributions of the \hat{a} 's were examined for goodness-of-fit to both normal and lognormal probability distributions. Initially, the method of moments was used to estimate the variance, skewness coefficient, and kurtosis, respectively, of the distributions:

$$s_a^2 = \bar{M}_a^2 \quad 4.31$$

$$g_1 = (\bar{M}_a^3) / (\bar{M}_a^2)^{\frac{3}{2}} \quad 4.32$$

$$g_2 = (\bar{M}_a^4) / (\bar{M}_a^2)^2 \quad 4.33$$

where \bar{M}_a^i is the i^{th} central moment of \hat{a} , given by

$$\bar{M}_a^i = \frac{1}{N} \sum_{i=1}^N (\hat{a}(i) - \bar{a})^i \quad 4.34$$

The test statistic

$$X^2 = \sum_{i=1}^m \frac{(O(i)-E(i))^2}{E(i)} \quad 4.35$$

where the observed variable is grouped into m class intervals, and $O(i)$ and $E(i)$ are the observed and expected frequencies, respectively, of the i^{th} class interval, was calculated for the estimated residuals \hat{a} as a measure of the discrepancy between the observed frequency distributions and theoretical (assumed) normal and lognormal distributions. The Chi-square goodness-of-fit test was performed by comparing the statistic X^2 to a theoretical χ^2 variable at the α percent significance level and with $m-3$ degrees of freedom for both theoretical distributions.

A second goodness-of-fit test, the Kolmogorov-Smirnov (K-S) test, for the \hat{a} 's against the normal and lognormal probability distributions was also performed. As a measure of deviations, the statistic

$$D_{K-S} = \max |F_O(\hat{a}(i)) - F_E(\hat{a}(i))| \quad (i=1,2,\dots,N) \quad 4.36$$

where F_O and F_E are, respectively, the observed and theoretical cumulative probability distribution functions, was calculated for the \hat{a} 's. The goodness-of-fit test involved comparison of D_{K-S} to a table of critical values of D_{K-S} at the α percent significance level.

To test the randomness assumption the $\hat{a}(t)$ series were subjected to a set of non-parametric randomness tests (15). The clustering test counts the runs of the series in each of four class intervals of the \hat{a} 's. For a random variable, the quantity

$$\frac{(G_1 + 0.5 - M_1)}{\sigma_1} \quad 4.37$$

where G_1 is the total number of runs, is approximately a standard normal variable, with mean

$$M_1 = \frac{N(N+1) - \sum_{i=1}^m n_i^2}{N} \quad 4.38$$

and standard deviation

$$\sigma_1 = \left[\frac{\sum_{i=1}^m n_i^2 \left[\sum_{i=1}^m n_i^2 + N(N+1) \right] - 2N \sum_{i=1}^m n_i^3 - N^3}{N^2 (N-1)} \right]^{\frac{1}{2}} \quad 4.39$$

where N is the total number of observations, n_i is the number of observations in the i^{th} class, and m is the number of classes (4 in this application).

The directional runs test counts the upward and downward runs for the series over its full range. If the variable is truly random the quantity

$$\frac{(G_2 + 0.5 - M_2)}{\sigma_2} \quad 4.40$$

where G_2 is the number of runs, is approximately a standard normal variable with mean

$$M_2 = \frac{(2N-1)}{3} \quad 4.41$$

and standard deviation

$$\sigma_2 = \left(\frac{16N-29}{90}\right)^{\frac{1}{2}} \quad 4.42$$

The signs test checks for predominating directional movement by counting the numbers of positive and negative changes in direction along the series. An approximately standard normal variable,

$$\frac{(M_3 - G_3 - 0.5)}{\sigma_3} \quad 4.43$$

where G_3 is the lesser of the number of positive and negative signs, has mean

$$M_3 = \frac{N-1}{2} \quad 4.44$$

and standard deviation

$$\sigma_3 = \left(\frac{N+1}{12}\right)^{\frac{1}{2}} \quad 4.45$$

Each of the randomness statistics for the $\hat{a}(t)$ series was compared to the appropriate theoretical normal distribution. If the inadequacy of an ARIMA model was indicated by the correlation, spectrum, frequency distribution, or randomness tests on the estimated residuals, another model was proposed and the procedure repeated until a satisfactory model was obtained.

4.2 Monte Carlo Simulation

Once deterministic-stochastic time series models were developed to adequately describe the original time series, the Monte Carlo technique for data generation was employed to produce

a number of series segments having the same properties as the original.

To begin the procedure, pseudo-independent random uniformly distributed numbers x in the range 0.0 to 1.0 were generated on the computer. These numbers were transformed to the series of independent random normal shocks $a(t)$, having a pre-specified mean of 0.0 and standard deviation s_a , through the application of the Central Limit Theorem to means of groups of the uniformly distributed random numbers. An independent normal random variable a with population mean μ_a and standard deviation σ_a can be approximated (29) by

$$a = \mu_a + \sigma_a \frac{\sum_{i=1}^k x_i - \frac{k}{2}}{\left(\frac{k}{12}\right)^{\frac{1}{2}}} \quad 4.46$$

where the x_i are uniformly distributed random numbers between 0 and 1.0, and k is the number of values of x_i used in the approximation. As k approaches infinity the expression yields asymptotically normally distributed values of a . For this study Equation 4.46 was used with k equal to 12 to reduce computation time.

The desired persistence in the generated series $\tilde{z}_S(t)$ was produced through the introduction of the values of $a(t)$ one by one into a form of Equation 4.26,

$$\begin{aligned} \tilde{z}_S(t) = & C(1)\tilde{z}_S(t-1) + \dots + C(j)\tilde{z}_S(t-j) - CF(1)a(t-1) - \dots \\ & \dots - CF(i)a(t-i) + a(t) \end{aligned} \quad 4.47$$

in which the coefficients were determined from the parameter values of the chosen ARIMA model.

The final generated wastewater flowrate series is the sum of the deterministic periodic component and the stochastic ARIMA model-generated series. This series is the sum of the two independent series for daily means and diurnal fluctuations. In order to add in the respective periodic components, the generated stochastic series $z_S(t)$ had to be divided into two parts, each being the stochastic component of its respective series, as during the observed series analysis.

An expression for the discrete time series stochastic component z_{S1} at time (i,j) where i refers to the particular day and j to the time of day, can be written as defined in general terms in Section 4.1.3 as

$$z_{S1}(i,j) = z_{S(DM)}(i) + z_{S(DF)}(i,j) \quad 4.48$$

$$z_{S1}(i,j) = \frac{z_{(DM)}(i) - ZAV_{(DM)}(i)}{ZS_{(DM)}(i)} * s_{S(DM)} + \frac{z_{(DF)}(i,j) - ZAV_{(DF)}(j)}{ZS_{(DF)}(j)} * s_{S(DF)} \quad 4.49$$

The subscripts (DM) and (DF) refer to daily mean and diurnal fluctuations, respectively, with other terms as previously defined. For n discrete average flowrates in one day and n generated values of z_{S1} , n realizations of Equation 4.49 can be written, with $n+1$ unknowns, i.e., $z_{(DM)}$ and the n values of $z_{(DF)}$. In addition,

$$\sum_{j=1}^n z_{(DF)}(i,j) = 0 \quad 4.50$$

The desired flowrate series was determined by means of the simultaneous solution of Equation 4.50 and the n Equations 4.49 for each day of generated stochastic component, and the addition of the daily mean and diurnal fluctuation components. Final generated flowrate series values less than zero flow were reset to zero.

4.3 Time Series Forecasts

The combined deterministic-stochastic time series models developed in Section 4.1 were employed in forecasting. The periodic component of any time series forecast, by definition, depends only on time, and therefore is completely predictable. The stochastic component depends on previous values of the stochastic component, whether observations or forecasts.

Referring to Equation 4.47, the conditional expectation $E[\tilde{z}_S(t)]$ of $\tilde{z}_S(t)$ before time t has been reached is the result of all the terms on the right except $a(t)$, which cannot be predicted. On this principle, forecasts for this study were computed at time t_0 for l time-steps ahead as (19)

$$E[\tilde{z}_S(t_0+l)] = C(1)\tilde{z}_S(t_0+l-1)+\dots+C(j)\tilde{z}_S(t_0+l-j) \\ -CF(1)a(t_0+l-1)-\dots-CF(i)a(t_0+l-i) \quad 4.51$$

Since forecasts at time t_0 presume no knowledge of observations for $t > t_0$, observed values of $\tilde{z}_S(t_0+l-j)$ and $a(t_0+l-i)$ were used in Equation 4.51 for $(t_0+l-j) \leq t_0$ and $(t_0+l-i) \leq t_0$ only. For $(t_0+l-j) > t_0$, previously computed forecasts $E[\tilde{z}_S(t_0+l-j)]$ were

used for the $\tilde{z}_s(t_0+l-j)$. Similarly, for $(t_0+l-i) > t_0$, the forecasts $E[a(t_0+l-i)]$, which must be zero, were used for the $a(t_0+l-i)$.

Transformation of the forecasts for the stochastic and periodic components to one time series of forecasts $E[z(t_0+l)]$ was accomplished by means of the procedure of Section 4.2.

The error z' in the l -step ahead forecast made at time t_0 was defined as

$$z'_l(t_0) = E[z(t_0+l)] - z(t_0+l) \quad 4.52$$

i.e., the forecasted flowrate minus the actual flowrate. Estimates of the mean, variance, skewness coefficient, and kurtosis of the distribution of forecast errors were calculated by the method of moments according to Equations 4.1, 4.34, 4.31, 4.32, and 4.33.

CHAPTER 5

RESULTS AND DISCUSSION

Raw wastewater inflow rates for Ottawa's Green Creek and Watts Creek pollution control plants were modelled using a combined deterministic-stochastic time series approach. Based on the flow-rate models for Green Creek data, sample flowrate data were generated. The input of these samples to a computer program used for control of equalization basin operation provided examples of expected performance for basins of various maximum storage capacities. Design relations were obtained from this simulated performance.

5.1 Time Series Modelling

5.1.1 Time Series Analysis of Raw Wastewater Flowrates.

The results of the detailed time series analysis of raw wastewater flowrates for the Green Creek wastewater treatment plant for the years 1970, 1974, and 1975 are given in Table 5.1, and for the Watts Creek wastewater treatment plant for the year 1975, in Table 5.2.

For the 3 years of Green Creek WWTP flowrates shown in Table 5.1, the estimated deterministic component (Equations 4.18, 4.19) accounts for 31.5 to 60.5 percent of the total series variance, the remaining 68.5 to 39.5 percent of the variance being attributed to non-deterministic components (Equation 4.24). Similarly, for the

TABLE 5.1
 STATISTICAL COMPONENTS OF GREEN CREEK WWTP 3-HOURLY RAW FLOWRATE
 SERIES SEGMENTS

Component	Explained Variance, MGD ² *, (with % of Total Series Variance in brackets)	
	1970	1975
Original Series	338.4 (100.)	462.8 (100.)
Daily Means of Orig. Series	198.3 (58.6)	223.6 (48.3)
Diurnal Fluctuations about Daily Means	140.1 (41.4)	239.2 (51.7)
<hr/>		
Component	Explained Variance, MGD ² *, (with % of Total Series Variance in brackets)	
	1970	1975
Original Series	338.4 (100.)	462.8 (100.)
Periodic Component	204.7 (60.5)	145.7 (31.5)
Stochastic Component, total (incl. Trends)	133.7 (39.5)	317.1 (68.5)
- ARIMA Model	69.6 (20.6)	217.1 (46.9)
- Residuals	64.1 (18.9)	100.0 (21.6)

* MGD² X 4546² = (m³/d)²

TABLE 5.2
 STATISTICAL COMPONENTS OF WATTS CREEK WWTP HOURLY RAW FLOWRATE
 SERIES SEGMENTS

Component	Explained Variance, MGD ² *, (with % of Total Series Variance in brackets)		
	1975 all	1975 1st 120 days	1975 2nd 120 days
Original Series	5.68 (100.)	12.29 (100.)	2.27 (100.)
Daily Means of Orig. Series	4.60 (80.9)		2.56 (100.)
Diurnal Fluctuations about Daily Means	1.08 (19.1)		

Component	Explained Variance, MGD ² *, (with % of Total Series Variance in brackets)		
	1975 1st 120 days	1975 2nd 120 days	1975 3rd 120 days
Original Series	12.29 (100.)	2.27 (100.)	2.56 (100.)
Periodic Component	10.38 (84.5)	0.49 (21.6)	1.24 (48.4)
Stochastic Component, total (incl. Trends)	1.91 (15.5)	1.78 (78.4)	1.32 (51.6)
- ARIMA Model	1.64 (13.4)	1.50 (66.1)	1.04 (40.7)
- Residuals	0.26 (2.1)	0.28 (12.3)	0.28 (10.9)

* MGD² X 4546² = (m³/d)²

one year of Watts Creek WWTP flowrates analysed in detail, the seasonal breakdown shown in Table 5.2 attributes 21.6 to 84.5 percent of the total series variance to the deterministic component and 15.5 to 78.4 percent to the non-deterministic components. This clearly demonstrates the need for a combined deterministic-stochastic analysis.

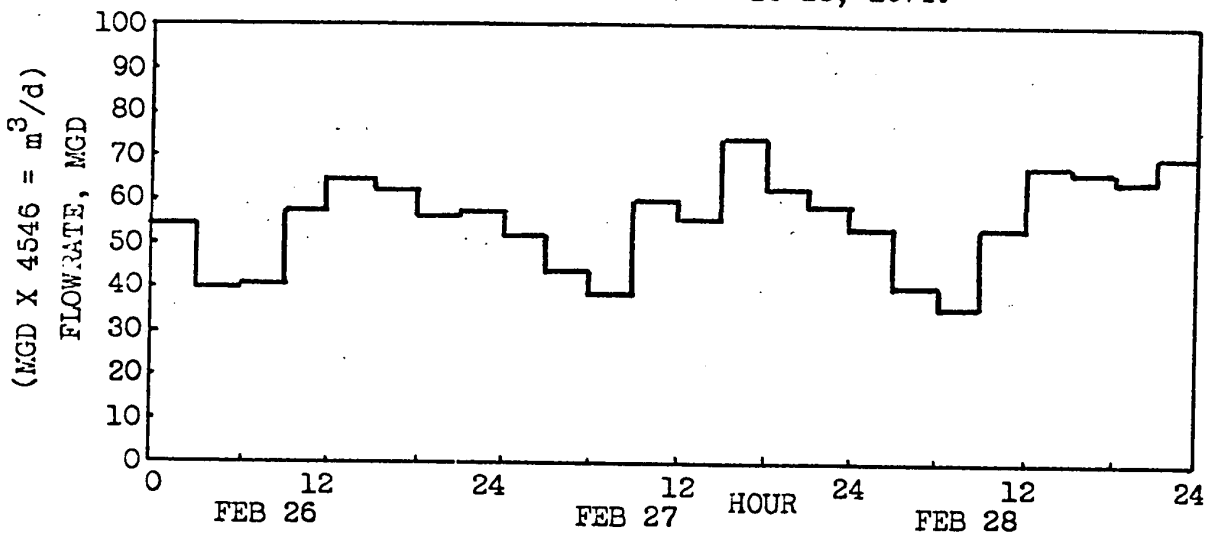
Contributions to total series variance by the daily mean subseries are higher than those by the diurnal fluctuation subseries. The independent random component accounts for about 20 percent of the original series variance for the Green Creek plant and about half that for the Watts Creek plant. Differences apparent from year to year in the Green Creek results are probably mostly attributable to sampling variations, since, as shall be shown below, a one-year sample length spans only one fundamental period. For the one year of analysed Watts Creek series, seasonal variation is clearly visible.

Examples of the raw flowrate time series at each step of their individual analyses are shown in Figure 5.1 for the Green Creek series, February 26 to February 28, 1974, and in Figure 5.2 for the Watts Creek series, February 25 to February 27, 1975.

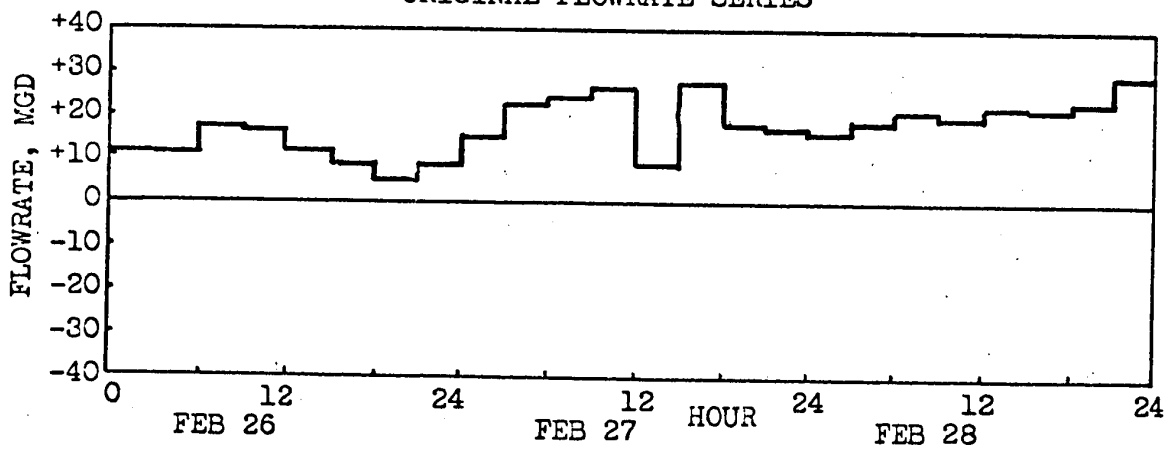
The correlograms obtained at each step of the analyses of the 1974 Green Creek series and the first 120 days of the 1975 Watts Creek series are given in Figures 5.3 and 5.4, respectively.

Results of significance tests (Equations 4.4, 4.5) on the autocorrelation coefficients (Equation 4.3) are shown in Table 5.3 for the 1974 Green Creek series and the first 120 days of the 1975 Watts Creek series.

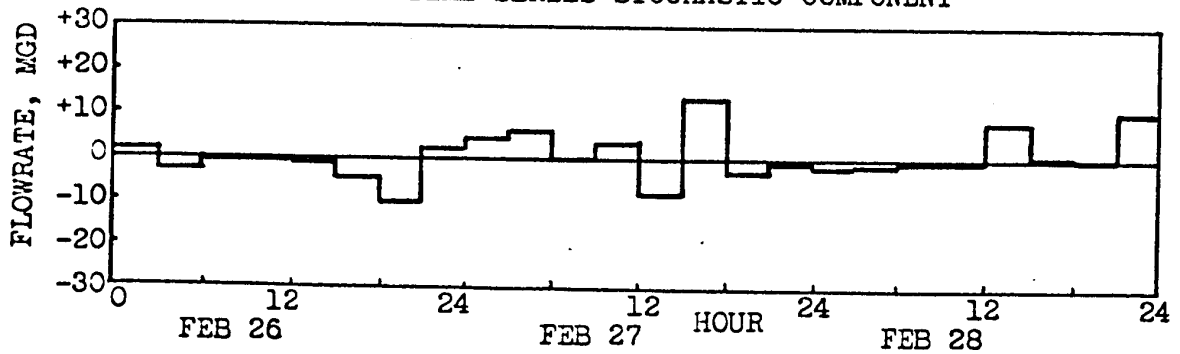
FIGURE 5.1
COMPONENTS OF GREEN CREEK WWTP 3-HOURLY FLOWRATE
TIME SERIES - FEBRUARY 26 TO 28, 1974.



ORIGINAL FLOWRATE SERIES

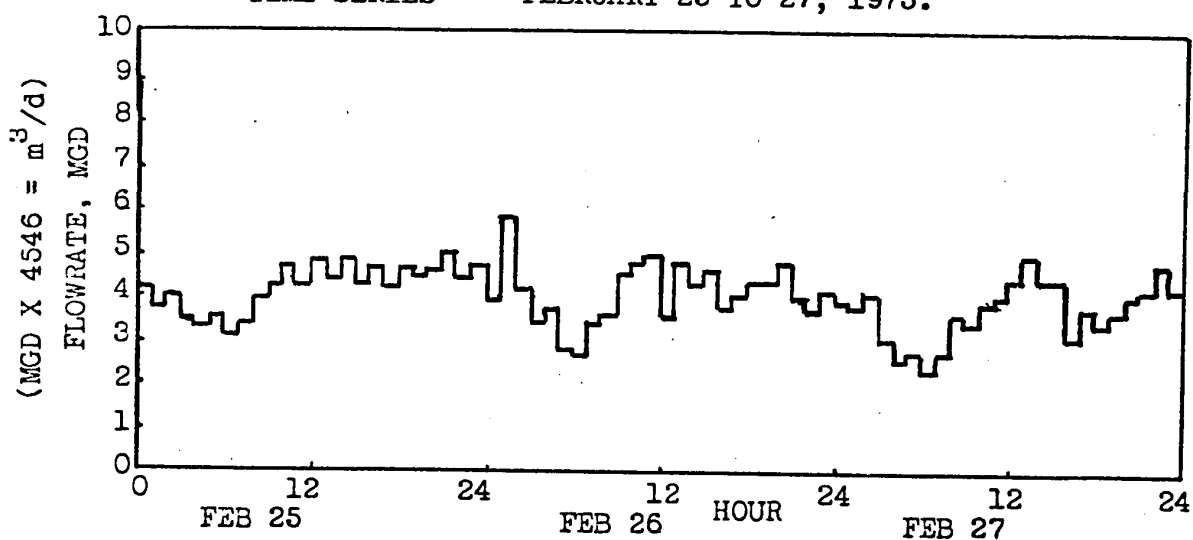


FLOWRATE TIME SERIES STOCHASTIC COMPONENT

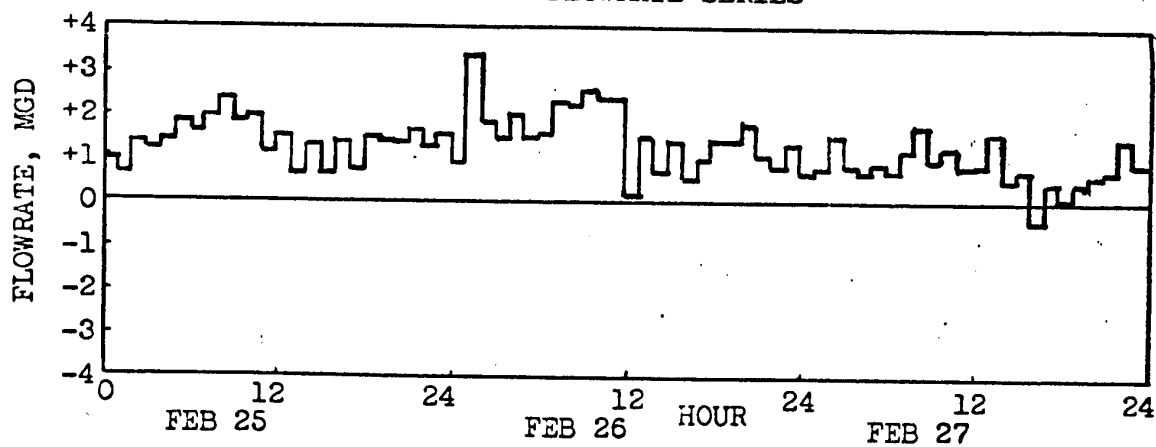


FLOWRATE TIME SERIES MODEL RESIDUALS

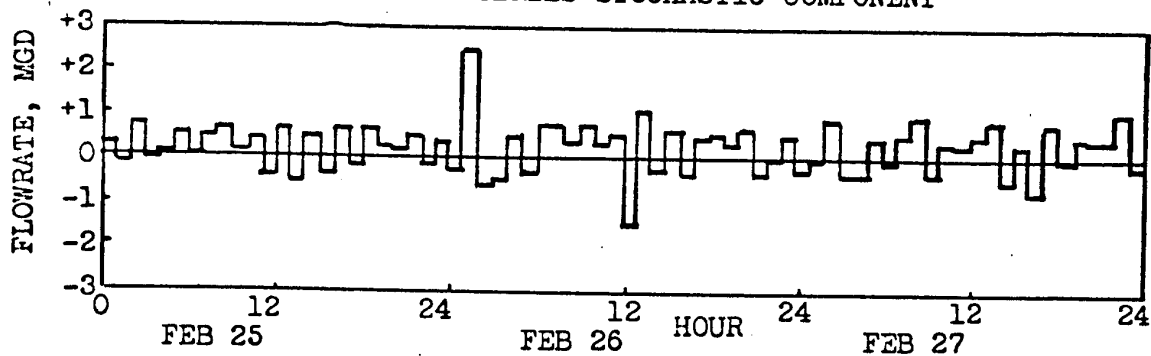
FIGURE 5.2
COMPONENTS OF WATTS CREEK WWTP HOURLY FLOWRATE
TIME SERIES - FEBRUARY 25 TO 27, 1975.



ORIGINAL FLOWRATE SERIES

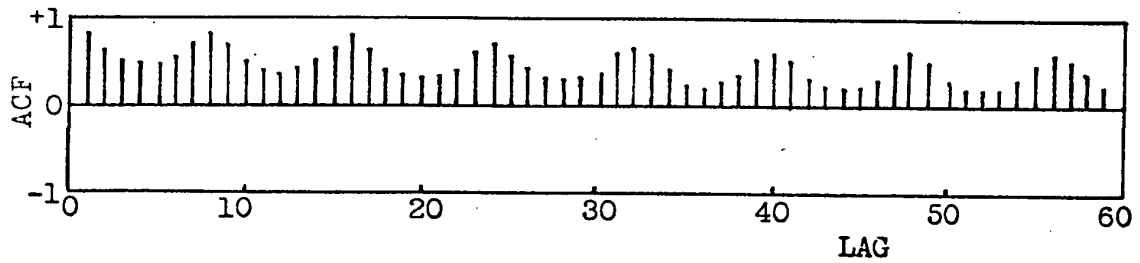


FLOWRATE TIME SERIES STOCHASTIC COMPONENT

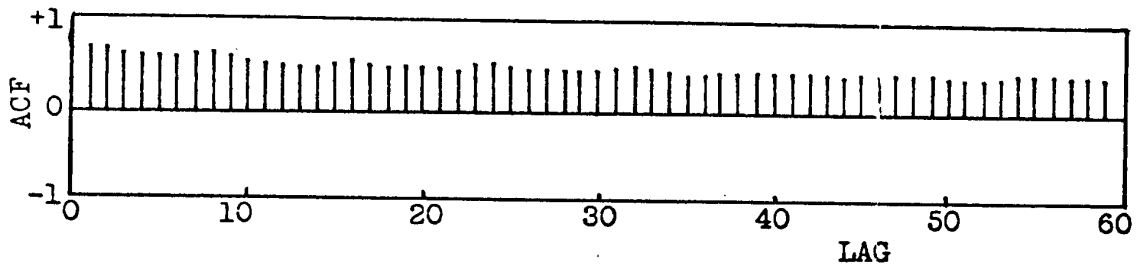


FLOWRATE TIME SERIES MODEL RESIDUALS

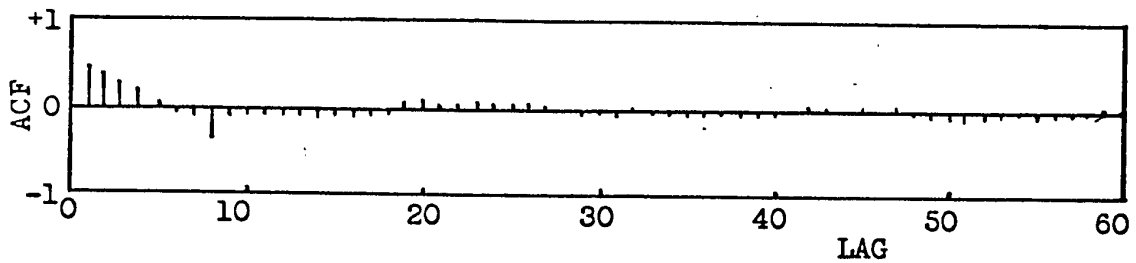
FIGURE 5.3
CORRELOGRAMS FOR TIME SERIES ANALYSIS OF 1974 GREEN CREEK WWTP
3-HOURLY FLOWRATES



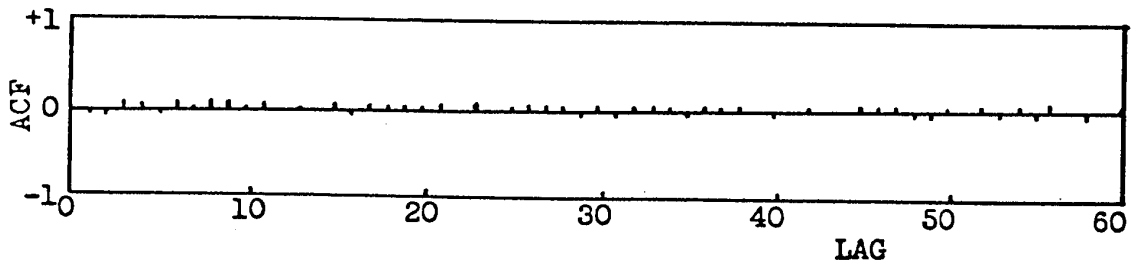
ORIGINAL FLOWRATE TIME SERIES



FLOWRATE TIME SERIES STOCHASTIC COMPONENT



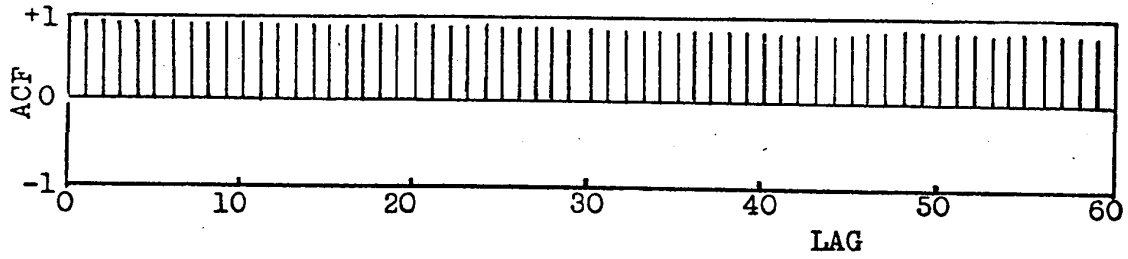
SERIES STOCHASTIC COMPONENT SEASONALLY DIFFERENCED ON LAG 8



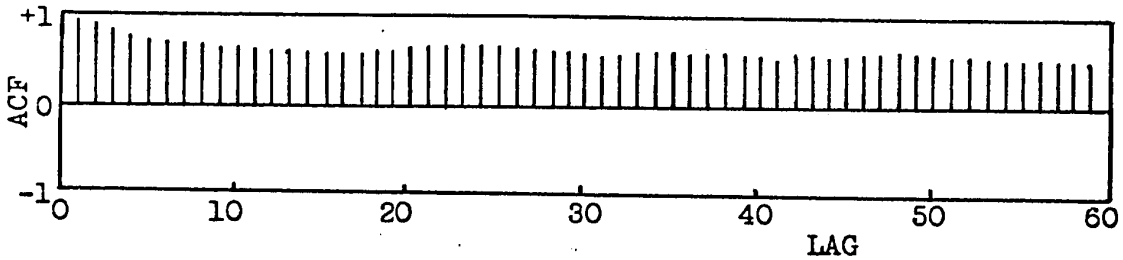
FLOWRATE TIME SERIES MODEL RESIDUALS

FIGURE 5.4

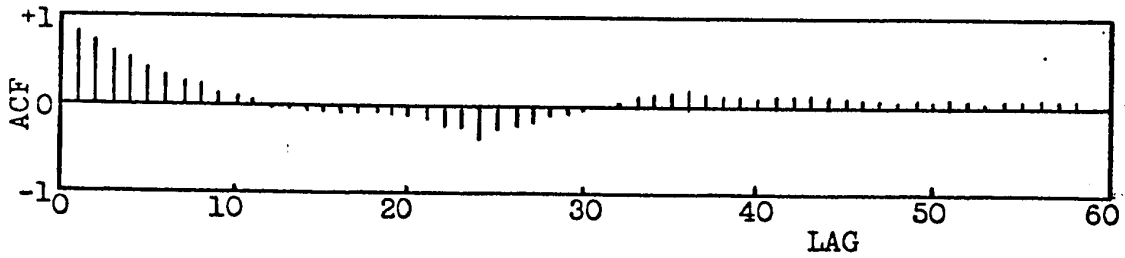
CORRELOGRAMS FOR TIME SERIES ANALYSIS OF 1975 Ja01 - Ap30
WATTS CREEK WWTP HOURLY FLOWRATES



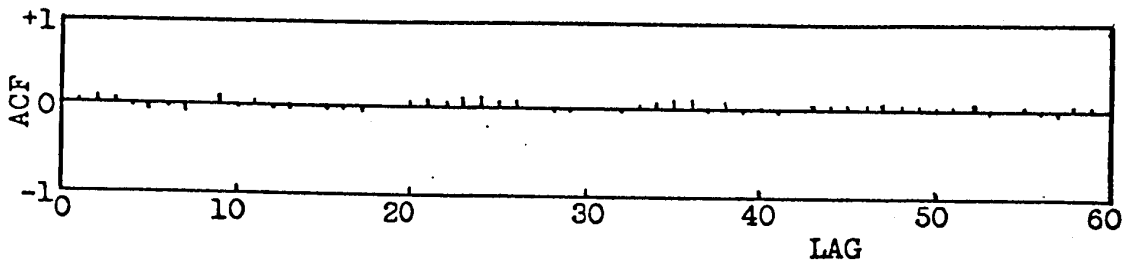
ORIGINAL FLOWRATE TIME SERIES



FLOWRATE TIME SERIES STOCHASTIC COMPONENT



SERIES STOCHASTIC COMPONENT SEASONALLY DIFFERENCED ON LAG 24



FLOWRATE TIME SERIES MODEL RESIDUALS

TABLE 5.3
 RESULTS OF STATISTICAL TESTS ON SAMPLE AUTOCORRELATION COEFFICIENTS FOR GREEN AND
 WATTS CREEK WWTP RAW FLOWRATE TIME SERIES ANALYSES

Stage of Analysis	Serial Independence Test for $\rho(1) = 0.0$ $r(1)$, (with 95 % Confidence Ints. on $\rho(1) = 0.0$ in brackets)	D.F. Test Statistic	Theoretical Chi-square Statistic
Green Creek WWTP 1974 Ja01 - De31			
Original Series	0.785 (-0.037,+0.036)	150	51900
Stochastic Component	0.770 (-0.037,+0.036)	150	67900
Seasonally Differenced Stochastic Component	0.448 (-0.037,+0.036)	150	2240
Model Residuals	-0.030 (-0.037,+0.036)	97	179
Watts Creek WWTP 1975 Ja01 - Ap30			
Original Series	0.988 (-0.037,+0.036)	120	205000
Stochastic Component	0.926 (-0.037,+0.036)	120	98800
Seasonally Differenced Stochastic Component	0.796 (-0.037,+0.036)	120	8490
Model Residuals	0.005 (-0.037,+0.036)	57	210
			75.6

For each step of the same 1974 Green Creek series and 1975 Watts Creek series analyses, the sample partial correlation coefficients (Equations, 4.6, 4.7, 4.8) are shown in Figures 5.5 and 5.6, respectively.

Sample variance spectra for the steps of the analyses are given in Figures 5.7 and 5.8, respectively, using the Bartlett window. In all cases Hanning and Parzen windows gave similar results, and are not shown.

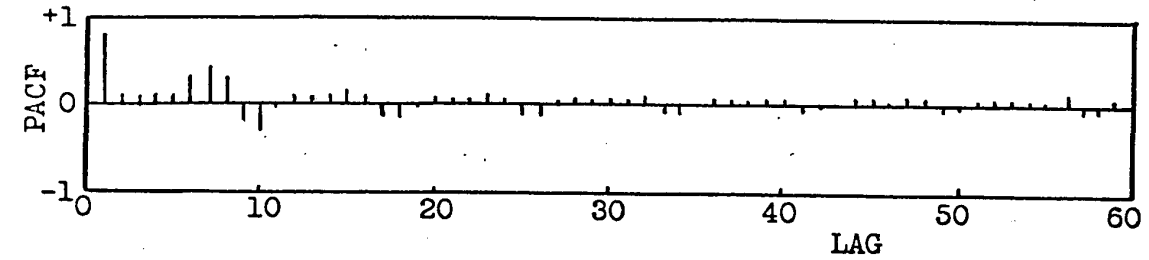
Figure 5.9 shows the relation between the daily mean flowrate and a measure of the diurnal variation about the daily mean (Section 3.2) for 699 days of data from the years 1970 and 1974 for the Green Creek 3-hourly flowrate series.

The sample correlation coefficient (Equation 3.2) relating the two variables is significantly different from zero at the 1 percent level, but the assumption of independence was made and employed in Section 3.2. The division of the original flowrate series into two independent and additive subseries allows the use of shorter data records for the determination of the periodic components, which are assumed in time series analysis to be time-invariant.

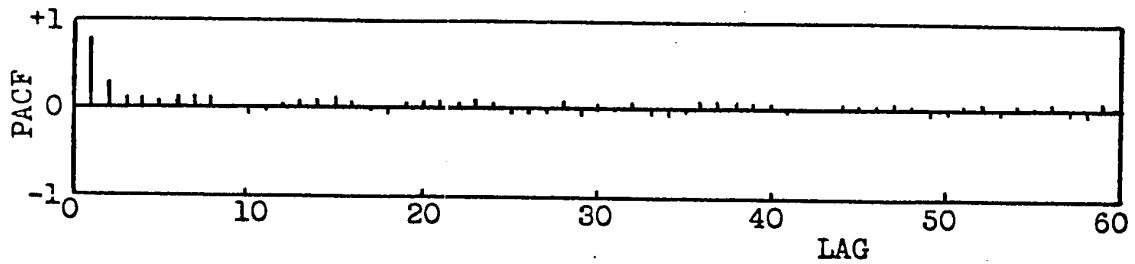
Examples of the flowrate subseries used in this study appear in Figures 5.10, 5.11, 5.12, 5.13. The daily mean flowrate series for the Green Creek plant for 1974 is shown in Figure 5.10, while the diurnal fluctuation about the daily mean series for February 26 to 28, 1974 for Green Creek appears in Figure 5.12. For the Watts Creek

FIGURE 5.5

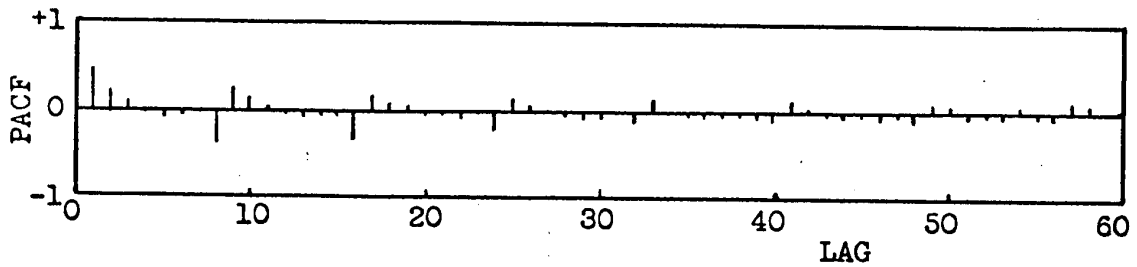
SAMPLE PARTIAL AUTOCORRELATION FUNCTION FOR TIME SERIES ANALYSIS
OF 1974 GREEN CREEK WWTP 3-HOURLY FLOWRATES



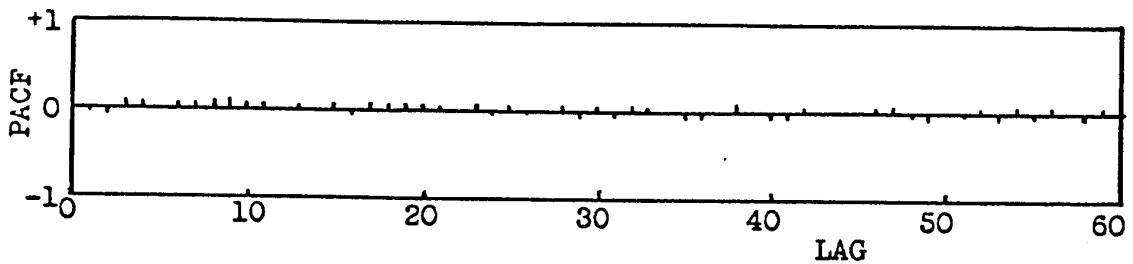
ORIGINAL FLOWRATE TIME SERIES



FLOWRATE TIME SERIES STOCHASTIC COMPONENT



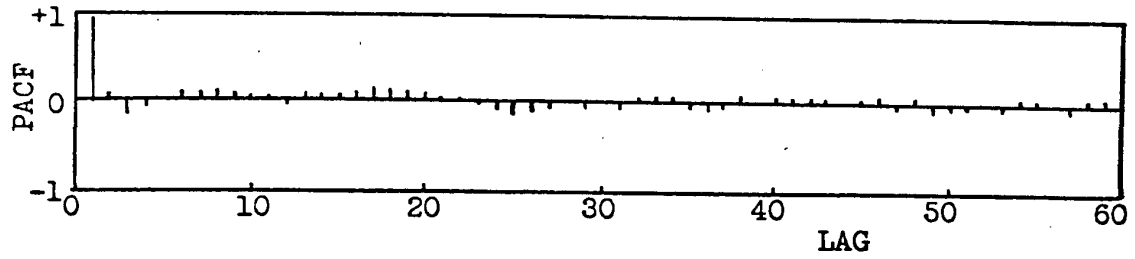
SERIES STOCHASTIC COMPONENT SEASONALLY DIFFERENCED ON LAG 8



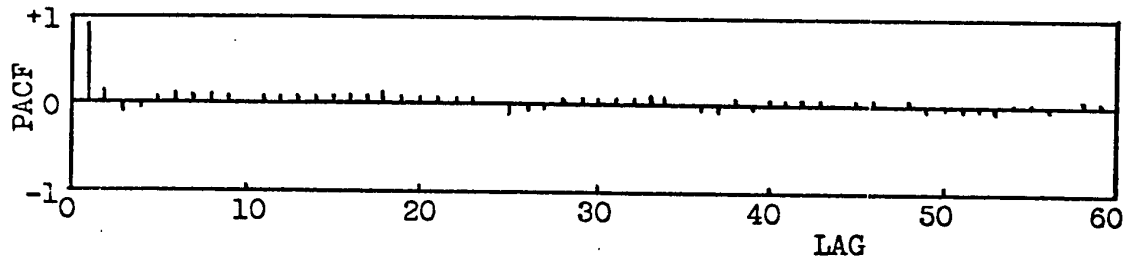
FLOWRATE TIME SERIES MODEL RESIDUALS

FIGURE 5.6

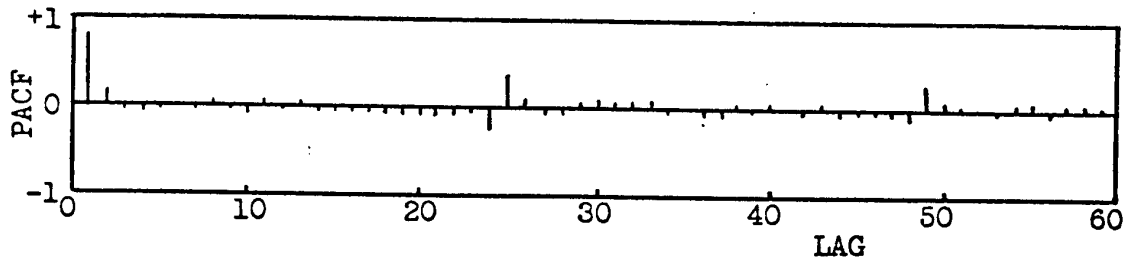
SAMPLE PARTIAL AUTOCORRELATION FUNCTION FOR TIME SERIES ANALYSIS
OF 1975 Ja01 - Ap30 WATTS CREEK WWTP HOURLY FLOWRATES



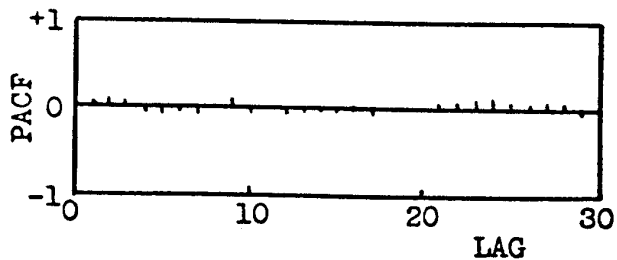
ORIGINAL FLOWRATE TIME SERIES



FLOWRATE TIME SERIES STOCHASTIC COMPONENT



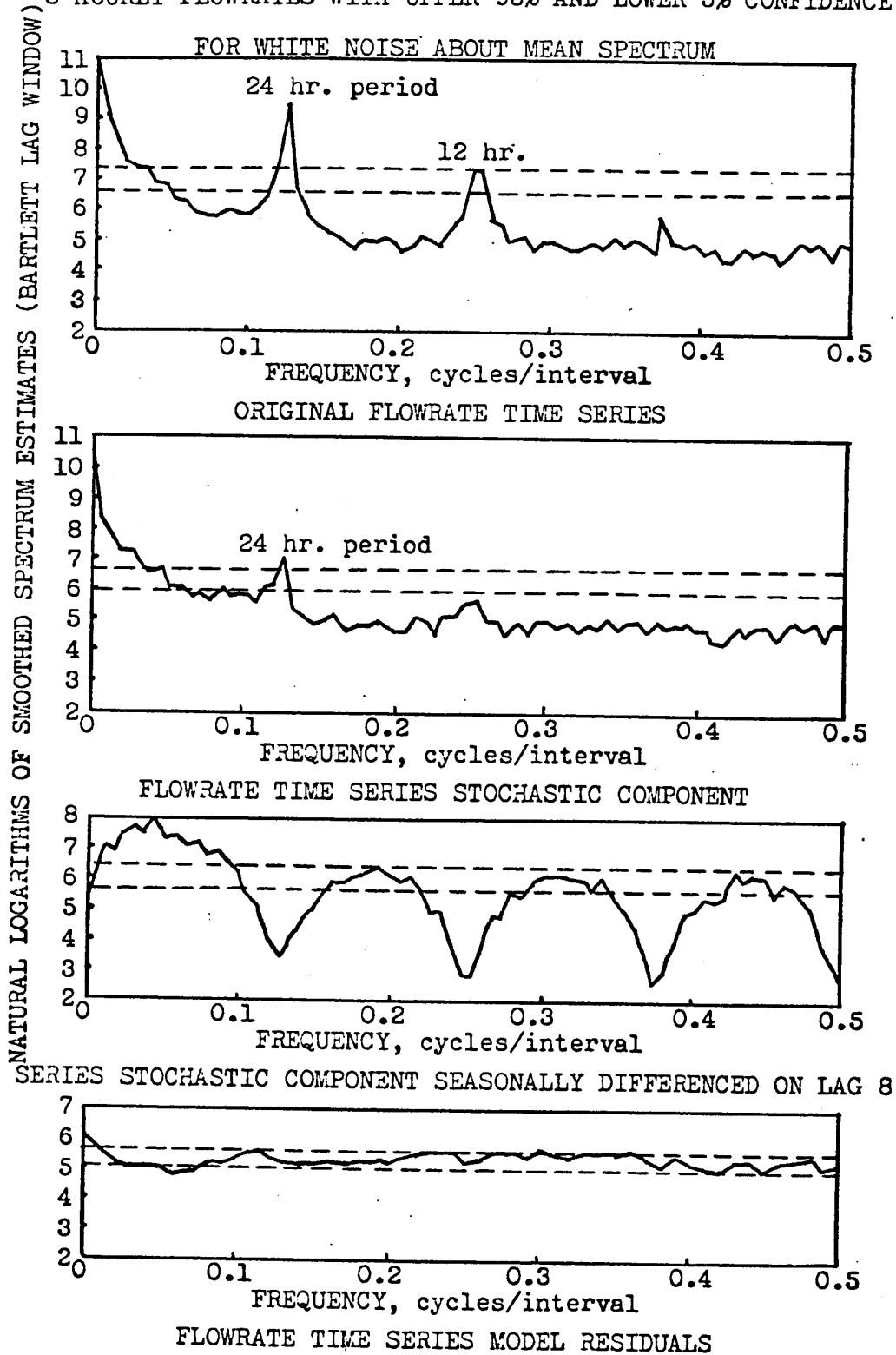
SERIES STOCHASTIC COMPONENT SEASONALLY DIFFERENCED ON LAG 24



FLOWRATE TIME SERIES MODEL RESIDUALS

FIGURE 5.7

VARIANCE SPECTRA FOR TIME SERIES ANALYSIS OF 1974 GREEN CREEK WWTP
3-HOURLY FLOWRATES WITH UPPER 95% AND LOWER 5% CONFIDENCE LIMITS



VARIANCE SPECTRA FOR TIME SERIES ANALYSIS OF 1975 Ja01 - Ap30
WATTS CREEK WWTP HOURLY FLOWRATES WITH UPPER 95% AND LOWER 5%
CONFIDENCE LIMITS FOR WHITE NOISE ABOUT MEAN SPECTRUM

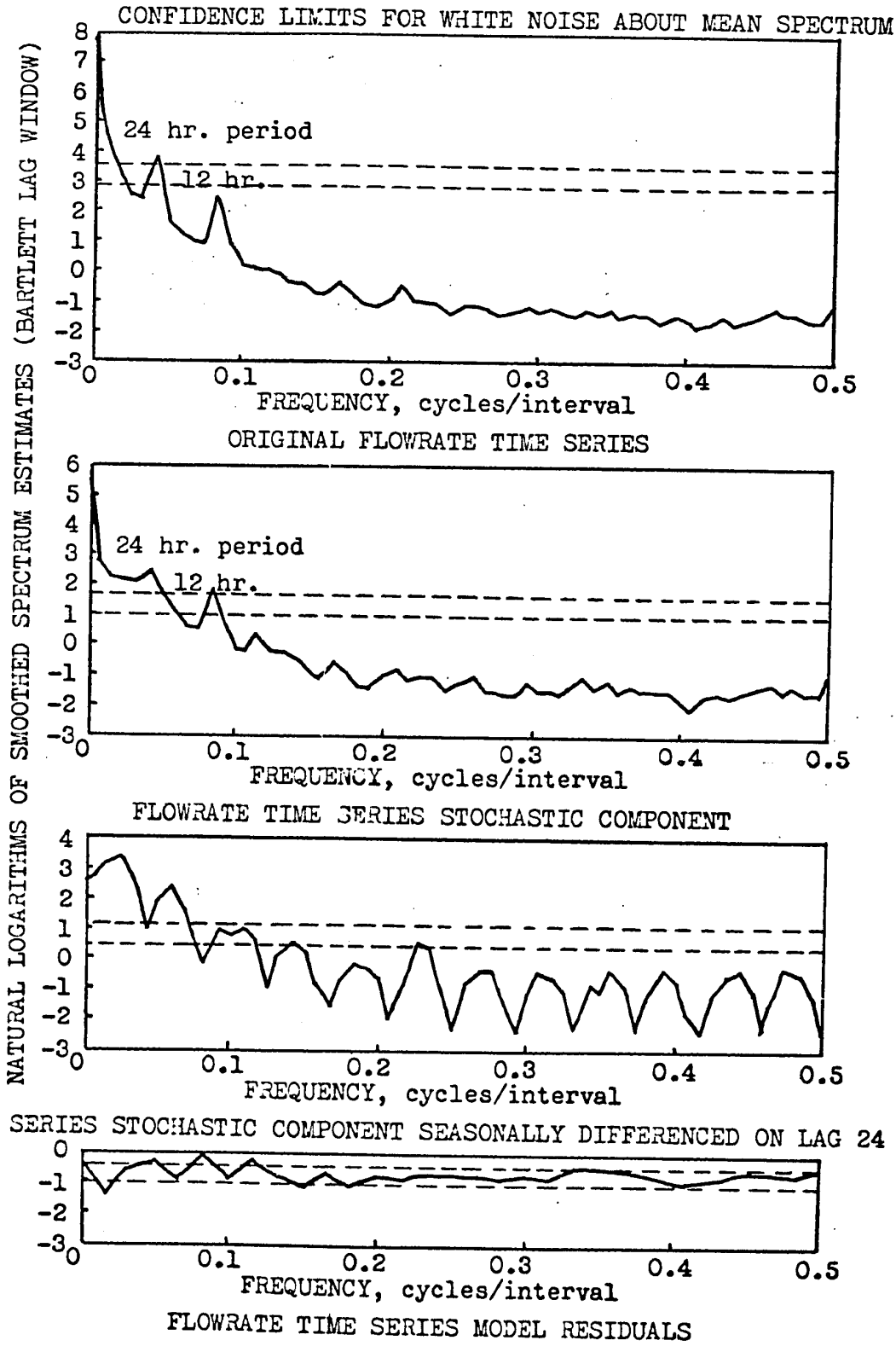


FIGURE 5.9

SCATTERGRAM

DIURNAL VARIATION FACTORS VS. DAILY MEAN FLOWRATES
GREEN CREEK WWTP, 1970, 1974 (excluding October 1974)

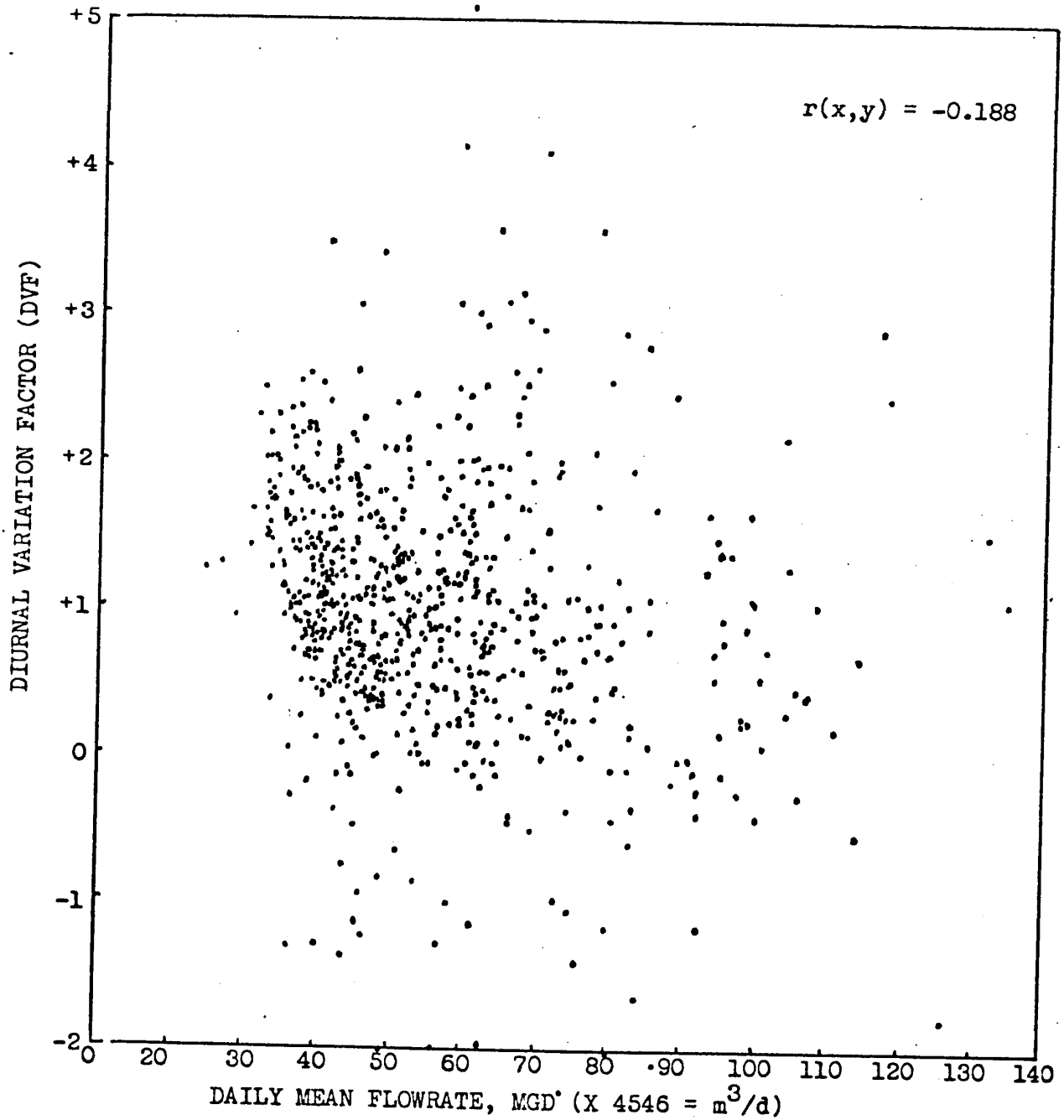


FIGURE 5.10
DAILY MEAN FLOWRATE TIME SERIES - GREEN CREEK WWTP 1974

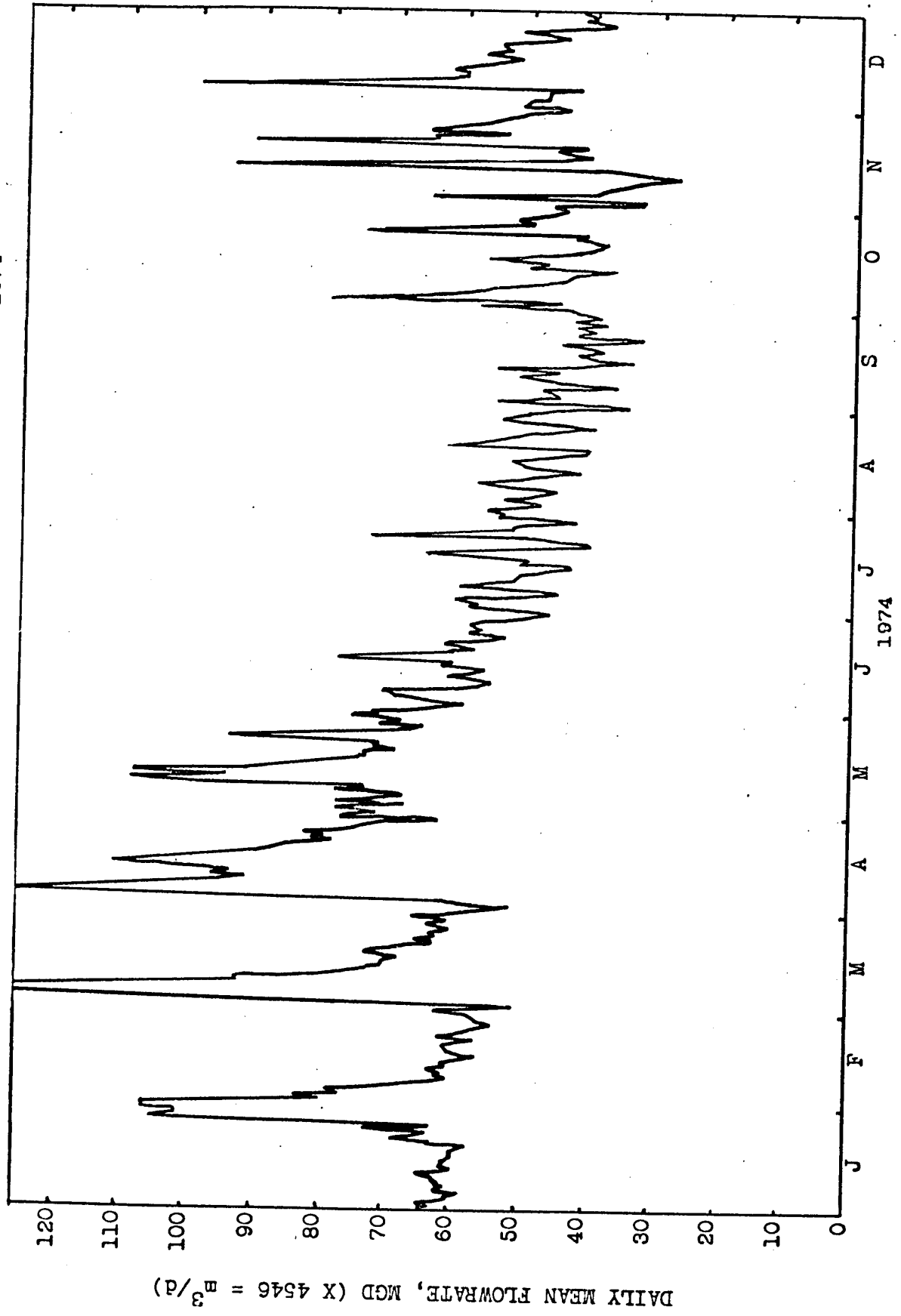


FIGURE 5.11
DAILY MEAN FLOWRATE TIME SERIES - WATTS CREEK WWTP 1975

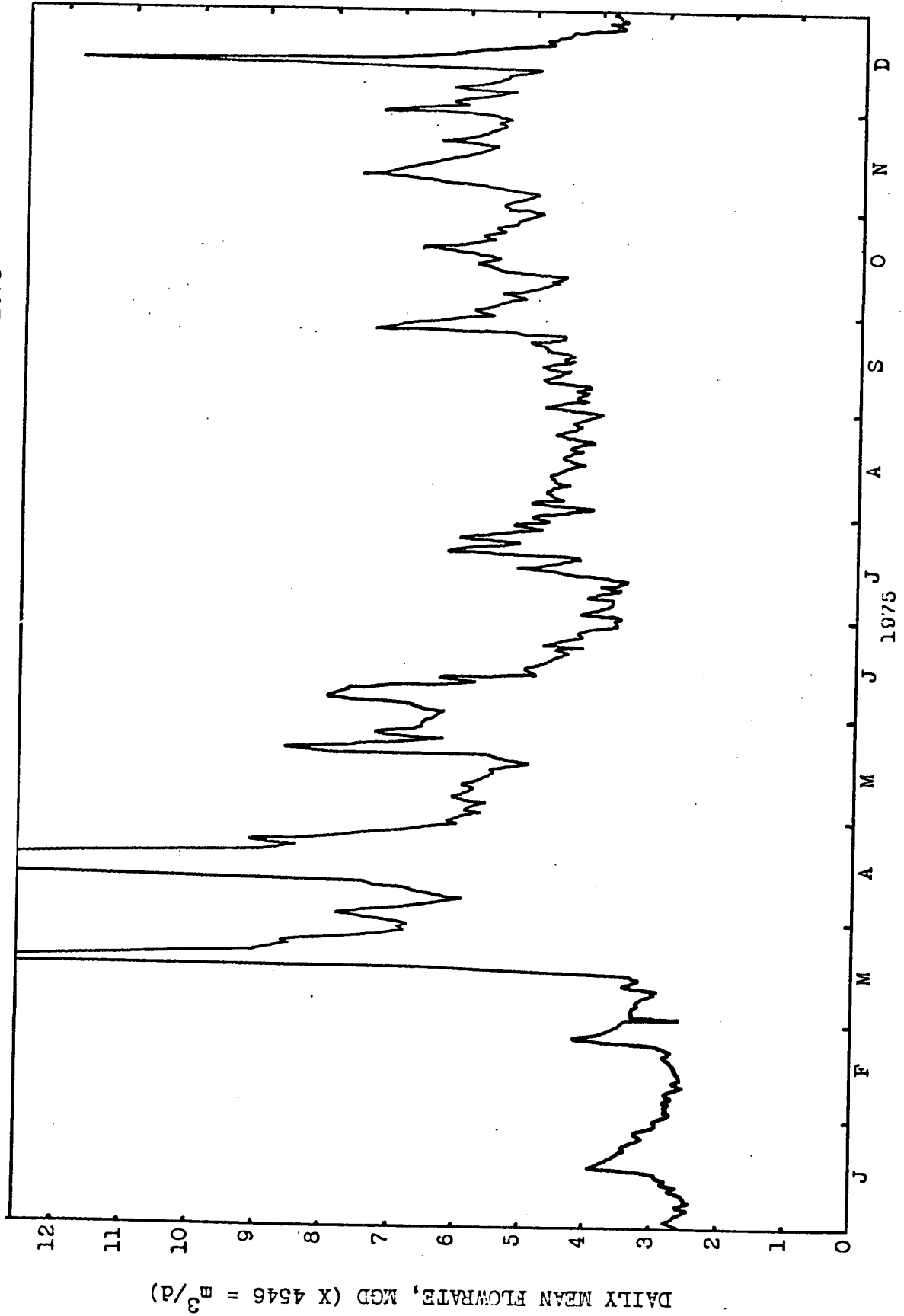


FIGURE 5.12
DIURNAL FLOWRATE FLUCTUATION ABOUT DAILY MEAN FLOWRATE
GREEN CREEK WWTP, FEBRUARY 26 TO 28, 1974

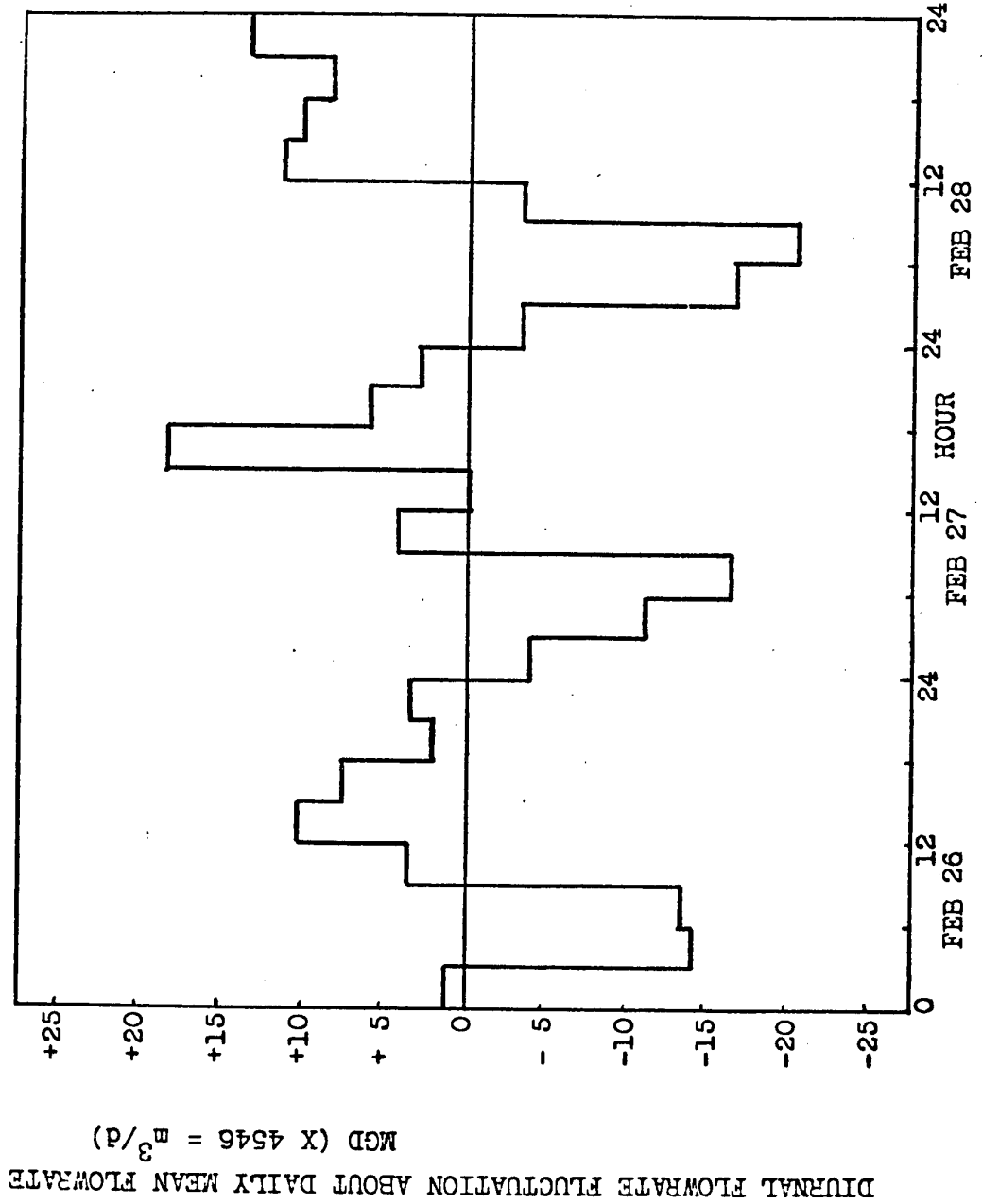
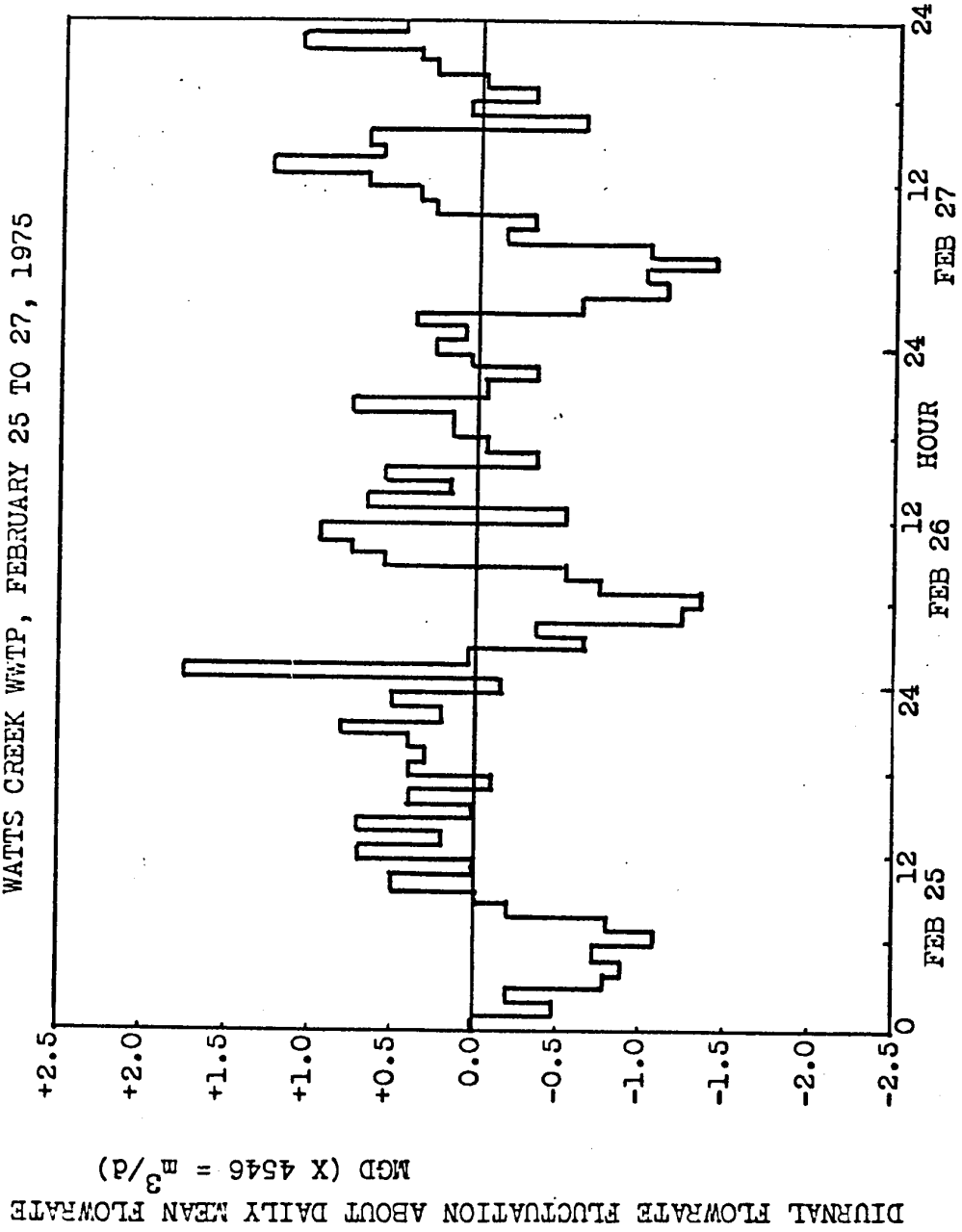


FIGURE 5.13
DIURNAL FLOWRATE FLUCTUATION ABOUT DAILY MEAN FLOWRATE
WATTS CREEK WWTP, FEBRUARY 25 TO 27, 1975



flowrates, the daily mean series for 1975 is given in Figure 5.11, and the diurnal fluctuation series for February 25 to 27, 1975 in Figure 5.13.

Despite the order of magnitude difference in wastewater volumes pumped, and the difference in the sampling intervals, the time series of the two plants exhibit similar behaviour, especially in the diurnal patterns. Flows to the smaller Watts Creek facility show sharp and narrow peaks, indicating a high degree of infiltration or surface inflows during wet weather. Dry weather flows show little fluctuation from day to day, an expected characteristic due to the homogeneous residential nature of the service area. More day-to-day random variation throughout the year is evident in the Green Creek plant flowrates of Figure 5.10, likely attributable to the behavioural uncertainty in the much larger number and variety of wastewater sources.

5.1.1.1 Periodic Components

The results of a Fourier analysis on the 1970 Green Creek 3-hourly flowrate series are given in Table 5.4. For certain harmonics of a fundamental period of 364 days, the explained percentage of the series variance (Equations 4.16, 4.17) is reported. Table 5.4 is typical of the Fourier analysis results from the Green Creek and Watts Creek treatment plant flowrate series.

Evidence of strong daily periodicity and less marked 7 day periodicity in the raw flowrates appears in the upper graphs of Figures 5.1 through 5.8. Not so visible are low frequency periodicities

TABLE 5.4
 SUMMARY OF FOURIER ANALYSIS OF 1970 GREEN CREEK WWTP
 3-HOURLY RAW FLOWRATE SERIES

Harmonic	Period days	% Explained Variance	Harmonic	Period days	% Explained Variance
1	364.0	5.20	130,143,156,		0.16
2	182.0	17.56	169,182,195		
3	121.3	9.47			
4	91.0	1.52	208	1.8	0.14
5	72.8	2.55	221,234,247,		0.02
6	60.7	3.70	260	1.4	0.13
7	52.0	0.30	273,286,299		0.10
8	45.5	0.79			
9	40.4	0.45	312	1.2	0.16
10	36.4	0.19			
11	33.1	0.09	325,338,351		0.05
12	30.3	0.50	364	1.0	20.97
13	28.0	0.51	377,390,403		0.02
14	26.0	0.43	416	0.88	0.18
15	24.3	1.74			
16	22.8	0.37	429,442,455,		
17	21.4	0.59	468,481,494,		
18	20.2	0.14	507,520,533,		
19	19.2	0.24	546,559,572,		
20	18.2	1.02	585,598,611,		0.29
21	17.3	0.27	624,637,650,		
22	16.5	0.41	663,676,689,		
23	15.8	0.21	702,715		
24	15.2	0.01			
25	14.7	0.10	728	0.50	4.69
26	14.0	0.01	741,754,767		0.01
27	13.5	0.00	780	0.47	0.11
28	13.0	0.08			
29	12.6	0.00	793,806,819		
30	12.1	0.08	832,845,858,		
31	11.7	0.03	871,884,897,		0.32
32	11.4	0.02	910,923,936,		
33	11.0	0.02	949,962,975,		
34	10.7	0.18	988,1001,1014,		
35	10.4	0.19	1027,1040,1053,		
36	10.1	0.27	1066,1079		
37	9.8	0.94			
38	9.6	0.15	1092	0.33	0.26
39	9.3	0.67			
40	9.1	0.03	1105,1118,1131,		
			1144,1157,1170,		
52	7.0	0.43	1183,1196,1209,		
65,78,91		0.09	1222,1235,1248,		0.32
104	3.5	0.46	1261,1274,1287,		
117	3.1	0.11	1300,1313,1326,		
			1339,1352,1365,		
			1378,1391,1404,		
			1417,1430,1443,1456		

which are detected at long lags in the correlation analyses of Figures 5.2 to 5.6, and at the low frequency end of the variance spectra of Figures 5.7 and 5.8.

A fundamental period of 364 days was adopted because a significant contribution to the variance is made by the 52nd harmonic (and higher multiples) of the 364 day period, the period exactly 7 days in length. This represents the influence of man's weekly habits on wastewater flows. The use of the more common 365 day period would have meant the loss of this information.

Unfortunately, for series of many consecutive years of data, a false phase shift is introduced along with the 364 day period. To circumvent this problem the deletion of 7 consecutive days of data at the end of every 5 or 6 year segment of a wastewater flow time series is suggested. It is felt the resulting loss of information would be slight compared to that from the use of a 365 day period.

While a large contribution to series variance is made by the first 6 harmonics of the 364 day period, and the one- and half-day periodicities (total for these 8 harmonics is 65.7 percent of total variance) (Table 5.4), much of the remaining variance is distributed quite evenly among many harmonics. To avoid periodicity models containing many Fourier terms, vectors of periodic means and standard deviations were calculated (Equations 4.18, 4.19) for the daily mean and diurnal fluctuation subseries (Section 4.1.2). These vectors account for all harmonics of the fundamental periods.

The resulting periodic components (Equations 4.18, 4.19) are illustrated in Figures 5.14, 5.15, 5.16 and 5.17. The 364 periodic daily means and standard deviations of the daily means for Green Creek raw wastewater flowrate daily means for January 1, 1967 to December 21, 1974 are given in Figure 5.14. The 8 periodic 3-hourly diurnal fluctuation means and standard deviations of the means for the years 1970 and 1974 for Green Creek 3-hourly raw diurnal fluctuation flowrates appear in Figure 5.15. Similarly, for Watts Creek wastewater treatment plant raw flowrates, the 364 periodic daily means and standard deviations of the means from the daily mean series of the period January 1, 1973 to December 28, 1975 are given in Figure 5.16. Figure 5.17 shows the 24 periodic 1-hourly diurnal fluctuation means and standard deviations of the means from the 1975 Watts Creek diurnal fluctuation series.

Due to the short length of record (8 years for Green Creek; 3 years for Watts Creek) used to determine the models for the daily mean periodicities, sampling errors have contributed to the non-smoothness in their plots. Of necessity, any periodicity with period longer than 364 days is ignored. If any exists in the data, but is not detected here, it is assumed included with long term trends which are handled by the stochastic component models of Section 2.1.4.

The separation of the original flowrate series into the two subseries and construction of periodicity models for each also ignores most of the higher harmonics of the 364 day period. The periodic component of the 364 day fundamental period accounts for the

FIGURE 5.14
DAILY MEAN FLOWRATE PERIODIC COMPONENT - GREEN CREEK WWTP

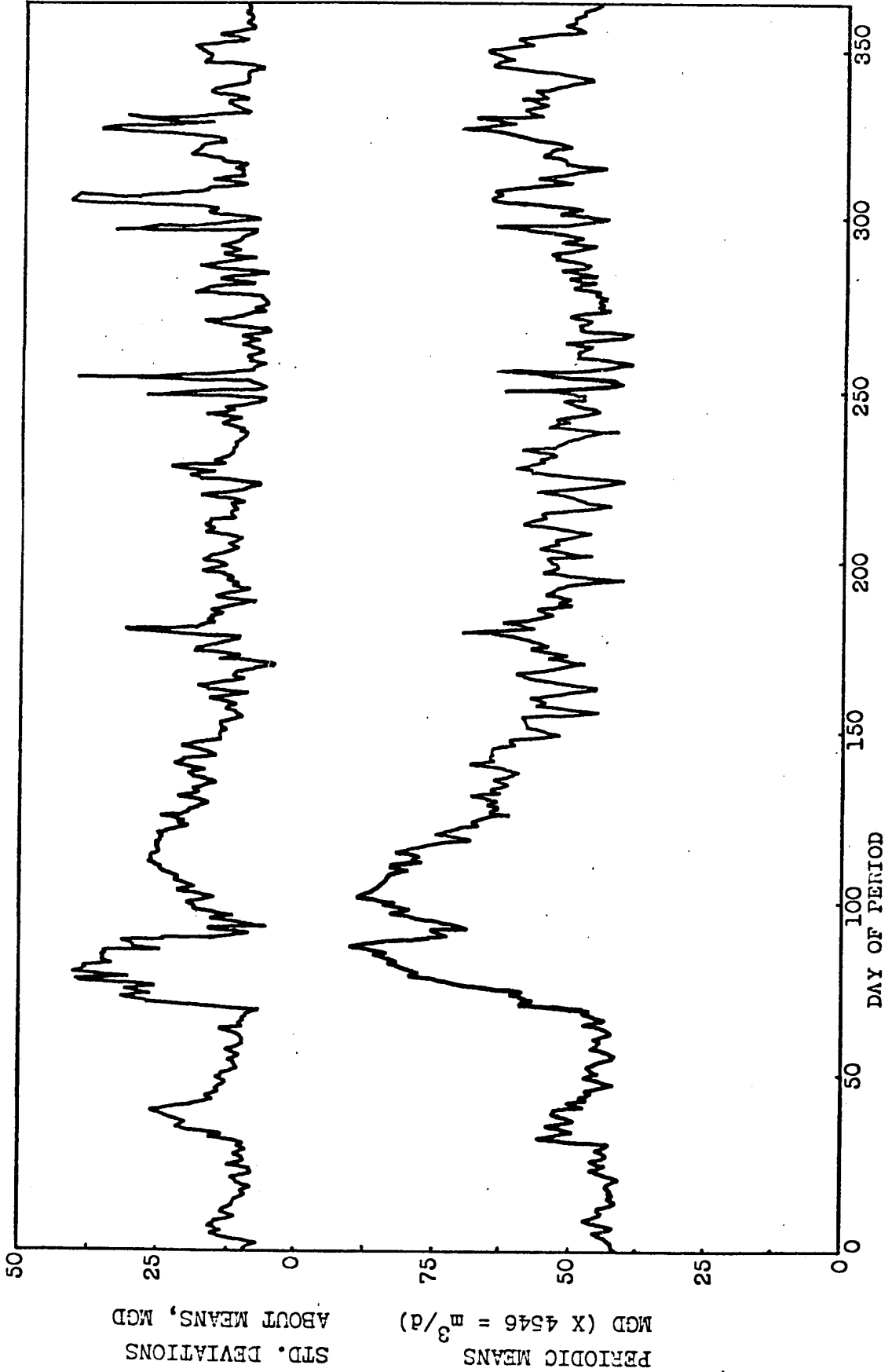


FIGURE 5.15
DIURNAL FLOWRATE FLUCTUATION PERIODIC COMPONENT - GREEN CREEK WWTP

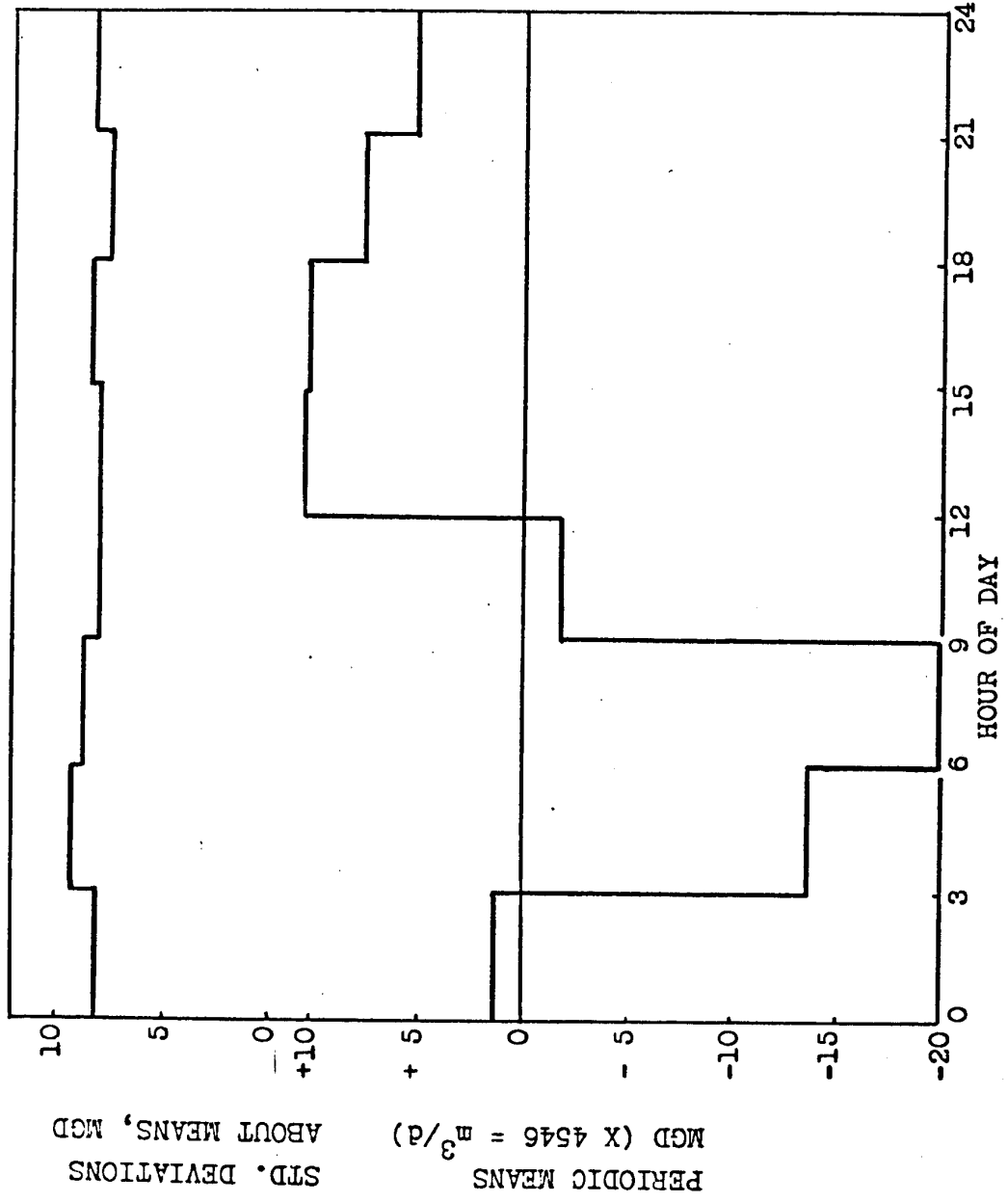


FIGURE 5.16
DAILY MEAN FLOWRATE PERIODIC COMPONENT - WATTS CREEK WWTP

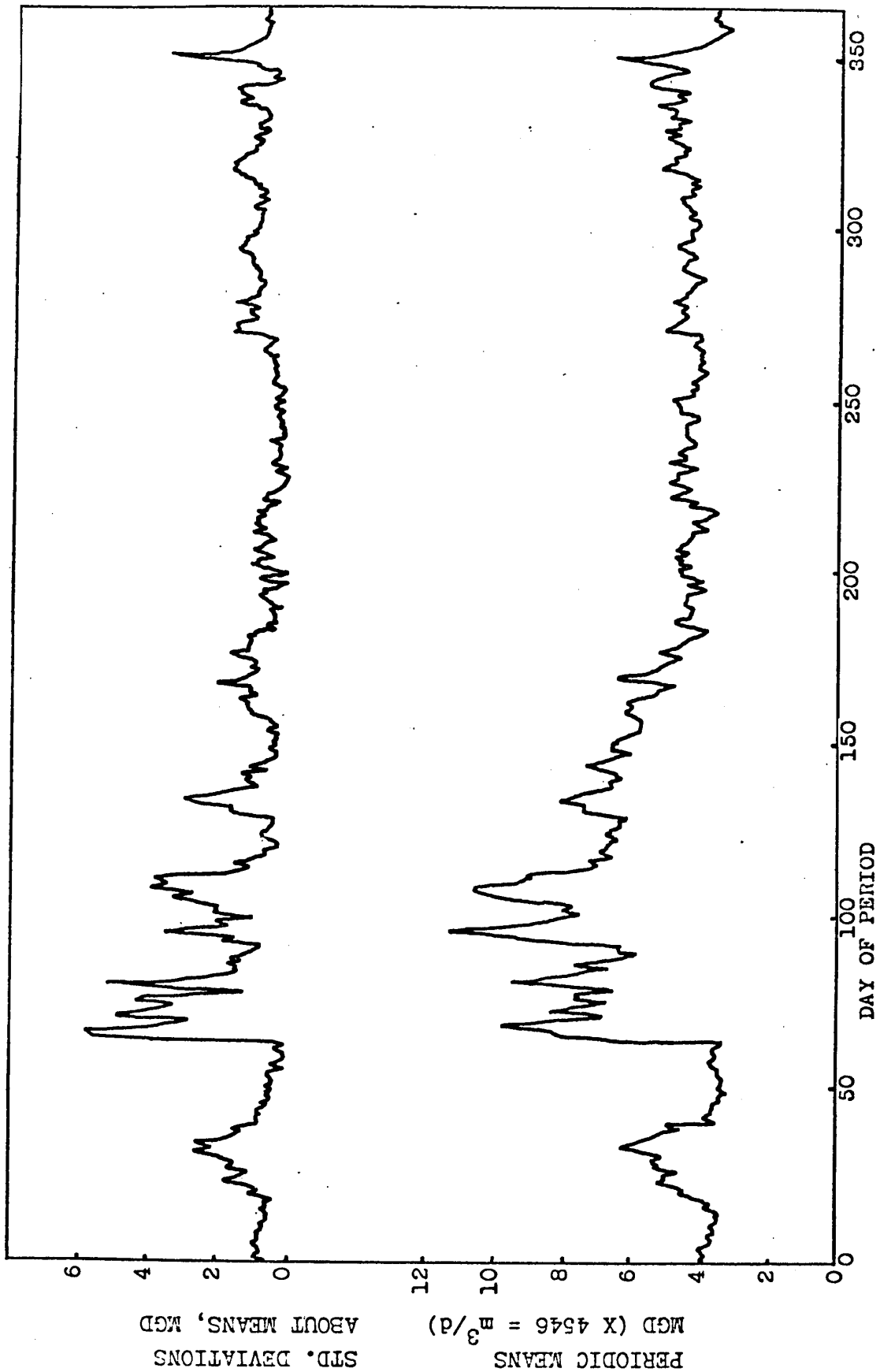


FIGURE 5.17
DIURNAL FLOWRATE FLUCTUATION PERIODIC COMPONENT - WATTS CREEK WWTP

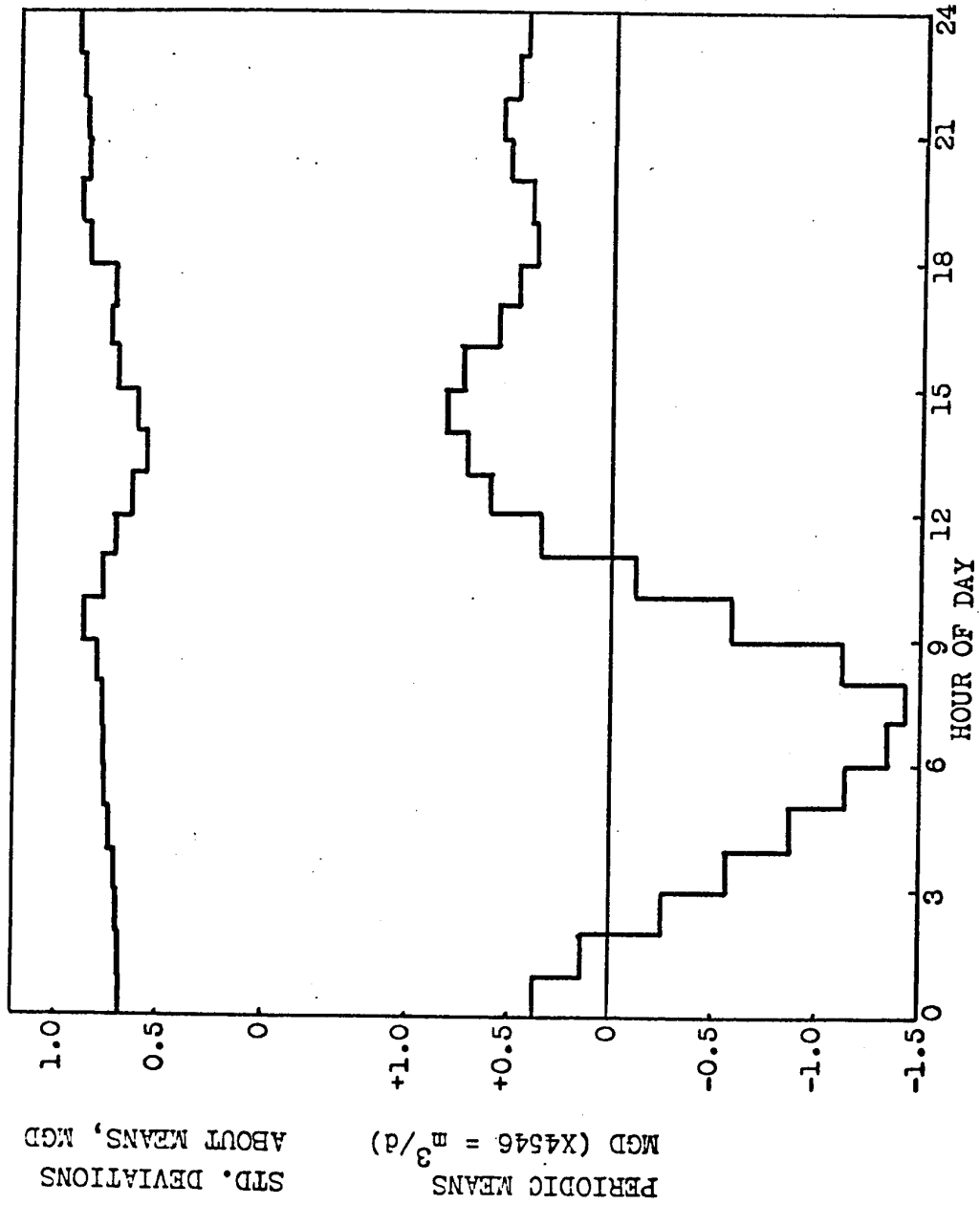


TABLE 5.5

STATISTICAL COMPONENTS OF LONG FLOWRATE SUBSERIES USED TO DERIVE DETERMINISTIC PERIODIC COMPONENTS FOR GREEN AND WATTS CREEK WWTP RAW FLOWRATES

Daily Mean Flowrate Subseries	Green Creek WWTP 1967 Ja01 - De21 1974	Watts Creek WWTP 1973 Ja01 - De28 1975
Fundamental Period, days	364	364
Values per period	364	364
Component	Explained Variance, MGD ² *, (with % of Original Variance in brackets)	
Original Series	405.9 (100.)	4.72 (100.)
Periodic Component, total	181.9 (44.8)	3.39 (71.8)
Means	131.1 (32.3)	2.42 (51.3)
Std. Deviations about Means	50.8 (12.5)	0.97 (20.5)
Stochastic, including Trends	224.0 (55.2)	1.33 (28.2)
Diurnal Fluctuations about Daily Means Subseries	Green Creek WWTP All 1970, 1974	Watts Creek WWTP All 1975
Fundamental Period, hours	24	24
Values per period	8	24
Component	Explained Variance, MGD ² *, (with % of Original Variance in brackets)	
Original Series	180.1 (100.)	1.08 (100.)
Periodic Component, total	110.9 (61.6)	0.51 (47.0)
Means	110.7 (61.5)	0.50 (46.2)
Std. Deviations about Means	0.2 (0.1)	0.01 (0.8)
Stochastic, including Trends	69.2 (38.4)	0.57 (53.0)

* MGD² X 4546² = (m³/d)²

first 182 harmonics, while the diurnal periodic component contributes the 364th harmonic and its higher multiples up to the $\frac{n}{2} * 364^{\text{th}}$ multiple, where n is the number of observation intervals in a day. The 183rd to 363rd, 365th to 727th, etc. harmonics of the 364 day fundamental period are thus not accountable by this procedure. The contribution of each of these higher harmonics to the total series variance is assumed to be negligible, since lower order harmonics in the region of the 100th to 180th harmonic (Table 5.4) show negligible contributions.

A summary of periodic component analyses for both Green Creek and Watts Creek plant flowrate series is shown in Table 5.5. Periodicity in the variance is noticeable in Table 5.5 on a seasonal level (daily mean series), illustrating the effects of the annual climatic cycle on uncertainty in the periodic mean flowrates.

5.1.1.2 Stochastic Components

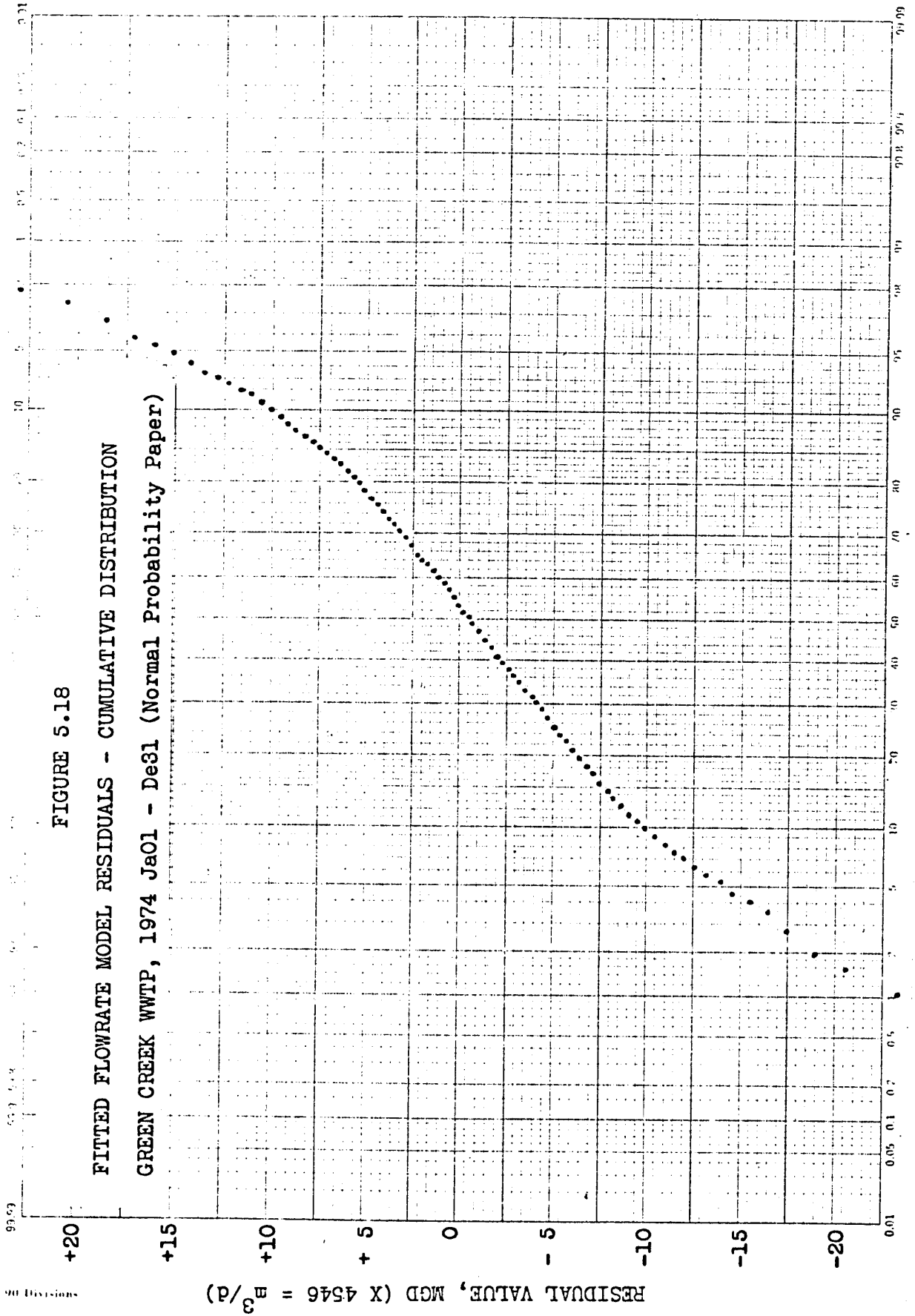
After the removal of periodicities from the original sub-series, the remaining portions of the subseries were considered to be the stochastic components, including stochastic trends, persistence, and random components. For both the Green Creek and Watts Creek wastewater treatment plant flowrate series the independent subseries stochastic components were added to produce a single stochastic series, each assumed to describe completely the uncertainty in the respective plant flowrate series.

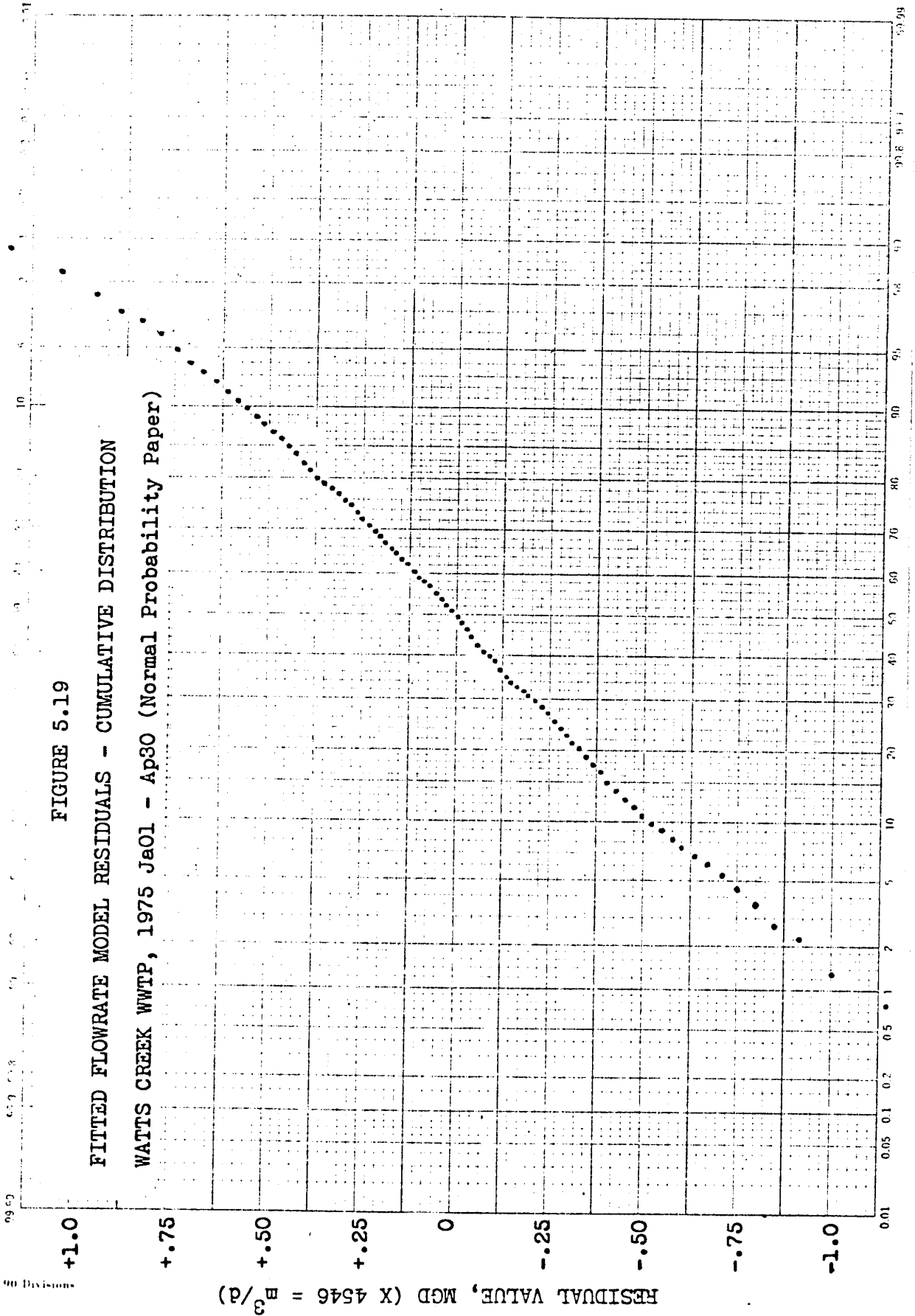
The stochastic component characteristics revealed in

Figures 5.1 to 5.8 indicate obvious non-stationarity remains in the series after removal of periodicities. This phenomenon is discussed by Delleur, Tao, and Kavvas (20). Part of the strong relation between stochastic series values separated by 24 hours may possibly have been introduced by the technique used here for periodicity removal, but the larger part can be attributed to actual serial correlation between flowrate (stochastic portion) values 24 hours apart. The ARIMA modelling procedure accounts for this type of non-stationarity through seasonal differencing, the effects of which, when applied to the stochastic series in this study, are shown in the third graphs of Figures 5.3 to 5.8.

First- or second-order autoregressive processes, along with an one-day moving average component, are suggested by these graphs to describe the behaviour of the differenced stochastic series. Characteristics of the residual series from the fitting of second-order autoregressive models, with 24-hour moving average terms, to the seasonally-differenced (24 hour lag) time series of wastewater flowrate stochastic components are illustrated in the lower graphs of Figures 5.1 to 5.8.

Results of tests of normality and randomness for the model residuals appear in Figure 5.18 and Table 5.6 for the 1974 Green Creek wastewater flowrate series, and in Figure 5.19 and Table 5.6 for the first 120 days of the 1975 Watts Creek series. Figures 5.18 and 5.19 are plots of the cumulative frequency distributions of the residuals on a normal probability scale. Table 5.6 contains residual





Probability Scale X Axis (Inverted)

TABLE 5.6
FLOWRATE MODEL RESIDUAL SAMPLE STATISTICS

Flowrate Series Sample	Green Creek WWTP 1974 Ja01 - De31	Watts Creek WWTP 1975 Ja01 - Ap30
Sample size	2910	2854
Mean, MGD (X 4546 = m ³ /d)	-0.114	-0.021
Variance, MGD ² (X 4546 ² = (m ³ /d) ²)	104	0.264
Skewness Coefficient	+0.290	+0.529
Kurtosis	14.8	21.8
Goodness-of-fit Tests		
Normal Distribution		
Chi-square Test Statistic	512	251
Degrees of Freedom	86	86
Theoretical Chi-square Statistic at 5 % Exceedence Level	109	109
Kolmogorov-Smirnov Test Statistic	.0889	.0547
Critical K-S Statistic at 5 % Exceedence Level	.0252	.0255
Lognormal Distribution		
Chi-square Test Statistic	4864	3155
Degrees of Freedom	86	86
Theoretical Chi-square Statistic at 5 % Exceedence Level	109	109
Kolmogorov-Smirnov Test Statistic	.272	.235
Critical K-S Statistic at 5 % Exceedence Level	.0252	.0255
Randomness Tests		
Clustering Test Std. Normal Variable	-3.62	-0.26
Critical Value at 5 % Level	-1.65*	-1.65*
Direct'nal Runs Test Std. N. Variable	87.25	96.69
Critical Value at 5 % Level	-1.65*	-1.65*
Signs Test Std. Normal Variable	0.06	1.30
Critical Value at 5 % Level	1.96**	1.96**
* Independent variables will exceed this minimum std. normal variate at 95 % level.		
** 2-Tail Test Std. Normal Variate.		

TABLE 5.7
STOCHASTIC COMPONENT ARIMA MODEL SUMMARY - GREEN CREEK WWTP 3-HOURLY FLOWRATES

General Model:		$\Phi_P(B^S)\Theta(B)\nabla_S^D\nabla^d z_S(t) = \Theta_Q(B^S)\Theta(B)a(t)$	$(p,d,q) \times (P,D,Q)_S$
Fitted Model:			
Sampling Interval = 3 hours			
S	=	8	
P	=	0	(2,0,0) x (0,1,1) ₈
D	=	1	
Q	=	1 (θ_1)	
P	=	2 (ϕ_1, ϕ_2)	$(1 - \phi_1 B - \phi_2 B^2)(z_S(t) - z_S(t-8)) = (1 - \theta_1 B^8)a(t)$
d	=	0	
q	=	0	

Series Segment	Sample size	ϕ_1	ϕ_2	θ_1	Upper Limits	Residual Variance MGD ² *
1970 Ja01 - De31	2920	0.52 (.49, .56)	0.19 (.15, .23)	0.90 (.89, .92)		64.1
1974 Ja01 - De31	2920	0.45 (.41, .48)	0.26 (.23, .30)	0.88 (.87, .90)		104.1
1975 Ja01 - De31	2920	0.63 (.59, .66)	0.21 (.18, .25)	0.93 (.91, .94)		100.0
1974 De02 - De31	240	0.65 (.52, .78)	0.19 (.06, .32)	0.80 (.72, .88)		61.7
1975 Ja01 - Ja30	240	0.52 (.40, .65)	0.39 (.26, .51)	0.84 (.77, .92)		98.9
1974 Oc28 - De31	520	0.70 (.61, .79)	0.13 (.04, .22)	0.95 (.91, .98)		82.1

* MGD² x 4546² = (m³/d)²

TABLE 5.8
STOCHASTIC COMPONENT ARIMA MODEL SUMMARY - WATTS CREEK WWTTP HOURLY FLOWRATES

General Model:		$\hat{\Phi}_P(B^S)\hat{\phi}(B)\nabla^D\nabla_S^d\tilde{z}_S(t) = \Theta_Q(B^S)\hat{\theta}_Q(B)a(t)$	$(p,d,q) \times (P,D,Q)_S$
Fitted Model:			
Sampling Interval = 1 hour			
s = 24			
P = 0			
D = 1			
Q = 1 (Θ_1)			
p = 2 (ϕ_1, ϕ_2)			
d = 0			
q = 0			
		$(1 - \phi_1 B - \phi_2 B^2)(z_S(t) - z_S(t-24)) = (1 - \Theta_1 B^{24})a(t)$	$(2,0,0) \times (0,1,1)_{24}$
Series Segment	Sample size	Sample Expected Values of Parameters (with Lower, Upper Limits of 95 % Confidence Interval in brackets)	Residual Variance MGD ² *
1975 Ja01 - Ap30	2880	ϕ_1 +0.16 (+.13,+.20)	0.265
1975 My01 - Au31	2880	ϕ_2 -0.07 (-.11,-.04)	0.283
1975 Au29 - De26	2880	Θ_1 -0.18 (-.22,-.14)	0.284
1975 Jy01 - Au31	1488	ϕ_1 -0.13 (-.18,-.08)	0.301
1975 Jy01 - Jy31	744	ϕ_2 -0.15 (-.23,-.08)	0.256
1975 Au01 - Au31	744	Θ_1 -0.17 (-.24,-.09)	0.358

* MGD² x 4546² = (m³/d)²

sample statistics, mean, variance, skewness coefficient, and kurtosis, the results of Chi-square and Kolmogorov-Smirnov goodness-of-fit tests of the residuals to a normal probability distribution, and the results of three residual randomness tests.

While the test results indicate non-normal, non-random populations for the residual series, it must be noted that large samples were used. Consequently, the corresponding confidence intervals about the proposed random normal populations are narrow, so even slight deviations from normality and randomness become strong evidence for rejection of the hypotheses. Therefore, in the interests of parsimony in the stochastic models, and recognizing the apparent slight deviations from randomness and normality, the model residuals are assumed to be the random and normally distributed shocks affecting the stochastic process.

Summaries of the stochastic modelling results for the Green Creek and Watts Creek flowrate series are given in Table 5.7 for various series segments of the Green Creek series, and in Table 5.8 for Watts Creek series segments.

The sampling variations and possible local non-stationarities evident from Table 5.1 are again visible in Tables 5.7 and 5.8 in the values obtained for the ARIMA model coefficients. As expected, longer sample series lengths produce estimates of the coefficients with less variation from sample to sample, indicating asymptotic convergence to population values.

5.1.2 Performance of Time Series Models in Flow Forecasting

Theoretically, time series forecasts can be made for any lead time using the models developed in this study. For the operation of flow equalization basins, one-interval ahead forecasts are of prime concern (Section 2.3.1). A summary of statistics of the one-interval ahead flow forecast errors for the ten day data period (December 29, 1975 to January 7, 1976) immediately following the last day's data used in modelling Watts Creek wastewater treatment plant flowrates, and for various periods and model coefficients for the Green Creek flowrates of 1975, is given in Table 5.9.

Examples of the cumulative frequency distributions of one-interval ahead flow forecast errors are plotted on a normal probability scale in Figure 5.20 for Watts Creek forecasts, December 29, 1975 to January 7, 1976, and in Figures 5.21 and 5.22 for Green Creek forecasts, January 1, 1975 to July 1, 1975 and July 2, 1975 to December 30, 1975, respectively.

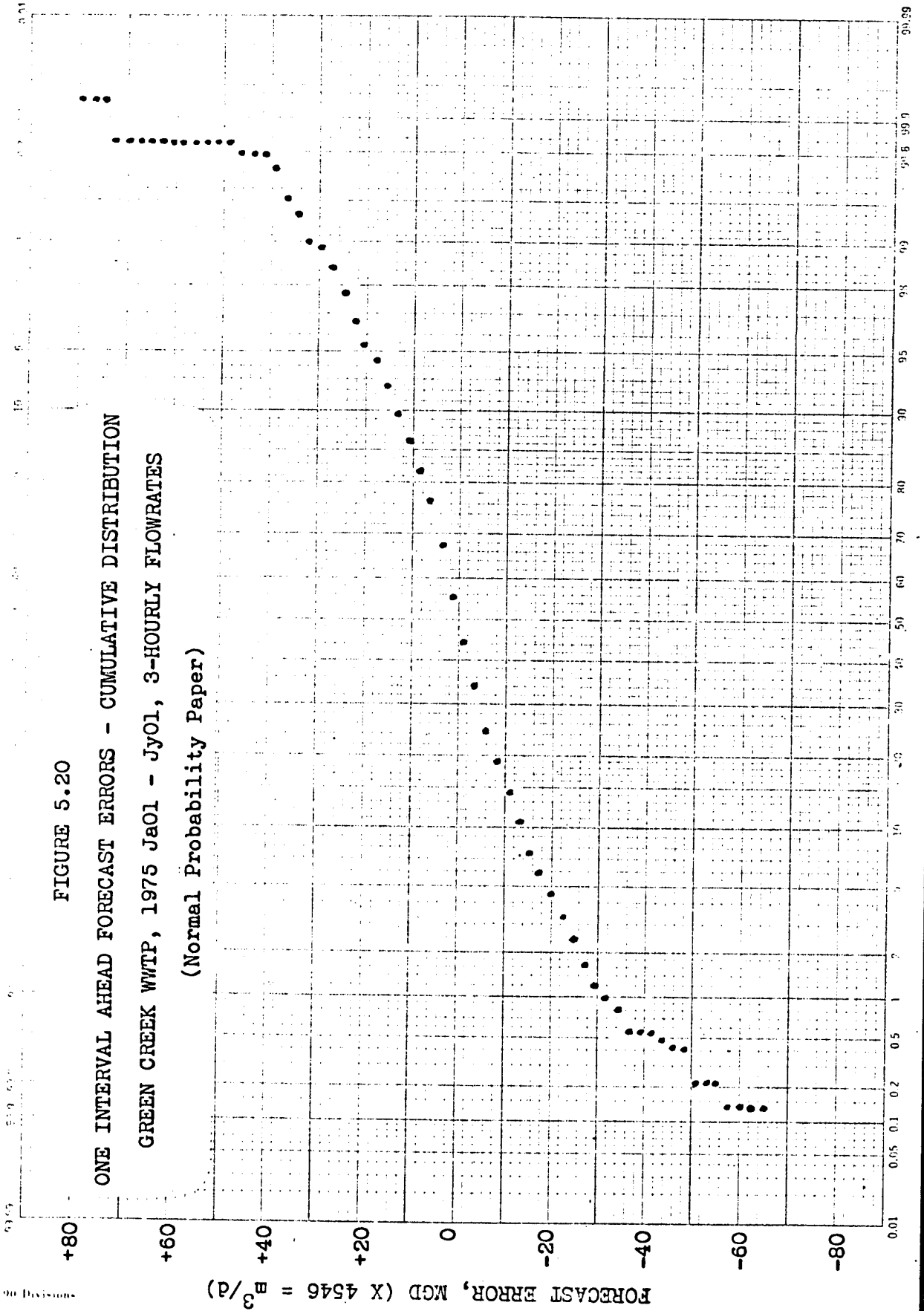
By definition (Equation 4.51) the one-interval ahead forecast for a stochastic ARIMA series is the conditional expectation of the series value just before it occurs. Therefore the one-interval ahead forecast errors z_1' (Equation 4.52) for an ARIMA series are exactly the estimated model residuals \hat{a} , with the opposite sign. The accuracy of one-interval ahead flow forecasts, then, theoretically depends solely on the choice of ARIMA parameters used in the forecasts, the deterministic component being completely predictable. The result will always be one-interval ahead stochastic component forecast

TABLE 5.9

STATISTICS OF ONE-INTERVAL AHEAD FLOWRATE FORECAST ERRORS FOR
WATTS AND GREEN CREEK WWTP RAW FLOWRATES

Series Segment	ARIMA Model	One-Interval Ahead Forecast Errors				
		Sample size	Mean MGD**	Variance MGD ² *	Skew. Coeff.	Kurtosis
Watts Creek WWTP 1975 De29 - Ja07 1976	(a)	216	0.015	0.445	-.212	6.79
Green Creek WWTP 1975 Ja01 - Jy01	(b)	1448	0.088	142	0.012	7.91
1975 Jy02 - De31 Green Creek WWTP	(b)	1456	0.090	169	-.251	6.20
	(c)	472	-.128	113	-.419	6.44
Green Creek WWTP 1975 Ja01 - Mr01	(d)	472	-.124	110	-.439	6.53
	(e)	472	-.126	111	-.431	6.50
	(f)	232	0.018	121	-.371	7.54
	(g)	232	0.019	128	-.298	7.62
	(d)	232	0.026	124	-.757	8.17
Green Creek WWTP 1975 Ja01 - Ja30	(b)	232	0.020	134	-.478	7.80
	(c)	232	0.020	127	-.732	8.08
	(d)	232	0.020	125	-.747	8.15
	(h)	232	0.019	139	-.486	7.59
Green Creek WWTP 1975 Ja01 - Ja30		232	0.020	125	-.747	8.15
Ja31 - Mr01		232	-.308	98	0.004	3.75
Mr02 - Mr31		232	0.874	165	0.638	10.81
Ap01 - Ap30		232	-.230	223	-.047	7.32
My01 - My30		232	-.079	135	0.194	4.41
My31 - Jn29	(e)	232	0.381	127	-.262	5.48
Jn30 - Jy29		232	-.261	188	-.026	5.02
Jy30 - Au28		232	0.228	95	-.029	3.75
Au29 - Se27		232	-.656	230	-.831	6.93
Se28 - Oc27		232	0.672	190	0.297	6.27
Oc28 - No26		232	0.285	200	-.069	3.74
No27 - De26		232	0.128	127	-.970	7.30
(a)	Parameters est. from 1975 Au29 - De26					
(b)	" 1975 Ja01 - De31				** MGD $\times 4546 = m^3/d$	
(c)	" 1970 Ja01 - De31					
(d)	" 1974 Ja01 - De31				* MGD ² $\times 4546^2$	
(e)	" avg. of (c), (d)				= $(m^3/d)^2$	
(f)	" 1974 De02 - De31					
(g)	" 1975 Ja01 - Ja30					
(h)	" 1974 Oc28 - De31					

FIGURE 5.20
ONE INTERVAL AHEAD FORECAST ERRORS - CUMULATIVE DISTRIBUTION
GREEN CREEK WWTP, 1975 Ja01 - Jy01, 3-HOURLY FLOWRATES
(Normal Probability Paper)



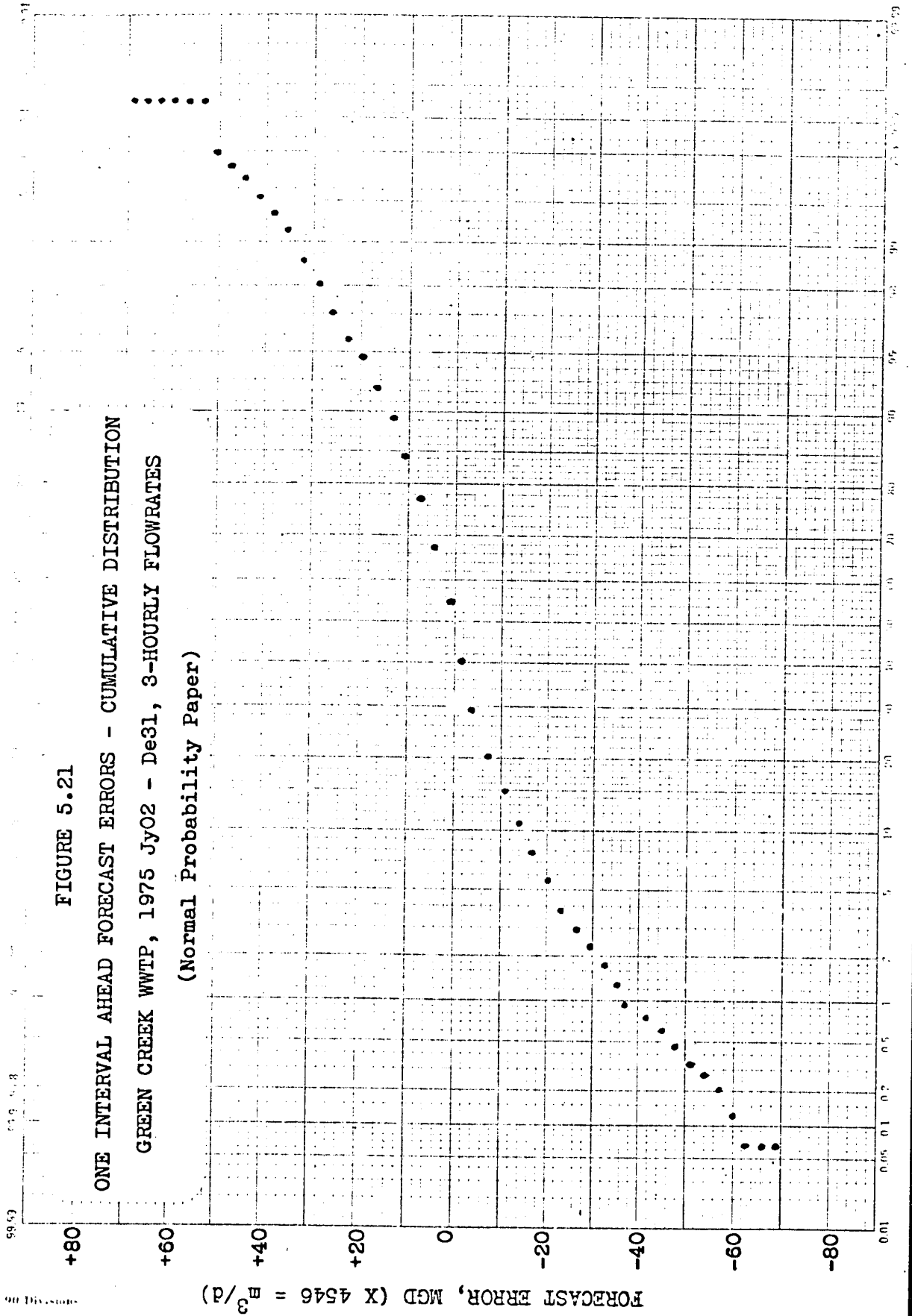
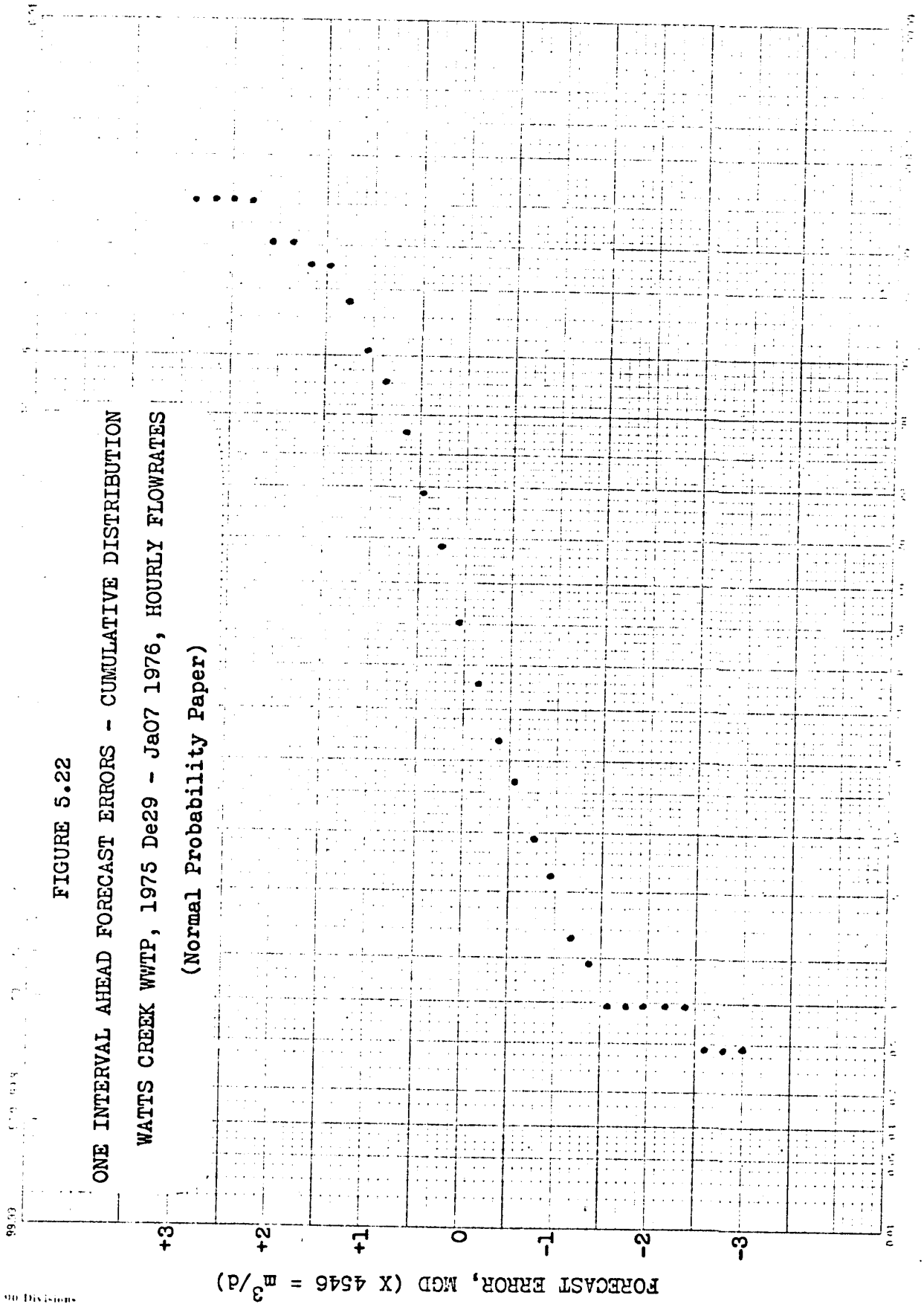


FIGURE 5.22
ONE INTERVAL AHEAD FORECAST ERRORS - CUMULATIVE DISTRIBUTION
WATTS CREEK WWTP, 1975 De29 - Ja07 1976, HOURLY FLOWRATES
(Normal Probability Paper)



errors having variance equal to the residual variance from the fitting of the same ARIMA parameters to the future flowrate data.

The flow forecast errors of Table 5.9 are only different in nature from the model residuals of Table 5.6 in sign and in the former's inclusion of the assumed invariant deterministic periodic components for the flow forecasts. Comparison with the model residual variance of 100.0 MGD^2 ($2.07 \times 10^9 \text{ (m}^3/\text{d)}^2$) (Table 5.1) for the 1975 Green Creek series shows the periodic component's inclusion serves to increase the forecast errors.

Due to the separation of daily mean and diurnal fluctuation subseries utilized in this study, a minimum of 24 hours and maximum of one time step less than 48 hours of stochastic component forecasts must be made in order to determine raw flowrate forecasts for 24 hours ahead. The larger uncertainty in farther ahead future stochastic components serves to increase uncertainty in the nearer future raw flowrates through the methods of calculation used (see Equations 4.48, 4.49, 4.50). Therefore it is not surprising the raw flowrate forecast errors are greater than the stochastic component model residuals. This aspect is not pursued further in this study.

Choice of parameters from anywhere within the ranges covered by the sample estimates obtained for year-long series segments appears to have little effect on accuracy of forecasts, as evidenced in Table 5.9. A detailed investigation of model sensitivity, while relevant to this discussion, is beyond the scope of this study.

Figure 5.23 gives an example of model forecasting performance for longer lead times for Green Creek series forecasts for 1975.

As expected, the variance of forecast errors appears to be increasing toward the asymptote of series raw variance as time-to-forecast increases. The negative skewness (equivalent to positive skewness of model residuals) reflects the generally larger forecast errors encountered on the sharply rising limbs of wet weather hydrographs than on the gradually declining recovery limbs. The peakedness expressed by the kurtosis coefficients can be explained in terms of the presence of a few large errors superimposed on otherwise near-normal error frequency distributions.

5.2 Stochastic Design of Flow Equalization Basins

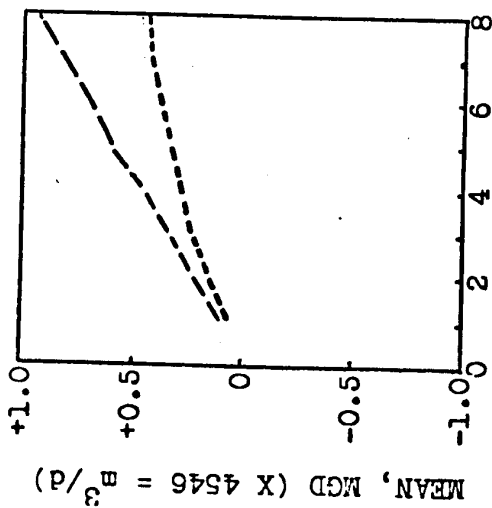
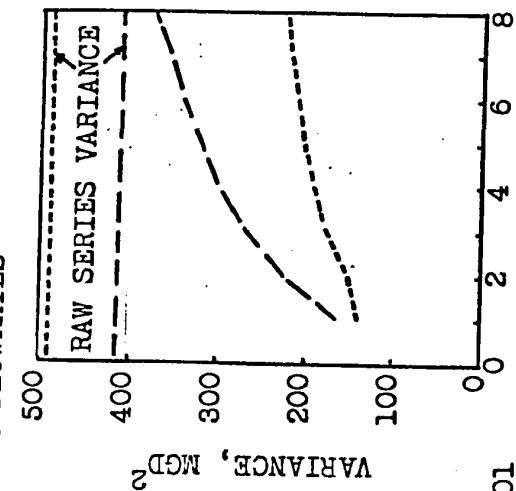
From the modelling experience of Section 5.1 it is assumed wastewater flowrate series in general can be represented by the type of combined deterministic-stochastic time series models used in this study. These models form the basis for the proposed flow equalization basin design method discussed in this section.

5.2.1 Generation of Flowrate Data Series

As an example of the characteristics of flowrate series generated using the combined deterministic-stochastic models developed in this study, statistics of 364 day series segments with deterministic and stochastic properties of the Green Creek flowrate series are presented in Table 5.10.

FIGURE 5.23

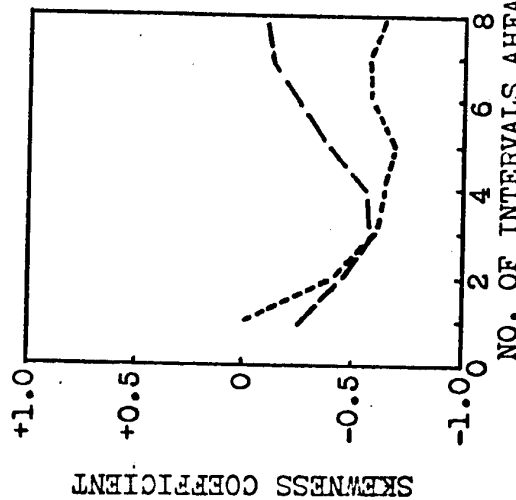
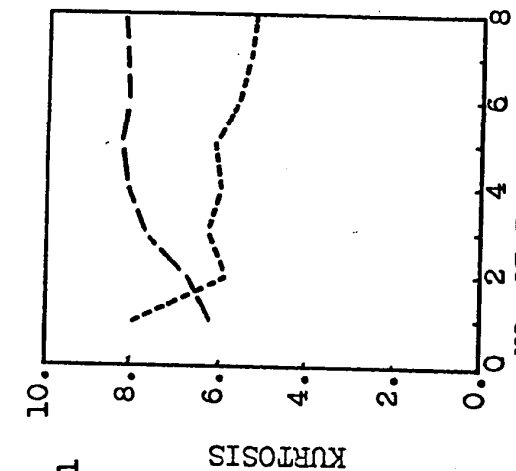
VARIATION OF FLOWRATE FORECAST ERROR STATISTICS WITH TIME-TO-FORECAST
GREEN CREEK WWTTP 1975, 3-HOURLY FLOWRATES



ARIMA MODEL
PARAMETERS
 $\phi_1 = .63$
 $\phi_2 = .21$
 $\theta_1 = .93$

1975 Ja01 - Jy01 -----

1975 Jy02 - De31 _____



NO. OF INTERVALS AHEAD FORECASTED

NO. OF INTERVALS AHEAD FORECASTED

TABLE 5.10
STATISTICS OF GENERATED 364-DAY SEGMENTS OF GREEN CREEK WWTP 3-HOURLY RAW FLOWRATES

Series	ARIMA		Mean Flowrate*	Variance* of Daily Means	Variance* of Diurnal Fluctuations	Total Series Segment Variance*	Seed Random Number
	1	2					
Observed, 1974 De29 - De27 1975	.63	.21	57.9	223	240	462	-
	(100.0)						
Generated							
364			11.3	130	147	278	11282937
Day			20.5	342	124	466	240266559
Series			22.1	225	128	353	942488935
Segments			22.5	225	101	326	44333
			28.3	225	179	404	652763
			32.5	449	297	747	31369669
			38.7	328	349	677	66954589
(after			39.9	437	331	768	61619
adjustment			40.1	423	208	631	62349999
for			40.4	349	156	505	83595
negative			43.3	680	489	1168	1582323
values)			46.2	644	212	855	3971
	.63	.21	47.5	398	569	967	87415041
	(100.0)		50.2	570	230	800	544083
			55.6	586	453	1040	1286421
			59.5	515	308	824	91255875
			69.5	579	591	1171	954589
			69.7	487	159	646	177319
			74.1	693	221	914	94883
			82.1	1029	533	1562	1263391
			82.7	790	743	1533	78053
			93.0	789	273	1062	23273
			152.7	3699	459	4158	891861
15	.63	.21	55.6	586	453	1040	1286421
24	.52	.19	60.9	441	665	1110	1286421
25	.45	.26	63.6	509	758	1270	1286421
	(100.0)						

* Flowrates in MGD (X 4546 = m³/d), Variance in MGD² (X 4546² = (m³/d)²)

The generation of each segment began with an independent random number so that each 364 day segment is independent of the others. Each segment begins with the first day of the 364 day cycle (Section 5.1.1) and ends on the last day, so that, in effect, each is an one year sample chosen at random from the infinite population of one year series having the desired characteristics.

From Table 5.10 it is apparent that the generated samples of flowrates are, on the whole, considerably more variable than the observed sample whose properties they have. While not shown here, many of these segments have large numbers of zero flow intervals, a condition not expected in practise.

An unfortunate side effect of the adjustment of negative generated flowrates to zero was the destruction of the property of the complete independence of daily means and diurnal fluctuation. The effect was to increase mean flowrates and reduce variances. The sample correlation coefficient relating generated series annual mean flowrate (a reflection of the level of the daily means) and diurnal fluctuation variance before adjustment was 0.23, a value not significantly different from zero at the 10 percent level. After adjustment, this correlation coefficient was 0.51, a value significantly different from zero at the 1 percent level.

While a certain amount of random variability can be attributed to the stochasticity in the generated flowrates, it is evident from Table 5.10 that a point of inadequacy, not detected during the model-building process, exists in the procedure to decompose in analysis and modelling, and subsequently reconstruct in simulation, the flowrate time series.

That some remaining serial correlation in the Green Creek WWTP flowrates is unaccounted for is the indication of the results of the clustering test (Table 5.6), but overall results favour the randomness assumption.

The difference between observed and simulated samples is most likely due to the non-normality of the estimated flowrate model random component. The effect of the few large residuals on increasing the overall residual variance (squaring the deviations emphasizes the tails of a distribution in calculating its variance), the statistic which forms the foundation of the Monte Carlo method for data generation, is likely significant. The effect shows up in the values of kurtosis obtained, all indicating a rather peaked distribution compared to a normal distribution.

The residual distributions also show skewness, the ignoring of which, in data generation, would create a difference between the long term means of the simulated data and observed data.

If the assumption of residual normality is the critical factor, future approaches could use the empirical residual distribution or some other theoretical probability distribution to which the residuals are a close fit in the Monte Carlo series generation in place of the normal distribution employed here. Pursuit of this possibility is not attempted in this study.

A discussion of residual dependence and non-normality appears in a paper by Hipel, McLeod and Lennox (30). Delleur, Tao, and Kavvas (20)

fitted several non-normal theoretical probability distributions to ARIMA model residuals for standardized, logarithmic-transformed monthly streamflows.

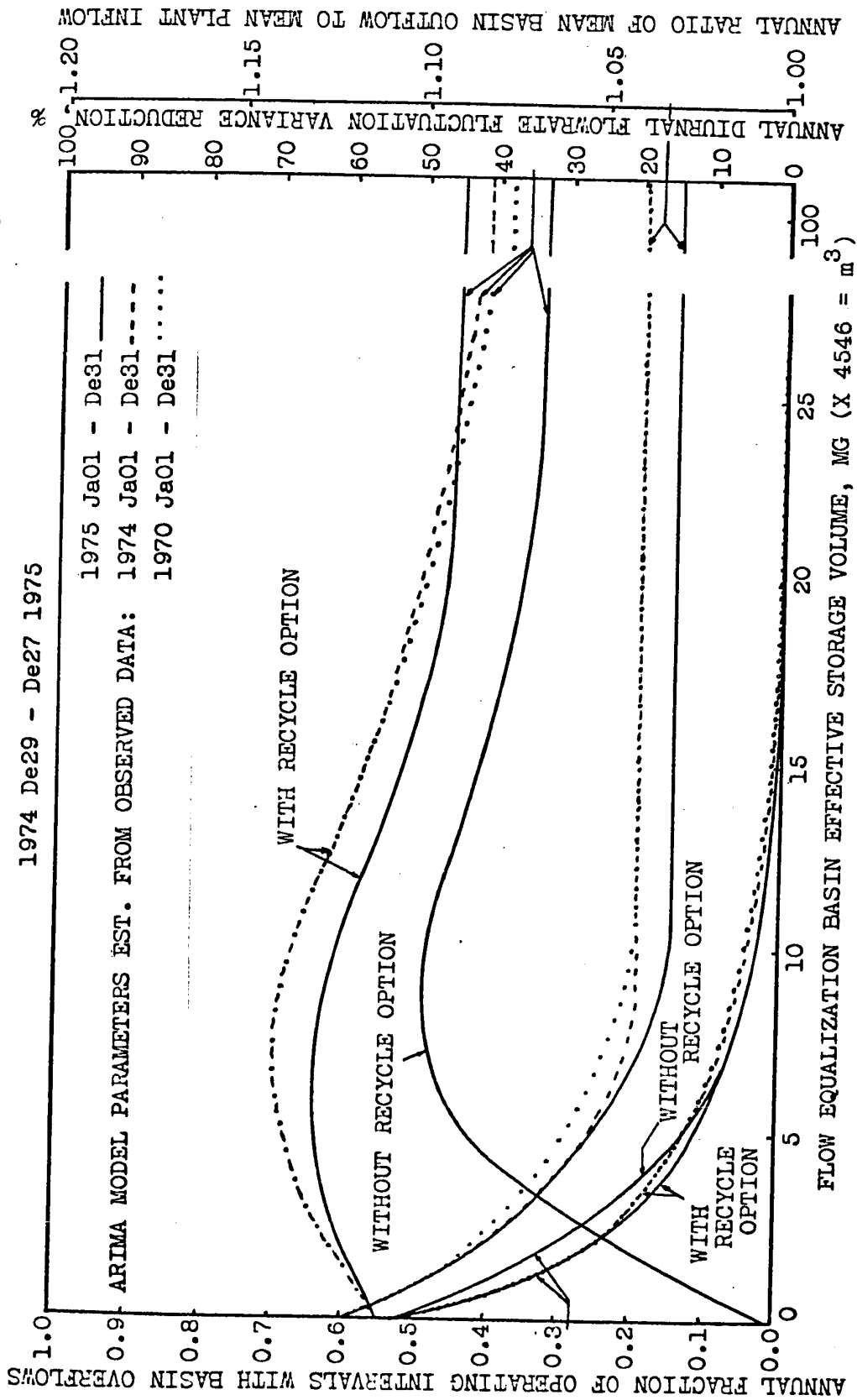
For the remainder of this study it is assumed the generated series samples and observed samples are drawn from the same population, regardless of any shortcomings indicated above in the flowrate time series models.

Also indicated in Table 5.10 is the fact the Monte Carlo simulation of the flowrate series is more dependent on the random shocks than the ARIMA parameters. The three segments generated from the same series of shocks but with different parameter values show little scatter compared to the ARIMA segments produced from different shock series, but with common parameter values.

5.2.2 Flow Equalization Basin Performance

Figure 5.24 shows the results of flow equalization basin performance tests obtained by routing the Green Creek observed wastewater flowrate series for December 29, 1974 to December 27, 1975 (364 days of record, from day one of the 364 day periodic cycle) through the basin operation procedure using stochastic model parameters estimated from three different observed series segments, 1970, 1974, and 1975. At each time step, the procedure involves observation of the latest flowrate and present volume in storage, forecasting of future flowrates, and subsequent adjustment of basin operation (Section 2.3.1).

FIGURE 5.24
FLOW EQUALIZATION BASIN PERFORMANCE USING GREEN CREEK WWTP RAW FLOWRATES
1974 De29 - De27 1975

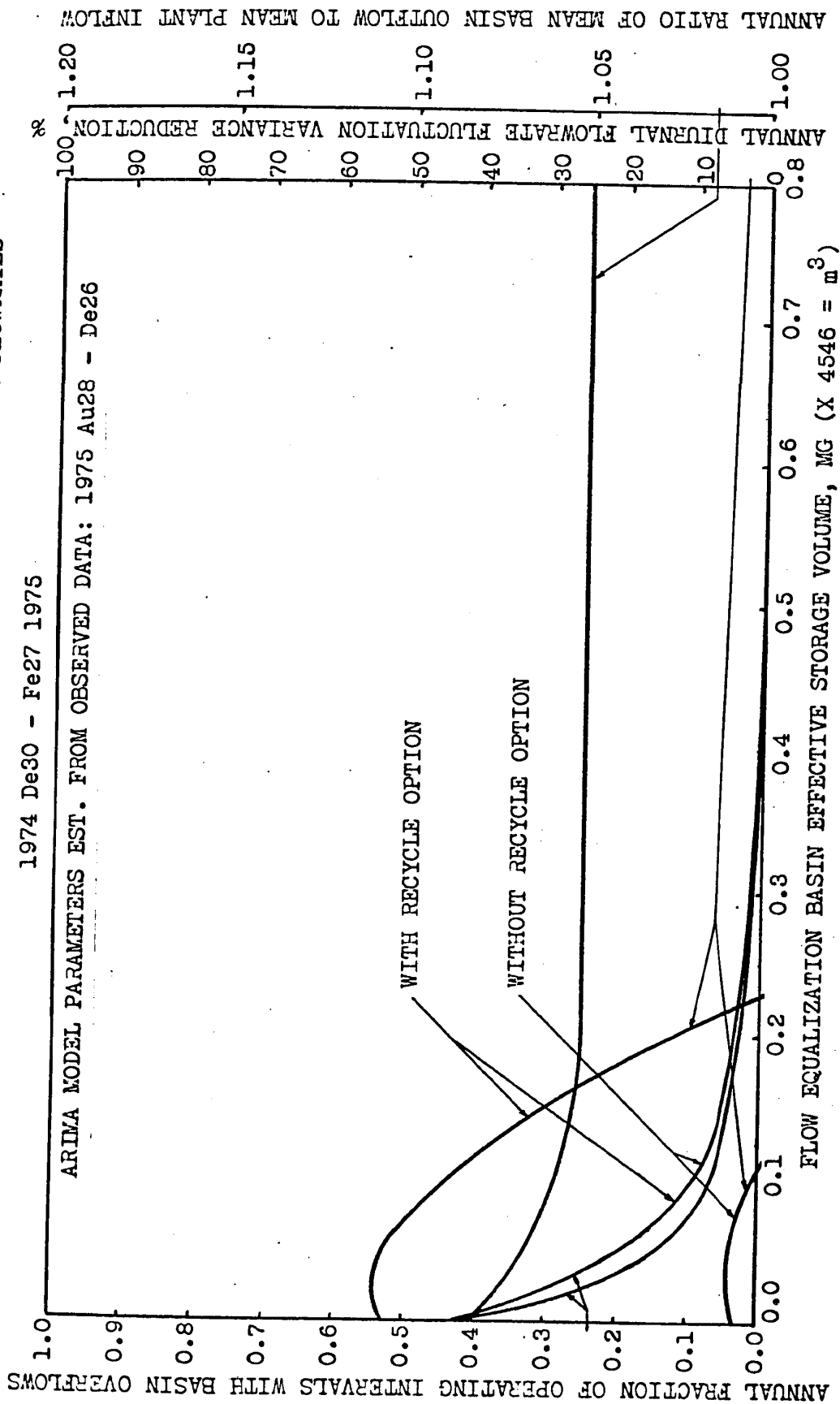


The effects of the recycling of plant effluent to avoid projected early depletion of basin contents are most noticeable in Figure 5.24 for smaller maximum basin volumes, as the operation procedure maintains uniform pumping rates out of the basins, instead of being forced, with empty tanks, to pump only the raw inflows. The accompanying increase in mean flow pumped out of the equalization stage is not severe, even for very small basin capacities. Larger basins generally have more stored wastewater to draw on after the peaking period has filled the basin, so the recycling capacity is called upon less often in larger basins, and consequently there generally is less advantage to its inclusion in the design.

At very large basin capacities, where one expects from reservoir theory that nearly perfect smoothing would be the result, a definite decrease in performance accompanies an increase in basin volume. This surprising result is attributable to the method of basin operation which attempts to completely pump out the stored wastewater by the end of the low flow period. Unusual peaks, instead of being passed through the plant as they would for smaller equalization basins, are stored in the larger basins. Later the stored wastewater must be completely pumped out in the projected low flow period, resulting in high pumping rates being specified.

It must be realized that the plan of basin operation adopted here is not the only one that could be used. Since the equalization basin design method proposed here presumes the resulting facility will be operated with the same routines as were used for design, the

FIGURE 5.25
FLOW EQUALIZATION BASIN PERFORMANCE USING WATTS CREEK WWTP RAW FLOWRATES
1974 De30 - Fe27 1975



performance predicted by the design routine will always reflect the operating plan.

Figure 5.25 shows the results of flow equalization basin performance tests using the observed Watts Creek wastewater flowrate series for December 30, 1974 to February 27, 1975.

Figure 5.24, in agreement with Table 5.9, indicates longterm operational performance with an adequate model, as in this case, may not be drastically affected by the choice of ARIMA parameter values if long-term (e.g., from 1 year's observed series) estimates are used. The behaviour over a shorter term, such as illustrated in Figure 5.25, may be poor due to the use of long-term average parameters when local variations are significant. Optimum performance in actual operation depends on the ARIMA parameters. Regular updating of parameters and annual revision of the deterministic periodic components are advised.

5.2.3 Design Based on Simulated Performance

Each generated flowrate series segment of Table 5.10 was routed through the equalization basin operating procedure to simulate performance, with the recycling option specified. Figure 5.26 shows the discrete family of curves describing basin overflows. Figure 5.27 gives the effect on the mean plant flowrate of the use of recycling capacity. Figure 5.28 shows the effects of the basins in smoothing the flowrates.

FIGURE 5.26
FLOW EQUALIZATION BASIN PERFORMANCE SIMULATIONS - BASIN OVERFLOWS:
GENERATED GREEN CREEK WWTP FLOWRATE SERIES ARIMA MODEL PARAMETERS
EST. FROM OBSERVED DATA: 1975 Ja01 - De31 (RECYCLE OPTION SPECIFIED)

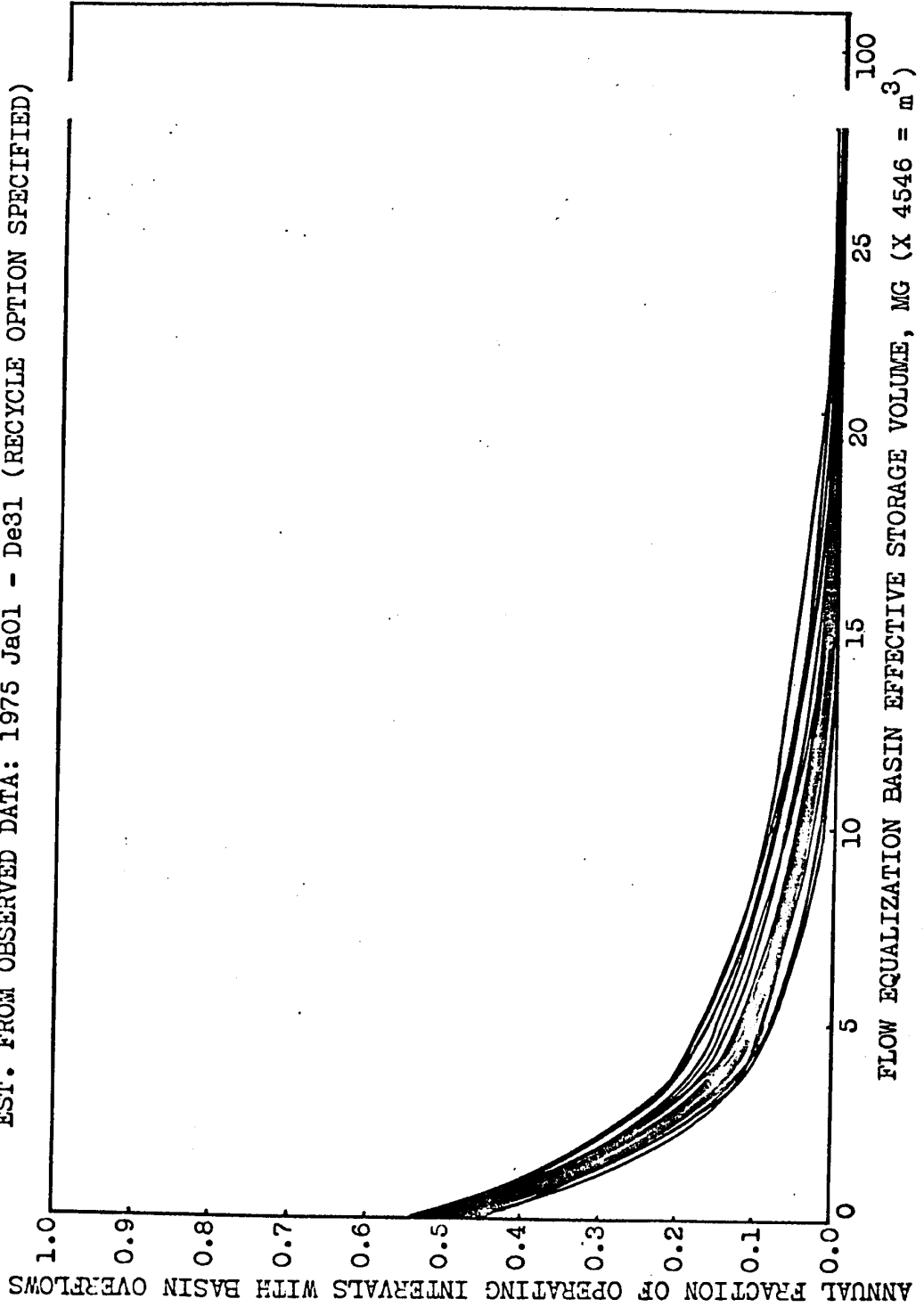


FIGURE 5.27
FLOW EQUALIZATION BASIN PERFORMANCE SIMULATIONS - EFFECT OF RECYCLE OPTION:
GENERATED GREEN CREEK WWTTP FLOWRATE SERIES ARIMA MODEL PARAMETERS
EST. FROM OBSERVED DATA: 1975 Ja01 - De31 (RECYCLE OPTION SPECIFIED)

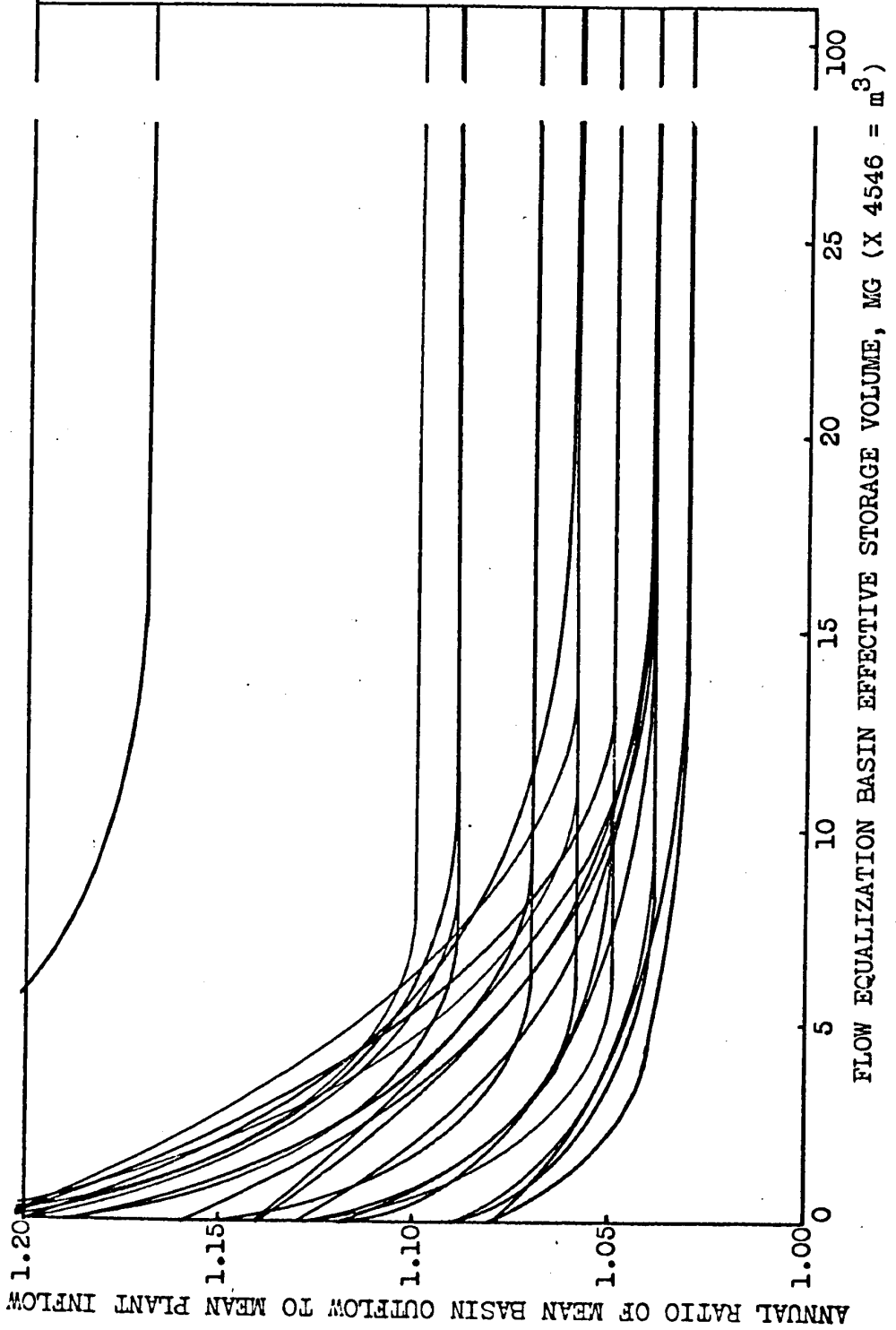
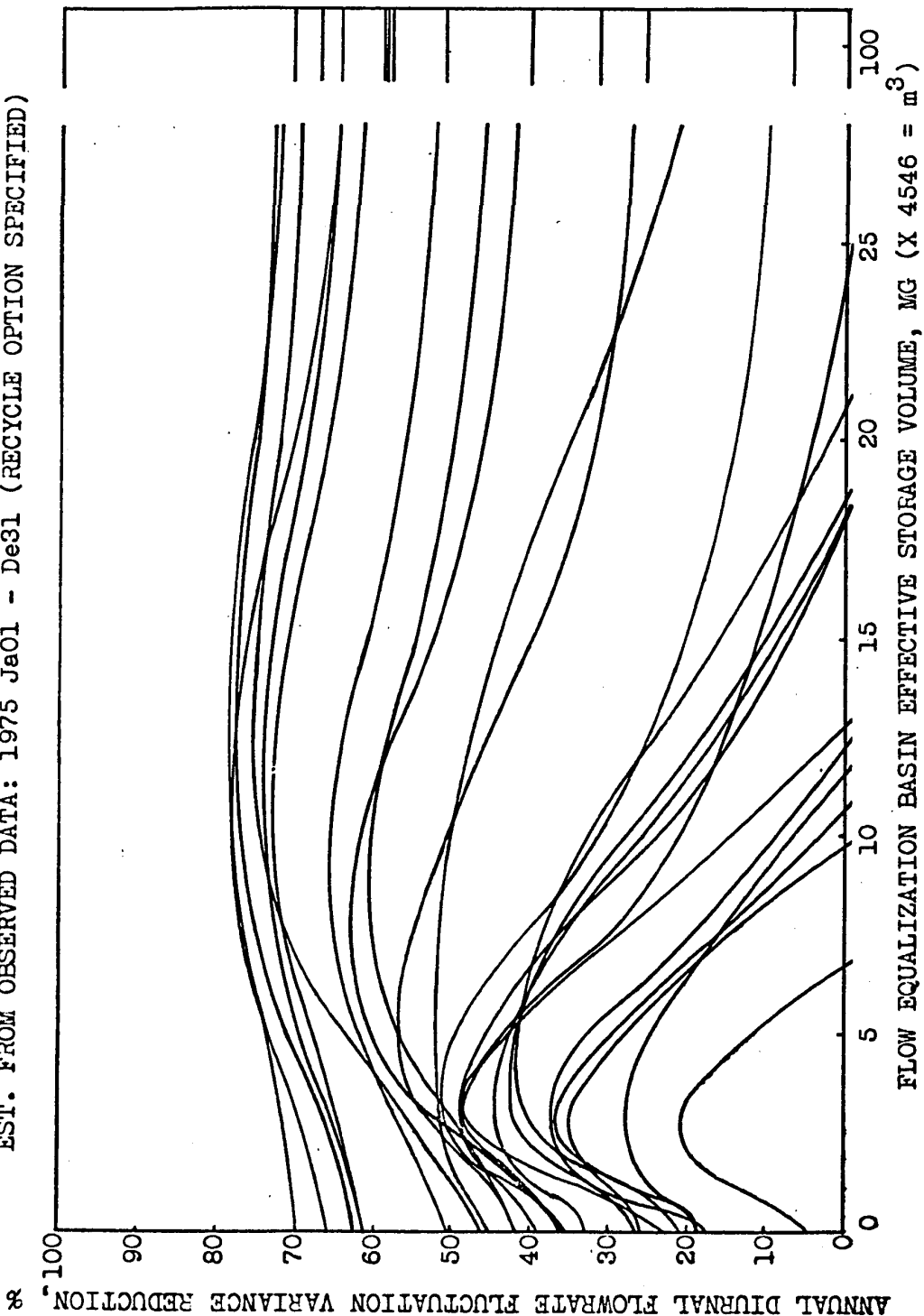


FIGURE 5.28
FLOW EQUALIZATION BASIN PERFORMANCE SIMULATIONS - VARIANCE REDUCTION
GENERATED GREEN CREEK WWTP FLOWRATE SERIES ARIMA MODEL PARAMETERS
EST. FROM OBSERVED DATA: 1975 Jø01 - De31 (RECYCLE OPTION SPECIFIED)



For interpretation of Figures 5.26, 5.27, and 5.28, it must be remembered that the values in the series of rates of outflow from the equalization basin depend on time as well as on the values of inflow rates. Therefore, any single point on one of these curves is a measure of average performance over a finite time span, in this case, 364 days, the period beyond which stationarity was assumed. The curves of each of Figures 5.26, 5.27, and 5.28 are independent and drawn at random from the respective infinite populations of curves describing year-long behaviour.

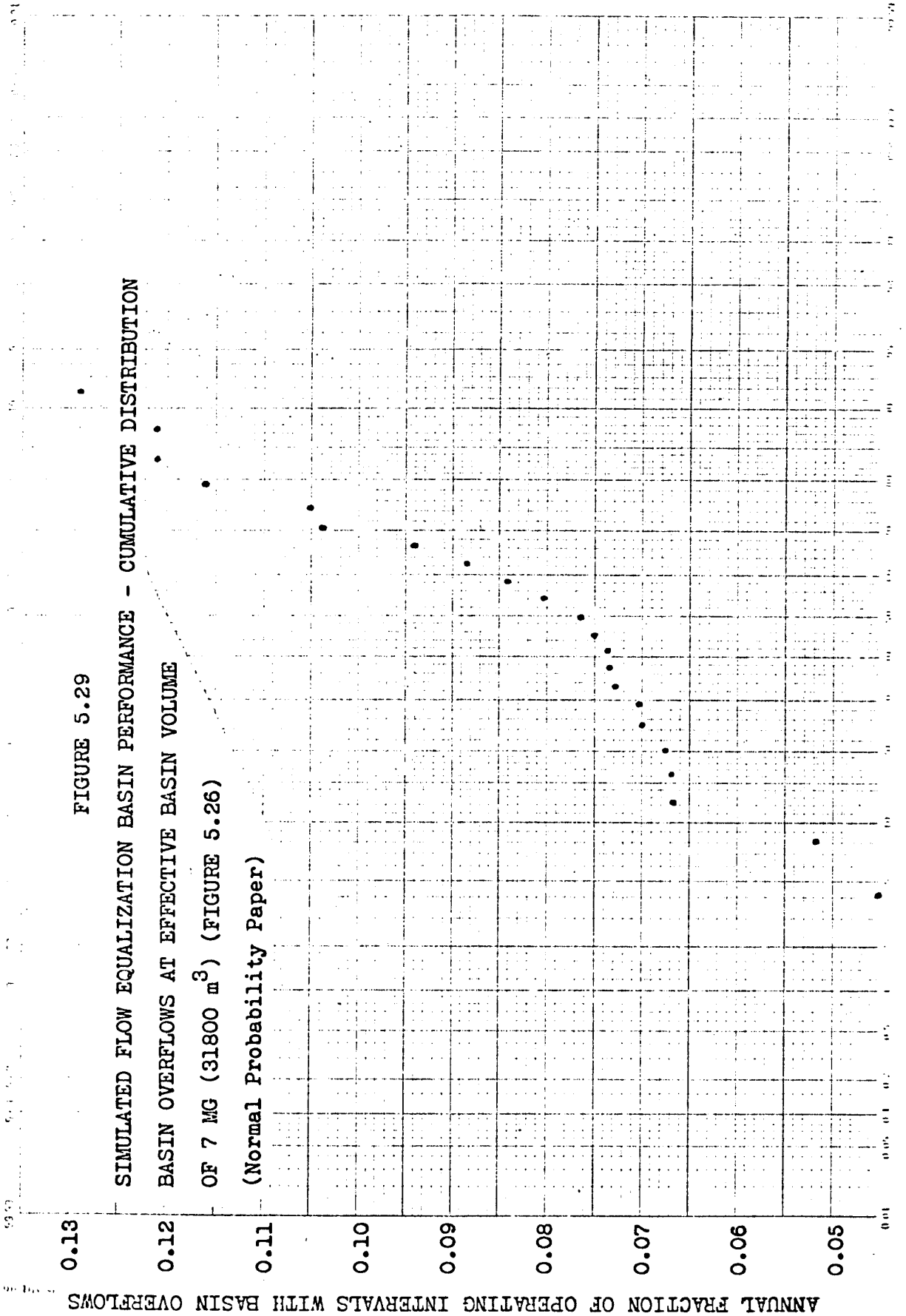
Most noticeable from Figures 5.26, 5.27, and 5.28 is the wide variability in the expected performance of one equalization basin from year to year. This shows clearly that a deterministic approach to WWTP facility design can be quite misleading.

The curves of Figure 5.24 fall within the ranges of the respective simulated curves of Figures 5.26, 5.27, and 5.28.

Examples of cumulative conditional distributions of the generated curves (1975 Green Creek parameters only, basin volume of 7 MG (31,800 m³)) of Figures 5.26, 5.27, and 5.28, respectively, are plotted on a normal probability scale in Figures 5.29, 5.30, and 5.31.

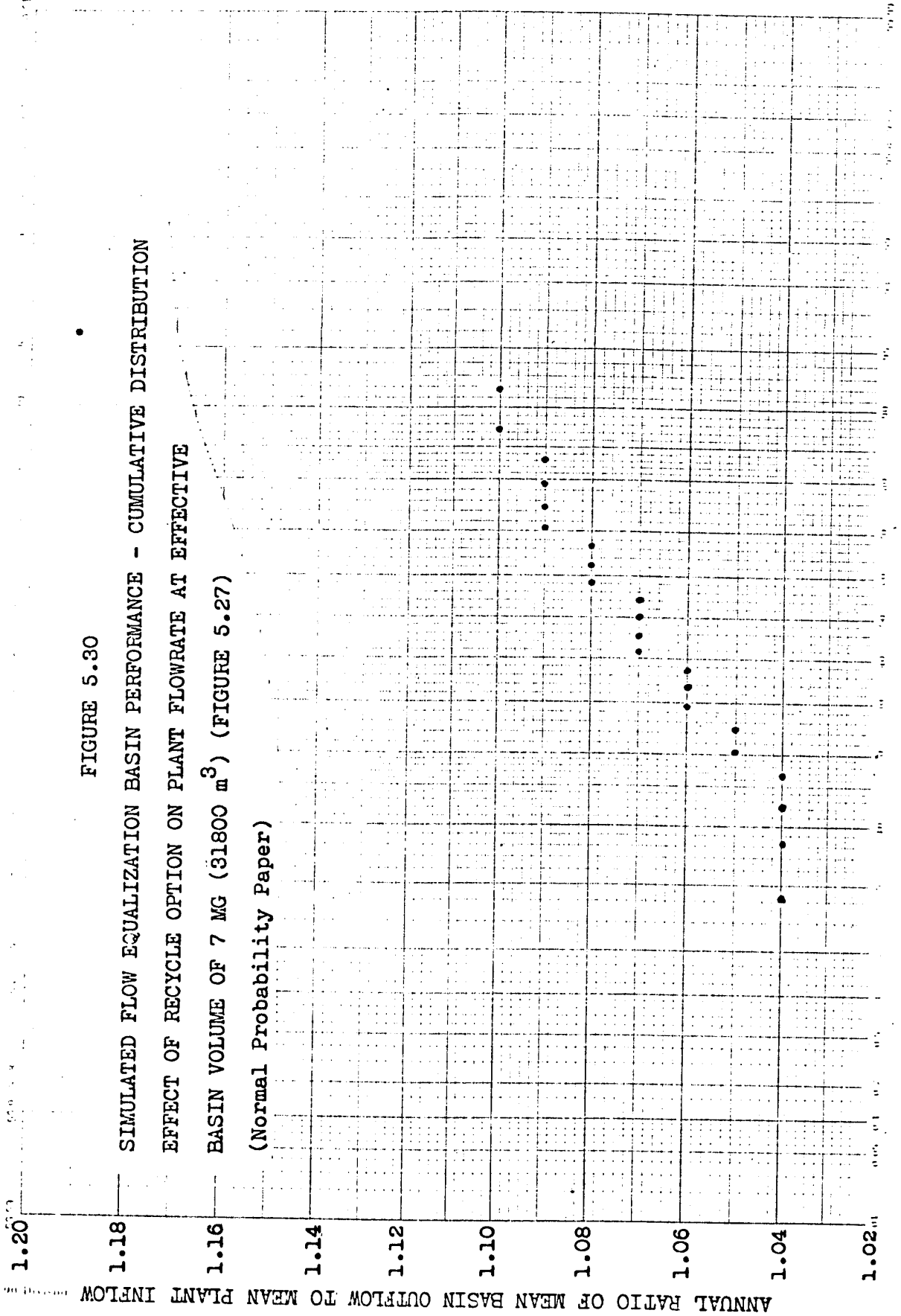
The basin design-by-simulated-operation procedure is a deterministic function which transforms stochastic inputs (the wastewater flowrates) to stochastic outputs (the design curves). For a given basin volume, the procedure applies a different restraint to

FIGURE 5.29
SIMULATED FLOW EQUALIZATION BASIN PERFORMANCE - CUMULATIVE DISTRIBUTION
OF 7 MG (31800 m³) (FIGURE 5.26)
(Normal Probability Paper)

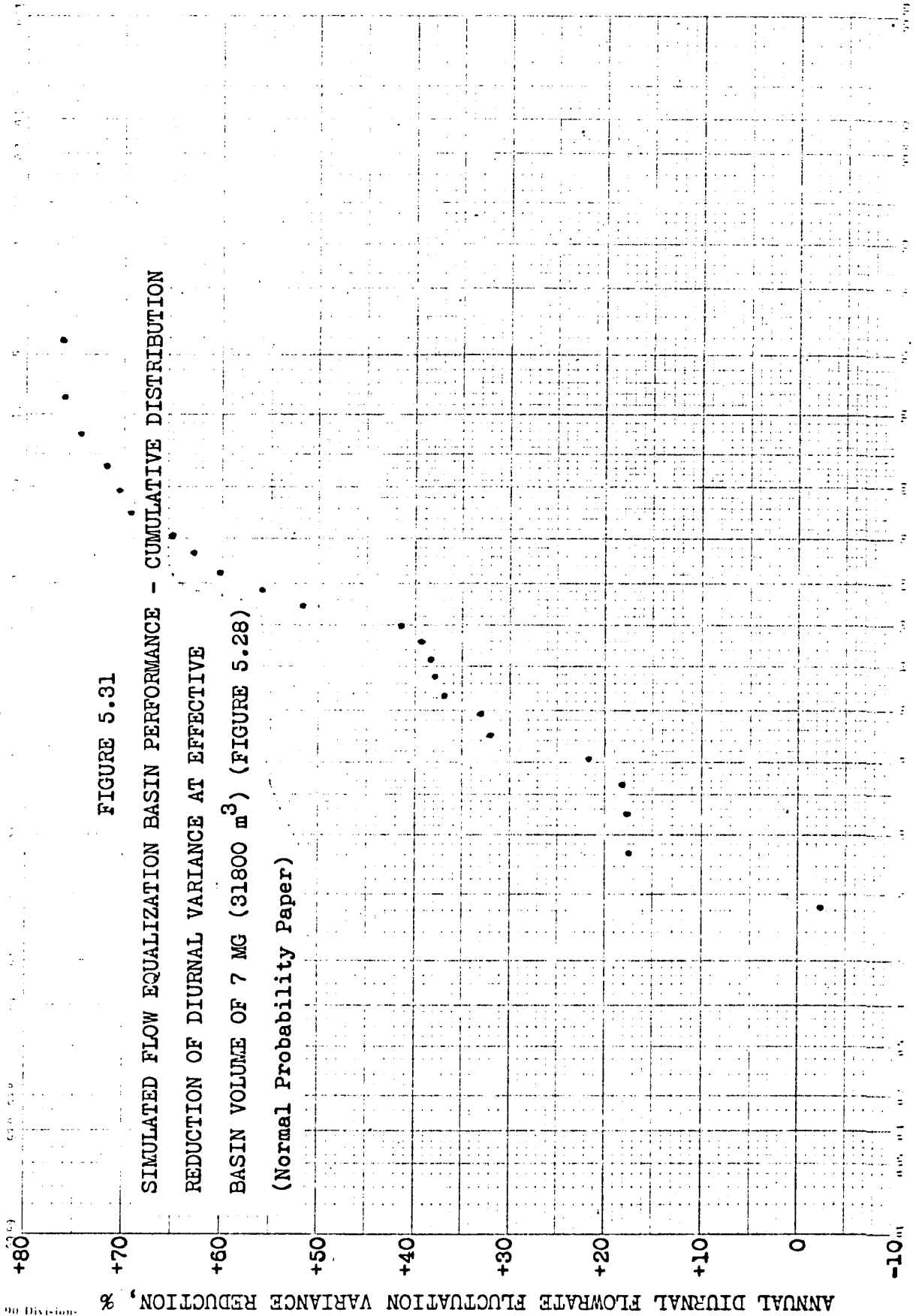


Probability Scale & Plot by

FIGURE 5.30
SIMULATED FLOW EQUALIZATION BASIN PERFORMANCE - CUMULATIVE DISTRIBUTION
EFFECT OF RECYCLE OPTION ON PLANT FLOWRATE AT EFFECTIVE
BASIN VOLUME OF 7 MG (31800 m³) (FIGURE 5.27)
(Normal Probability Paper)



ANNUAL RATIO OF MEAN BASIN OUTFLOW TO MEAN PLANT INFLOW



two equal wastewater inflow rates occurring at different times due to the occurrence of two different basin storage conditions brought about by the effect of the serial correlation of the flows. This non-linearity in the transfer function is evidenced by the non-normality of stochastic outputs (produced from near-normal stochastic inputs) shown in Figures 5.29, 5.30, and 5.31 for the conditional distributions of each of the performance variables.

The mean response to independent inputs from a transfer function can be estimated from the mean of the independent sample outputs, which, by the Central Limit theorem, is normally distributed regardless of output distribution, and has standard deviation of $s_{OUT}/N^{1/2}$ (64), where s_{OUT} is the sample output standard deviation, and N is the size of the output sample.

Confidence limits on the sample mean response can be stated as (64)

$$C.L._{\alpha} [\overline{OUT}] = \overline{OUT} \pm t_{1 - \frac{\alpha}{2}, N-1} \frac{s_{OUT}}{(N)^{1/2}} \quad 5.1$$

where t is a variate of the Student-t distribution for the α percent confidence interval and with $N-1$ degrees of freedom.

Figures 5.32, 5.33, and 5.34 show 95 percent confidence intervals on the sample mean responses of Figures 5.26, 5.27, and 5.28, respectively. Figure 5.35 shows the 95 percent confidence interval on the sample mean response for the variance of the outflow diurnal fluctuations. The 95 percent confidence interval on the sample mean

FIGURE 5.32
FLOW EQUALIZATION BASIN PERFORMANCE - BASIN OVERFLOWS:
POPULATION ESTIMATE AND 95% CONFIDENCE INTERVAL
GREEN CREEK WWTP (RECYCLE OPTION SPECIFIED)

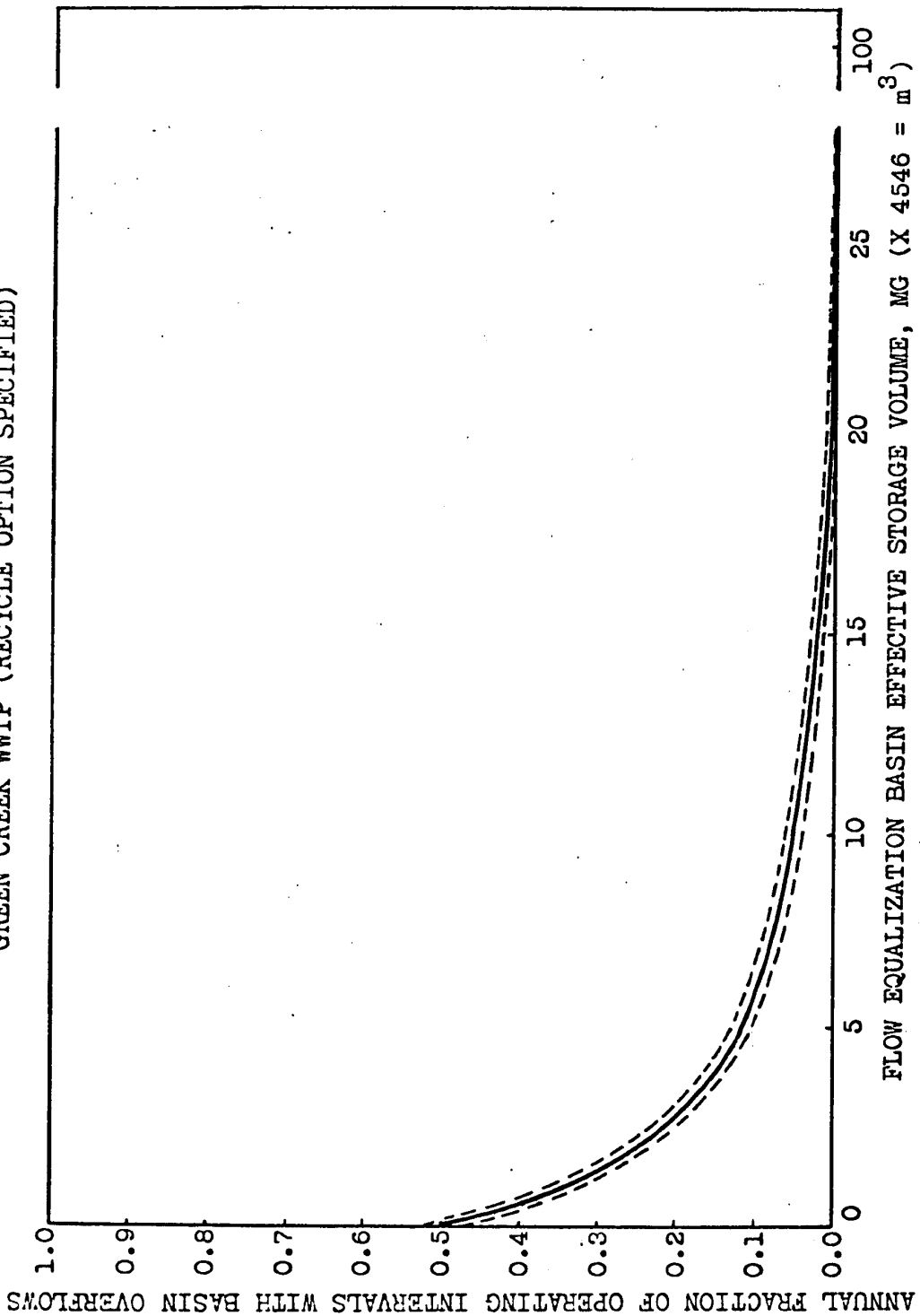


FIGURE 5.33
FLOW EQUALIZATION BASIN PERFORMANCE - EFFECT OF RECYCLE OPTION:
POPULATION ESTIMATE AND 95% CONFIDENCE INTERVAL
GREEN CREEK WWTP (RECYCLE OPTION SPECIFIED)

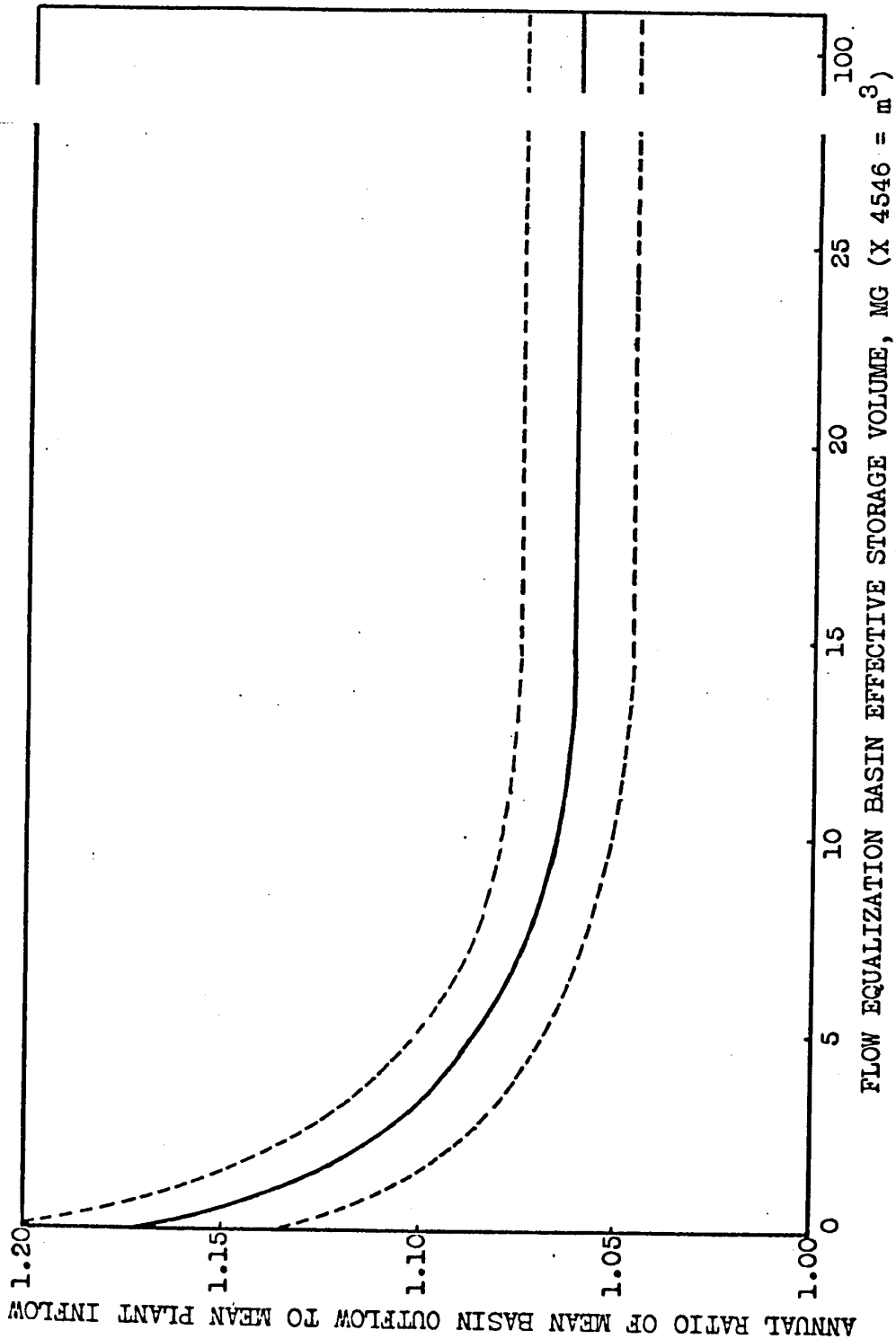


FIGURE 5.34
FLOW EQUALIZATION BASIN PERFORMANCE - VARIANCE REDUCTION:
POPULATION ESTIMATE AND 95% CONFIDENCE INTERVAL
GREEN CREEK WWTP (RECYCLE OPTION SPECIFIED)

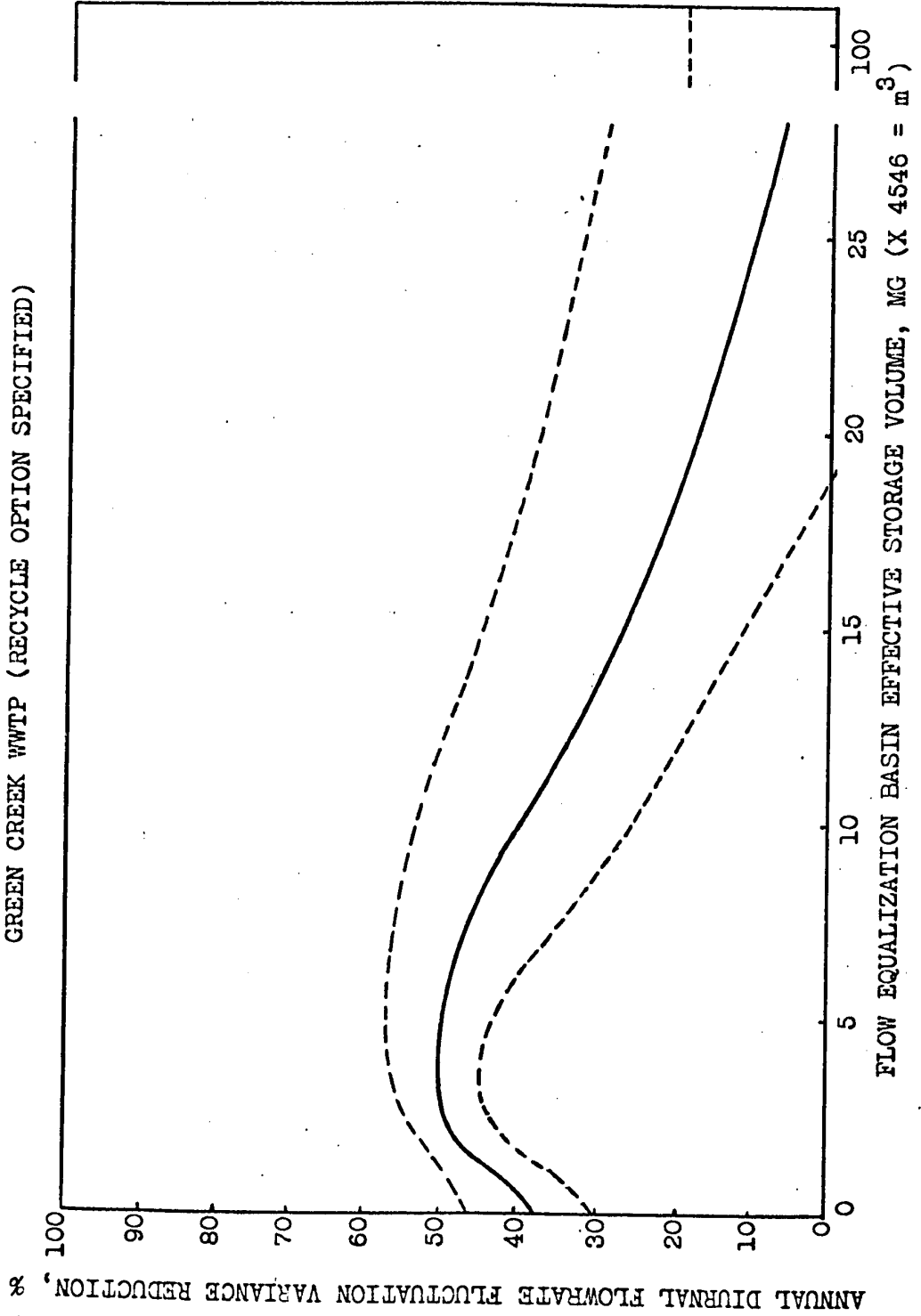


FIGURE 5.35
FLOW EQUALIZATION BASIN PERFORMANCE - BASIN OUTFLOW VARIANCE:
POPULATION ESTIMATE AND 95% CONFIDENCE INTERVAL
GREEN CREEK WWTP (RECYCLE OPTION SPECIFIED)

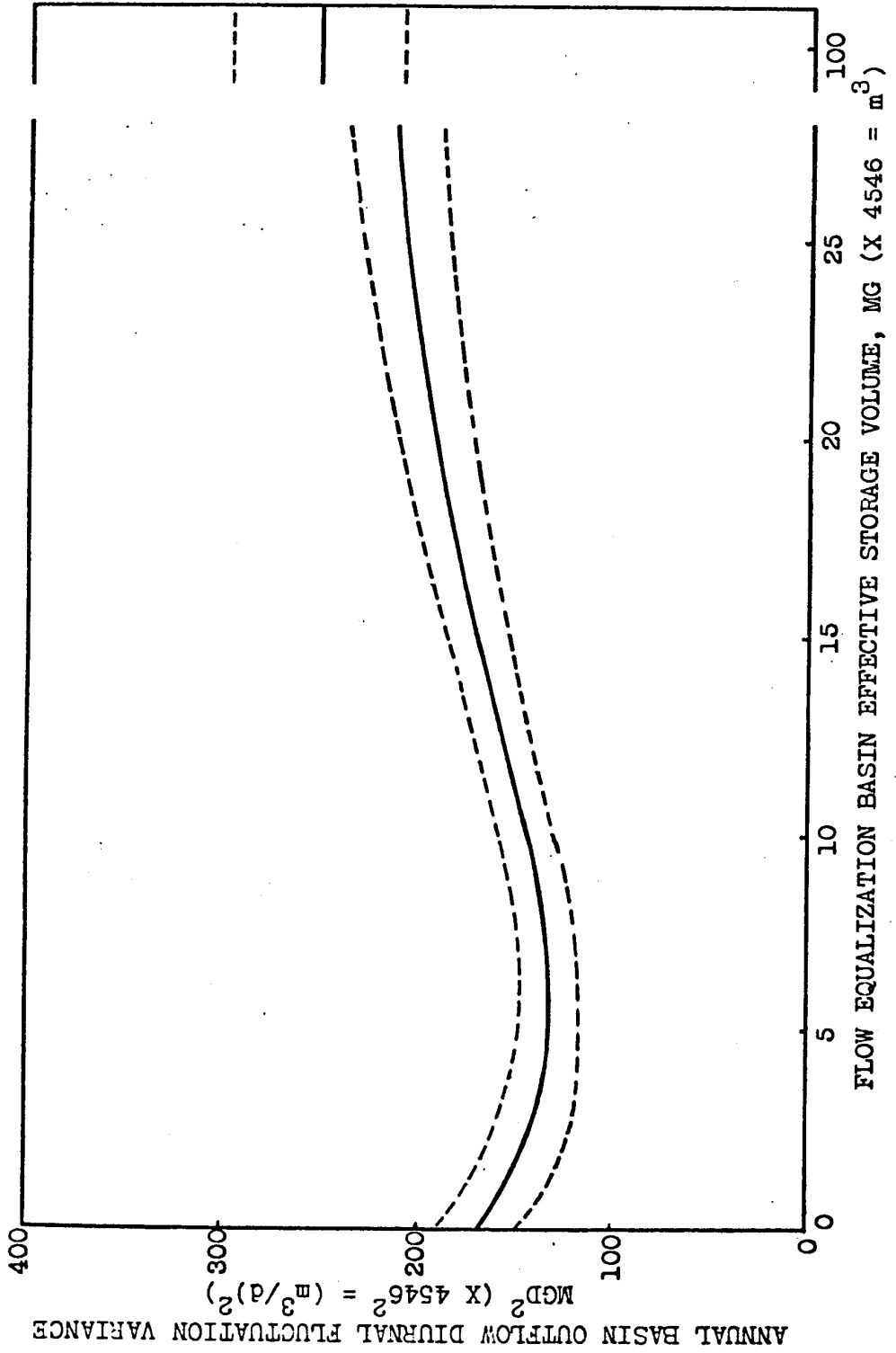
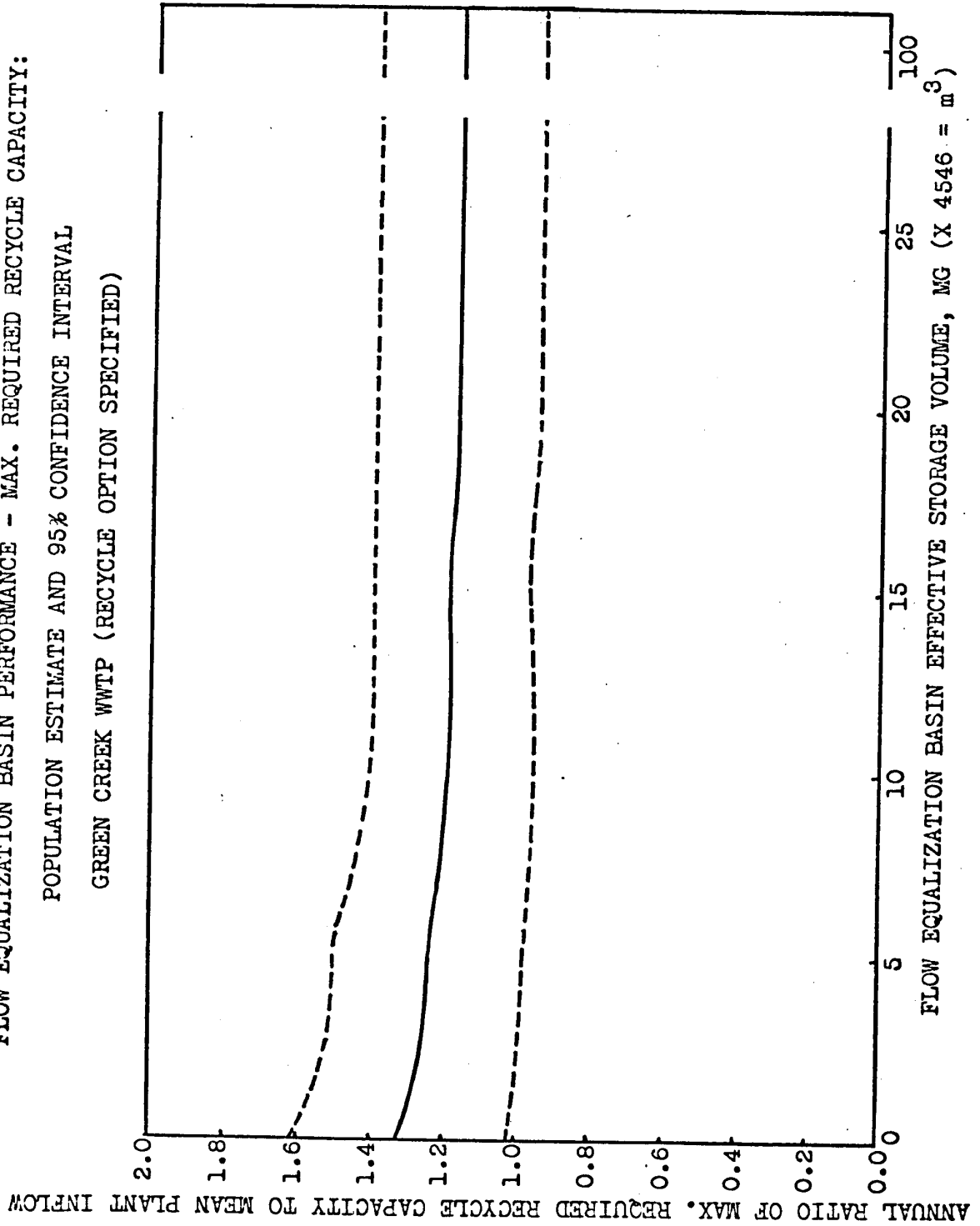


FIGURE 5.36
FLOW EQUALIZATION BASIN PERFORMANCE - MAX. REQUIRED RECYCLE CAPACITY:
POPULATION ESTIMATE AND 95% CONFIDENCE INTERVAL
GREEN CREEK WWTP (RECYCLE OPTION SPECIFIED)



maximum required recycle capacity over a 364 day period is given in Figure 5.36.

For the basin operation procedure selected here, comparison of Figures 5.32, 5.34, and 5.35 shows that optimum variance reduction is not achieved by the use of an arbitrarily large storage capacity to minimize basin overflows. Peak variance reduction is indicated when the fraction of intervals with overflows is about one in ten. The actual time fraction is less since any occurrence of overflow in an interval is counted.

Use of recycling capacity as an equalization tool does not have a severe effect, for the Green Creek case in Figure 5.33, on increasing the average flow through the downstream treatment stages. In general, if the situation for which flow equalization is proposed is not critical with respect to present or proposed treatment plant design flows, recycling may be extremely beneficial in reducing required basin capacity (refer to Figure 5.24). The maximum required recycle capacity for all 2912 time steps in a year's period, shown in Figure 5.36, exceeds the mean annual inflow rate. Unfortunately, the distributions of recycle requirements were not covered in this study, so Figure 5.36 reports only the extreme requirements.

The design relations of Figures 5.32, 5.33, 5.34, 5.35 and 5.36 are applied by selecting the basin volume at a desired confidence level corresponding to the desired year-long performance level.

5.2.3.1 Evaluation

Comparison with other design methods must be qualified. The commonly used mass curve analysis volume determination (Section 1.2.3.2 and (50)), and its variations (Section 1.2.3.2 and (26,37)), assume day-to-day flow independence and, in effect, presume foreknowledge of flowrates, so that optimum basin operation is achieved. These design methods result in basin volumes purported to give perfect flow smoothing, or, for example, "100 percent equalization 90 percent of the time" (26). Uncertainty in the flowrates is treated lightly, with safety factors, while the limitations of actual basin operation are not considered at all.

The effect of ignoring uncertainty in the presently proposed design method is shown in Figure 5.37, the equalization basin performance curves for the 364 day deterministic periodic component of the Green Creek raw flowrates.

As an example of the mass curve approach, the frequency distribution of required basin volumes calculated for each day ("equalized" flowrate to be the daily mean) from a mass curve analysis of 3 years (1970, 1974, and 1975) of Green Creek wastewater treatment plant raw 3-hourly flowrates is given in Figure 5.38.

The same mass curve approach to volume determination, using Watts Creek WWTP raw flowrates for 1975, is illustrated in Figure 5.39.

Even with an assumed deterministic wastewater flowrate series, predictable exactly, the basin operation procedure shows its

FIGURE 5.37
FLOW EQUALIZATION BASIN PERFORMANCE USING GREEN CREEK WWTP PERIODIC
COMPONENT OF 3-HOURLY FLOWRATES

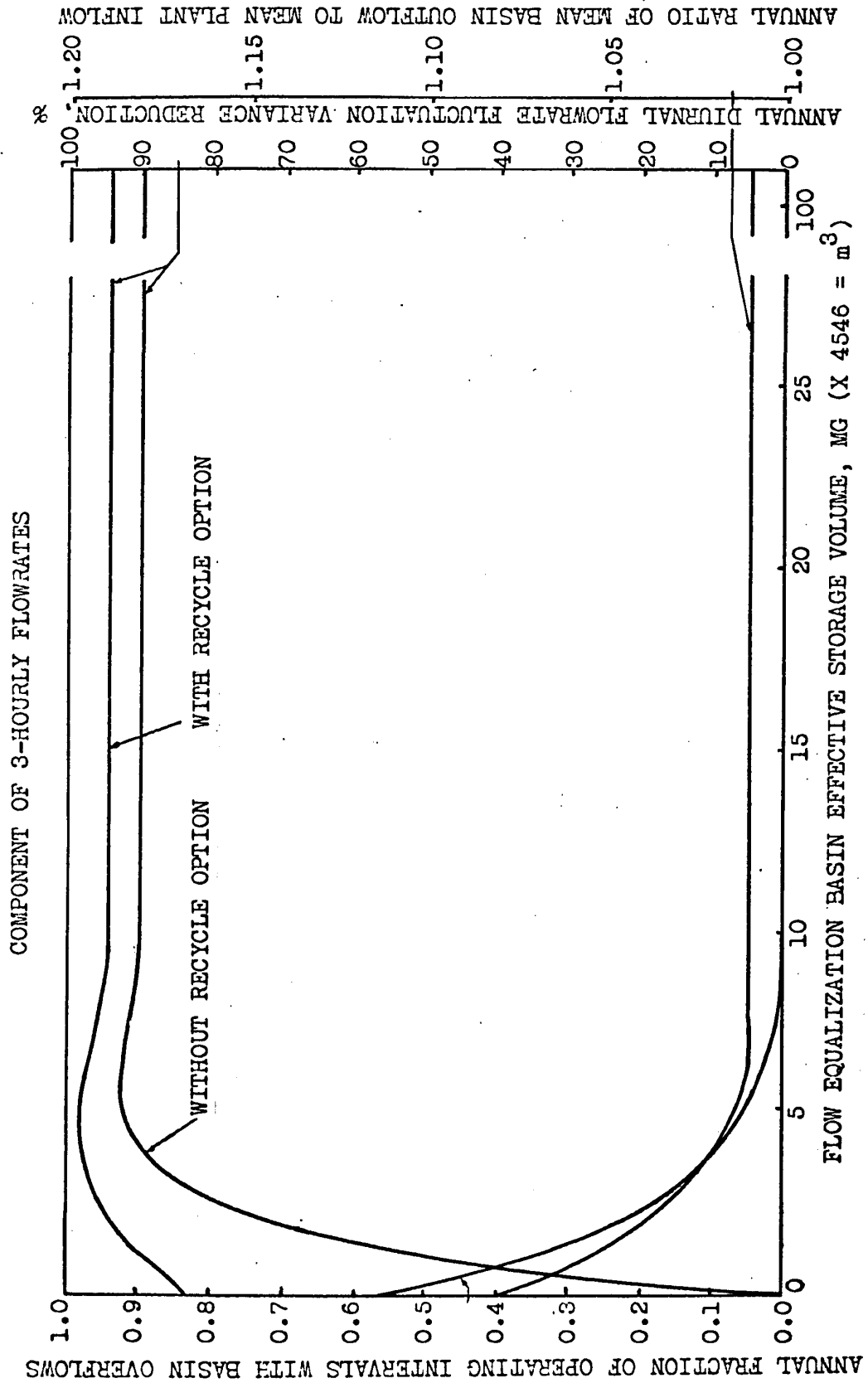


FIGURE 5.38
 INDEPENDENT DAILY MASS CURVE STORAGE REQUIREMENTS - FREQUENCY HISTOGRAM
 BASED ON GREEN CREEK WWTP RAW 3-HOURLY FLOWRATES
 1970 Ja01 - De31, 1974 Ja01 - De31, 1975 Ja01 - De31

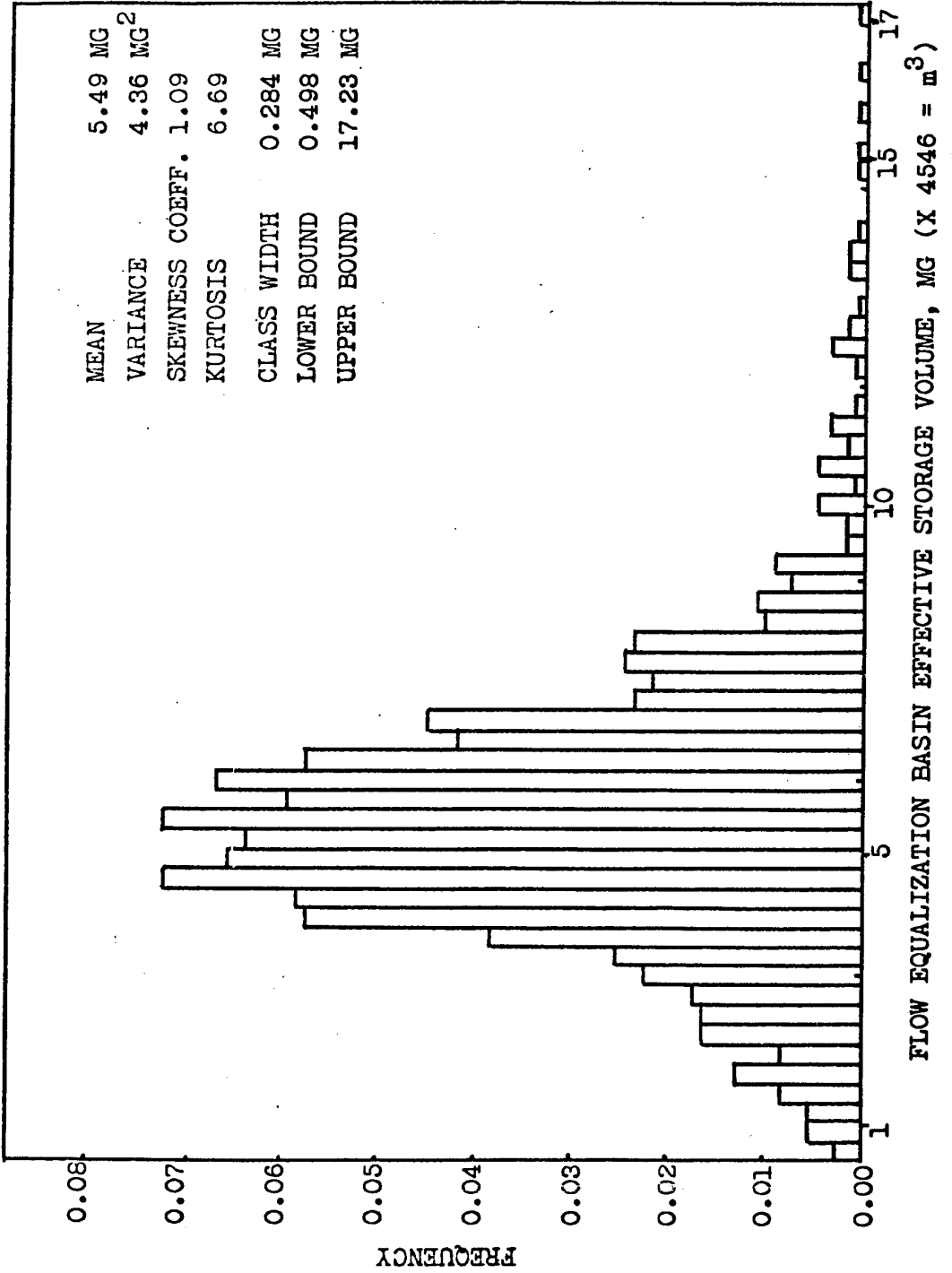
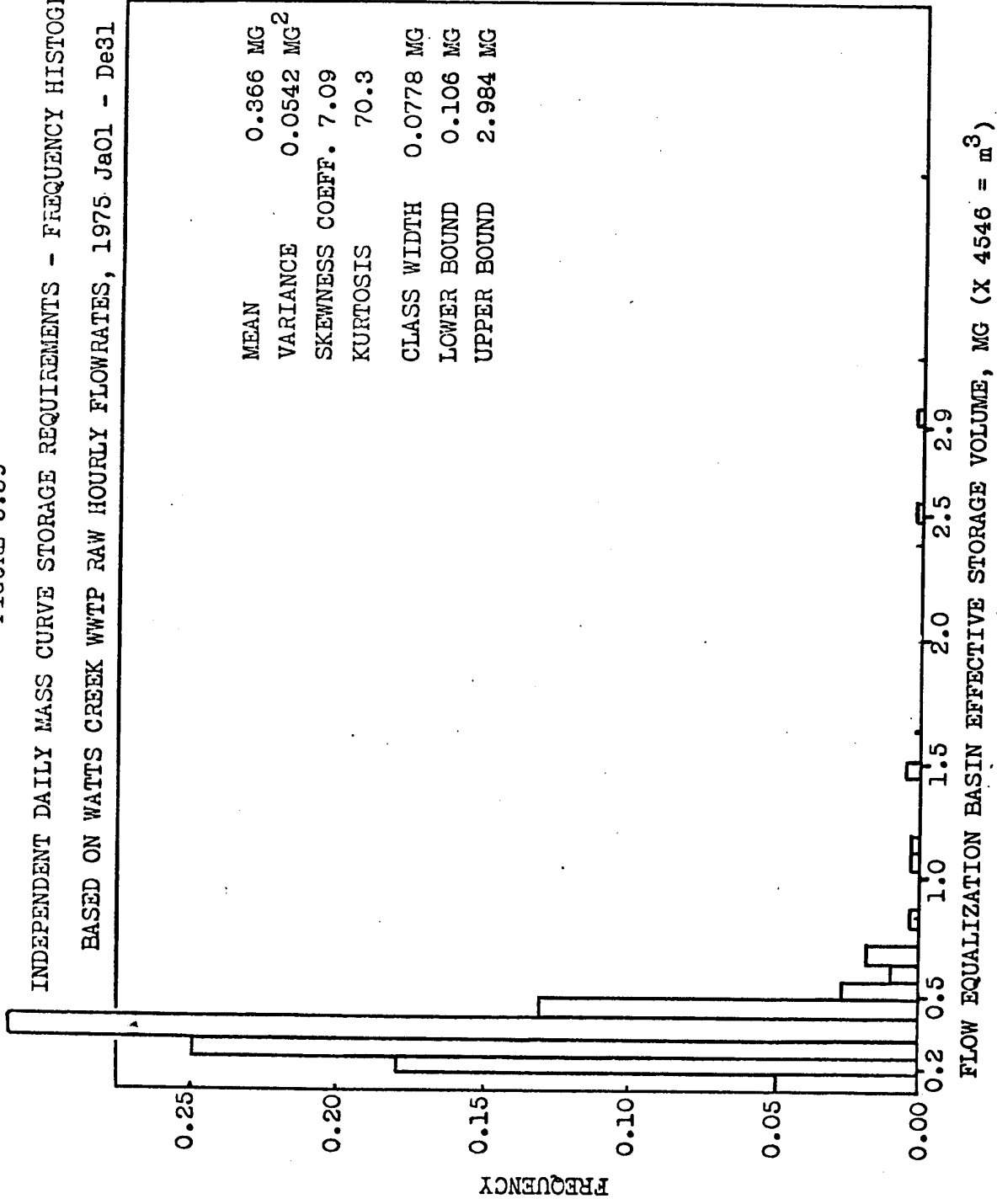


FIGURE 5.39
INDEPENDENT DAILY MASS CURVE STORAGE REQUIREMENTS - FREQUENCY HISTOGRAM
BASED ON WATTS CREEK WWTP RAW HOURLY FLOWRATES, 1975 Ja01 - De31



fallibility in Figure 5.37. Whatever its form, the operating plan is probably the limiting factor for performance, whereas design by Figure 5.38 would suggest perfect flow equalization could be achieved with a large enough basin.

As a rough comparison, the application of LaGrega's proposal (Section 1.2.3.2 and (37)) to Figure 5.38 results in suggested storage requirements of 5.5 MG (25,000 m³), 7.5 MG (34,000 m³), and 17.2 MG (78,000 m³) for "equalized" flowrates for 50 percent, 90 percent, and 100 percent of the days, respectively. Others (26,50) have suggested the required equalization basin storage capacity is in the range of 10 to 20 percent of the annual mean daily flow, or about 5.6 MG (25,000 m³) to 11.2 MG (51,000 m³) in this case. This study shows best results would be obtained with a basin capacity of 9.0 MG (41,000 m³), without, and 6.5 MG (30,000 m³) with, the recycle option included in the design.

Despite varying complexities, these methods give similar responses, but the claimed "equalization" provided by the first two is replaced by the new method's more realistic statements about expected performance.

Figures 5.39 and 5.25 cannot be similarly compared as the latter reflects only a small portion of a year's flowrates.

No attempt is made in this study to suggest a decision once the design curves are drawn. As yet there is not enough knowledge of the downstream effects of flow equalization to allow the specification of basin performance requirements. Only the relation between performance and volume has been determined.

CHAPTER 6

CONCLUSIONS

6.1 Summary

Time series analyses of raw hourly and 3-hourly wastewater flowrates to two Ottawa municipal treatment facilities showed that neither a deterministic periodic component nor a stochastic component, which included trends, persistence, and a random element, dominated the series. For one-year samples of the 3-hourly Green Creek WWTP flowrate series, approximately 31 to 61 percent of series variance was explained by the deterministic component, and the remainder by the stochastic component. For four-month samples of the hourly Watts Creek WWTP flowrate series, approximately 21 to 85 percent of the variance, with a strong seasonal effect, was explained by the deterministic component, and the remainder by the stochastic component.

The flowrate time series were modelled using combined deterministic-stochastic time series models. The deterministic component models used accounted for periodicities in both the level and the variance of the series by means of a standardization technique. The ARIMA, or Box-Jenkins, group of stochastic time series models was employed to represent the flowrate stochastic components.

An ARIMA model of the form $(2,0,0) \times (0,1,1)_s$, where s is the number of flowrate observations per day, was found in all cases to be the flowrate stochastic component model combining best fit and

parsimony. Fitted model parameter estimates showed seasonal variation, but were consistent from year to year.

The random element, estimated by the fitted model residuals, constituted approximately 18 to 21 percent of the series variance for the Green Creek WWTP flowrates, and 2 to 12 percent for the Watts Creek WWTP flowrates. The randomness hypothesis for the model residuals was accepted in each case, but the normality hypothesis was rejected.

Application of the adopted time series models to flowrate forecasting showed that the characteristics of the one-interval ahead forecast errors were similar to those of the fitted model residuals, as expected by definition, but the variance of the forecast errors was slightly greater, due to the effect of the periodic component being included.

Monte Carlo simulation of Green Creek WWTP flowrates failed to preserve satisfactorily the properties of the observed flowrates when a normal distribution was assumed for the independent random component.

Using a pre-determined flow equalization basin operation plan, which included observation of present conditions, forecasting of future conditions, and adjustment of controls, performance of hypothetical basins in smoothing diurnal flowrates was estimated by routing observed and simulated wastewater flowrate series through the basins. A stochastic design method was developed which related expected performance (with confidence intervals) to maximum storage capacity. Volume requirements suggested by this method for the Green Creek WWTP agreed with those by previous design methods.

6.2 Significance

The proposed flow equalization design method represents a dramatic improvement over methods currently advocated or in use.

Inclusion of stochastic analysis in the design allows probability statements to be made about process uncertainty where the present practice would be to smother the unknown with a blanket safety factor. The uncertainty is the same in each case; previous methods merely do not come to grips with it.

Most methods try to smooth diurnal flow fluctuations only, this method included. Previous methods, however, assume day-to-day independence of flowrates, while the procedure proposed here considers the obvious correlation between flows on different days.

Finally, as the basin is to be operated in the real world, the design method accounts for the performance reduction due to operational limitations. Previous methods ignore this completely.

The strength, then, in this design method proposal lies in its close ties with the later utilization of the design product. The same computer routines are used for both design and day-to-day operation, an economic plus.

An admitted weakness is the requirement of 24 hour operation. At discrete time intervals the operation procedure must be performed. At this time it is anticipated manual adjustment of basin controls would be instigated. The operational procedure developed here presumes this; however, conversion to automated operation conceivably could be accomplished with the proper technology.

Costs of computation depend on time interval width. Matrix-like operations in the flow-forecasting and generating, and operating routines cause computation time to increase approximately as the square of the number of time steps. The generation and simulated operation of 364 days (2912 time steps) of Green Creek flowrate data through 9 separate basins consumed approximately one minute of machine time on an IBM 360/365 computer. Improved pollution control cannot be had without expense and effort.

Totally automated wastewater treatment may become a reality if effluent standards continue to tighten, and there is no reason to doubt that they will. While certainly not the panacea, the stochastic design and operation method proposed here for flow equalization is a significant step in that direction. Meanwhile, its implementation is completely feasible.

CHAPTER 7

RECOMMENDATIONS

As documented experience with the ARIMA models is limited, unanswered questions arose during the course of this project. Investigation is therefore recommended into (1) the inadequacy of the flowrate models suspected in Section 5.2.1, (2) the variations or non-stationarity, within the fundamental period, of the stochastic model parameter estimates, and (3) the effect on forecast confidence limits of the transformation of the stochastic component forecasts to full flowrate forecasts by the inclusion of the periodic component.

With respect to the flow equalization design problem, it would be beneficial to investigate, (1) the analytical application of surplus, deficit, and range theory, (2) the determination of the optimum time interval for basin operation, (3) the philosophy of basin operation and use of recycle capacity as an equalization tool, and (4) the definition of variance reduction standards from a clear understanding of the downstream effects of flow equalization.

Finally, the potential of a stochastic approach to design should be investigated for other treatment processes and variables.

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APPENDIX A

COMPUTER PROGRAM SOURCE LISTINGS - MAIN PROGRAMS

<u>Main Program</u>	<u>Page</u>
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FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          12/58/12
0001          DIMENSION X(6000)          000000000
0002          COMMON /BK/ TITLE(20), LP, TITLE1(20)          000000010

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MAIN PROGRAM FOR FOURIER ANALYSIS.
DESCRIPTION OF PARAMETERS - SEE SUBROUTINE FOUR.
LREAD - INPUT INSTALLATION CODE FOR CARD READER.
THIS PROGRAM REQUIRES SUBROUTINES.....
FOUR, STANDX.

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```

.....
0003          FORMAT(8F5.2)          00000030
0004          FORMAT(16I5)          00000040
0005          FORMAT(20A4)          00000050
0006          LREAD=5          00000060
0007          LP=6          00000070
0008          READ (LREAD,2) TITLE          00000080
0009          READ (LREAD,3) NFP,ND,MM          00000090
0010          READ (LREAD,4) (X(I), I=1,ND)          0000100
0011          CALL FOUR (NFP,ND,MM,X)          00000110
0012          STOP          00000120
0013          END          00000130
          00000140

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CCCCCCCCCCCCCCCC4320

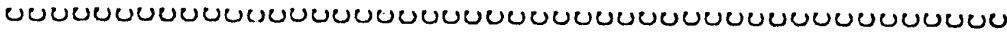
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PERIODIC AND STOCHASTIC COMPONENTS OF TIME SERIES.
 PROGRAM CALCULATES PRINTS AND PUNCHES PERIODIC AND STOCHASTIC COMPONENTS
 OF DISCRETE TIME SERIES WHERE OBSERVED RECORD IS COMPRISED OF A SHORT
 RECORD OF CLOSELY SPACED TIME-AVERAGED OBSERVATIONS AND AN OVERLAPPING
 LONGER RECORD OF TIME-AVERAGED OBSERVATIONS AT LARGER SPACINGS (EG., 2 YEARS
 OF HOURLY FLOWRATES WITH 8 YEARS OF DAILY MEAN FLOWRATES).

METHOD SUBTRACTS FROM ORIGINAL SERIES THE PERIODIC MEANS AND DIVIDES BY THE
 PERIODIC STD. DEVIATIONS ABOUT PERIODIC MEANS, THEN MULTIPLIES BY THE
 STOCHASTIC COMPONENT STD. DEVIATION TO REMOVE ALL HARMONICS OF THE
 FUNDAMENTAL PERIOD. ASSUMING SHORT RECORD PERIODICITY IS STATIONARY THROUGH
 ENTIRE LONG RECORD, FINAL STOCHASTIC COMPONENT ON SHORT RECORD SPACING
 IS CALCULATED BY SUMMING CORRESPONDING LONG AND SHORT RECORD STOCHASTIC
 COMPONENTS.

DESCRIPTION OF PARAMETERS.
 SERIES - ON 1ST READ STATEMENT (LINE 23), AN 80 CHARACTER DESCRIPTION OF
 LONG RECORD DATA, ON ONE DATA CARD. 40 CHARACTER DESCRIPTION OF
 NYRS - ON 2ND READ STATEMENT (LINE SPACES 70), ON ONE DATA CARD.
 NPERYR - SHORT RECORD OF FUNDAMENTAL PERIODS IN LONG RECORD INPUT DATA
 (EG., 1 YEAR OF DAILY MEAN FLOWRATES). LONG RECORD
 NDAY - INPUT NUMBER OF YEARS OF DAILY MEAN FLOWRATES PER YEAR.
 NPERDY - FUNDAMENTAL PERIOD (EG., 364 DAILY MEAN FLOWRATES PER YEAR).
 NSRT - INPUT NUMBER OF FUNDAMENTAL PERIODS IN SHORT RECORD INPUT DATA
 (EG., 1 YEAR OF HOURLY OBSERVATIONS). PER SHORT RECORD
 Z - FUNDAMENTAL PERIOD OF SHORT RECORD INPUT DATA. PERIOD IS THE SAME
 DATA STATEMENT KP, KR, KPUN... INSTALLATION SPECIFIC CODES FOR LINE PRINTER,
 CARD READER, AND CARD PUNCH.

THIS PROGRAM REQUIRES SUBROUTINE.... STANDX.



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FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          12/58/20
0001 DIMENSION RZ(800), ZAV(400), ZS(400), Z(9000)          00001000
0002 DIMENSION SERIES(20), T(10)          00001010
0003 DIMENSION DMSIO(3000), STOSID(2)          00001020
0004 DATA KP, K3, KPUN /6, 5, 4, /          00001030
0005 T(1), T(2), T(3), T(4), T(5), T(6), T(7), T(8), T(9), T(10), /, SHOR, T          00001040
+ RE, COEF, FLU, CS, ABOU, LO, NG R, ECR, D, /          00001050
0006 FORMAT(1H1)          00001060
0007 FORMAT(1H0, 8E11.4)          00001070
0008 FORMAT(1H0, 8E11.4)          00001080
0009 FORMAT(1H0, 8E11.4)          00001090
0010 PERIODIC MEANS, /          00001100
0011 PERIODIC MEANS, /          00001110
0012 PERIODIC MEANS, /          00001120
0013 PERIODIC MEANS, /          00001130
0014 PERIODIC MEANS, /          00001140
+ S.D.S. COMP. MEAN VARIANCE OF MEANS MEAN OF          00001150
FORMAT(1H0, 8E11.4)          00001160
FORMAT(1H0, 8E11.4)          00001170
FORMAT(1H0, 8E11.4)          00001180
FORMAT(1H0, 8E11.4)          00001190
FORMAT(1H0, 8E11.4)          00001200
FORMAT(1H0, 8E11.4)          00001210
FORMAT(1H0, 8E11.4)          00001220
FORMAT(1H0, 8E11.4)          00001230
FORMAT(1H0, 8E11.4)          00001240
+ ORIGINAL SERIES MEAN          00001250
FORMAT(1H0, 8E11.4)          00001260
FORMAT(1H0, 8E11.4)          00001270
FORMAT(1H0, 8E11.4)          00001280
FORMAT(1H0, 8E11.4)          00001290
FORMAT(1H0, 8E11.4)          00001300
FORMAT(1H0, 8E11.4)          00001310
FORMAT(1H0, 8E11.4)          00001320
FORMAT(1H0, 8E11.4)          00001330
FORMAT(1H0, 8E11.4)          00001340
FORMAT(1H0, 8E11.4)          00001350
FORMAT(1H0, 8E11.4)          00001360
FORMAT(1H0, 8E11.4)          00001370
FORMAT(1H0, 8E11.4)          00001380
FORMAT(1H0, 8E11.4)          00001390
FORMAT(1H0, 8E11.4)          00001400
FORMAT(1H0, 8E11.4)          00001410
FORMAT(1H0, 8E11.4)          00001420
FORMAT(1H0, 8E11.4)          00001430
FORMAT(1H0, 8E11.4)          00001440
FORMAT(1H0, 8E11.4)          00001450
FORMAT(1H0, 8E11.4)          00001460
FORMAT(1H0, 8E11.4)          00001470
0015 READ (KR, 102) SERIES          00001250
0016 READ (KR, 100) NYRS, NPEPYR          00001260
0017 NOB=NYSR*NPEPYR          00001270
0018 PEAD (KR, 104) (Z(I), I=1, NOB)          00001280
0019 LONGPD=NPEPYR          00001290
0020 NFP=NYSR          00001300
0021 KLL=1          00001310
0022 PRINT 112, SERIFS (NOB, Z, SERMEA, SERSTD)          00001320
0023 CALL STANDX(NOB, Z, SERMEA, SERSTD)          00001330
0024 SERVA=SERSTD*SERSID          00001340
0025 WRITE (6, 12) SERMEA, SERVA          00001350
0026 STDCOR=NFP/(NFP-1)          00001360
0027 STDCOR=SQRT(STDCOR)          00001370
0028 DO 200 I=1, LONGPD          00001380
0029 II=I-LONGPD          00001390
0030 DO 13 J=1, NFP          00001400
0031 II=II+LONGPD          00001410
0032 RZ(J)=Z(II)          00001420
0033 CALL STANDX(NFP, RZ, ZM, ZSTD)          00001430
0034 ZSTD=ZSTD*STDCOR          00001440
0035 II=I-LONGPD          00001450
0036          00001460
0037          00001470
0038          00001480
0039          00001490
0040          00001500
0041          00001510
0042          00001520
0043          00001530

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FORTRAN IV G LEVEL 21

MAIN

DATE = 77065

12/58/20

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0044 DO 16 J=1,NFP
0045 II=II+LONGPD
0046 Z(II)=Z(II-ZM)/ZSTD
0047 ZS(I)=ZSTD
0048 CALL STANDX(LONGPD,ZAV,ZMEAN,SIDM)
0049 VARM=STDM*SIDM
0050 CALL STANDX(LONGPD,ZS,ZSMEAN,S'DSD)
0051 VARSD=SIDSD*SIDSD
0052 WRITE (KPUN,210) (ZAV(I),I=1, LONGPD)
0053 PRINTT(210) (ZS(I),I=1, LONGPD)
0054 ZMEAN,VARM,ZSMEAN,VARSD
0055 PRINTT(248)
0056 PRINTT(249)
0057 PRINTT(250)
0058 PRINTT(251)
0059 PRINTT(252)
0060 PRINTT(253)
0061 STOSTD(KL)=SORT(SERVAP-VARM-VARSD)
0062 PPN=253, STOSTD(KL)
0063 DO 230 I=1,NOB
0064 Z(I)=Z(I)*STOSTD(KL)
0065 IF (KL.EQ.2) GO TO 444
0066 DO 302 I=1,NOB
0067 DMSTO(I)=Z(I)
0068 KL=2
0069
0070 READ (KR,102) SERIES
0071 NOB={KR,100} NDAYS,NPERDY,NSTRT
0072 NOB=NDAYS*NPERDY
0073 READ (KR,105) (Z(I),I=1,NOB)
0074 LONGPD=NPERDY
0075 NFP=NDAYS
0076 PRINT 260
0077 CALL STANDX(NOB,Z,SERMEA,SERSTD)
0078 SERVAR=SERSTD*SERSTD
0079 WRITE (KP,112) SERMEA,SERVAR
0080 DO 318 I=1,10
0081 SERIES(I+10)=I(I)
0082 DO 330 J=1,NDAYS
0083 SUM=0.0
0084 JJ=(J-1)*NPERDY
0085 DO 320 I=1,NPERDY
0086 JJ=JJ+1
0087
00001480
00001490
00001500
00001510
00001520
00001530
00001540
00001550
00001560
00001570
00001580
00001590
00001600
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00001800
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00001910
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00001940
00001950

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FOR-RAN IV G LEVEL 21          MAIN          DATE = 77065          12/58/20
0088      SUM=SUM+Z(JJ)          00001960
0089      DM=SUM/NPERDY          00001970
0090      JJ=JJ-NPERDY          00001980
0091      DO 325 I=1,NPERDY      00001990
0092      JJ=JJ+1                00002000
0093      Z(JJ)=Z(JJ)-DMM        00002010
0094      CONTINUE              00002020
0095      GO TO 9                00002030
0096      NFIN=MINO(NYES*NPERYR,NSTRT+NDAYS-1) 00002040
0097      NOB=(UPFIN+1-NSTRT)*NPERDY 00002050
0098      DO 460 K=NSTRT,NFIN    00002060
0099      JJ=(K-NSTRT)*NPERDY   00002070
0100      DM=DM+O(K)            00002080
0101      DO 455 I=1,NPERDY     00002090
0102      JJ=JJ+1                00002100
0103      Z(JJ)=Z(JJ)+DMM        00002110
0104      CONTINUE              00002120
0105      INOB=0                 00002130
0106      DO 236 I=1,NOB,6      00002140
0107      KK=I+5                 00002150
0108      INOB=INOB+1            00002160
0109      IF (KK.GT.NOB) GO TO 233 00002170
0110      WRITE (KPUN,232) (Z(K),K=I,KK),INOB 00002180
0111      GO TO 236              00002190
0112      WRITE (KPUN,234) (Z(K),K=I,NOB) 00002200
0113      CONTINUE              00002210
0114      WRITE (KPUN,234) STOSTD(1),STOSTD(2) 00002220
0115      PRINT 260              00002230
0116      STOP                   00002240
0117      END                     00002250

```

ARIMA MODEL IDENTIFICATION PROGRAM.

REFERENCE ON APPLICATION OF PROGRAM. BOLDUC P.-A. RUNNING THE
BOX-JENKINS MODEL, TECHNICAL NOTE NO. 15, MARINE ENVIRONMENTAL DATA
SERVICE, ENVIRONMENT CANADA, JUNE 1976.

DESCRIPTION OF PARAMETERS. STATEMENT 100
1ST READ STATEMENT, FORMATS, OBSERVATIONS TO BE COMPUTED (O.LE.NAC.LE.400).
NOB - NO. OF OBSERVATIONS TO BE COMPUTED (NPAC.GE.0).
NAC - NO. OF AUTOCORRELATIONS TO BE COMPUTED (NPAC.GE.0).
NPAC - NO. OF PARTIAL AUTOCORRELATIONS TO BE INVESTIGATED (NSD.GE.0).
NRD - NO. OF DIFFERENCES OF THE SERIES TO BE INVESTIGATED (NRD.GE.0).
NSD - NO. OF SEASONAL DIFFERENCES TO BE INVESTIGATED (NSD.GE.0).
NSEA - LENGTH OF LAG FOR SEASONAL DIFFERENTIAL AUTOCORR. PRINTED PER LINE.
NSEA - NO. OF AUTOCORRELATIONS AND PARTIAL AUTOCORR. PRINTED PER LINE.
NCHI - DEGREES OF FREEDOM FOR CHI-SQUARE STATISTIC (NCHI.LE.NAC).
MCSE - ZERO IF NO AUTO CORRELATIONS TO BE COMPUTED,
IF NO NONZERO IF YES.
ILDAC - DATA LISTING OPTION, ZERO IF NO, NONZERO IF YES.
IPDID - DATA PLOTTING OPTION, ZERO IF NO, NONZERO IF YES.
MPRINT - OUTPUT OF STATISTICS, OPTION, ZERO IF NO, NONZERO IF YES.
IWTPA - AUTOCORRELATION AND PARTIAL AUTOCORRELATION PLOTTING OPTION,
ZERO IF NO, NONZERO IF YES.
IWTSP - VARIANCE SPECTRUM COMPUTATION AND PLOTTING OPTION,
ZERO IF NO, NONZERO IF YES.
2ND READ STATEMENT, FORMATS, STATEMENT 102.
SERIES - 80 CHARACTER TITLE.
3RD READ STATEMENT, FORMATS, STATEMENT 104.
Z - ARRAY OF TIME SERIES OBSERVATIONS.

THIS PROGRAM REQUIRES SUBROUTINES
ACOR, CPROXY, ILOC, PACOR, PLOT, PRPLC, SPECT.

MINIMUM DIMENSIONS.
Z(NOB), RHO(NAC, NRD+1), STE(NAC, NRD+1), E(NRD+1), SM(NRD+1), PHI(NPAC, NRD+1),
SERIES(20), SCRATC(MAX. OF NOB, NPAC*(NPAC+1)/2)
DATA STATEMENT KR, KP, KPUNCH. INSTALLATION SPECIFIC CODES FOR CARD READER,
LINE PRINTER, AND CARD PUNCH.

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PORTRAN IV G LEVEL 21          MAIN          DATE = 77065          14/13/17
0001  DIMENSION Z(9000), RUO(150,2), STE(150,2), E(2), SM(2), PHI(150,2)          00003000
0002  DIMENSION SCPATC(9000)          00003010
0003  DIMENSION SERIES(20)          00003020
0004  COMMON/ACPAR/NED, NSD, NSEA, NAPL, NCHI, MCSE, ILDAC, IPDID, MPRINT, IWTPA,          00003030
      + IWTPSP          00003040
0005  DATA KR, KP, KPUNCH /5,6,7/          00003050
      00003060
0006  FORMAT (1H1)          00003070
0007  FORMAT (12F6.2)          00003080
0008  FORMAT (20A4)          00003090
0009  FORMAT (16I5)          00003100
0010  READ (KR, 100) NOB, NAC, NPAC, NRD, NSD, NSEA, NAPL, NCHI, MCSE, ILDAC, IPDID,          00003110
      + MPRINT, IWTPA, IWTPSP          00003120
0011  READ (KR, 102) SERIES          00003130
0012  READ (KR, 104) (Z(K), K=1, NOB)          00003140
0013  CALL ACOR(SERIES, Z, NOB, NAC, NPAC, NCHI, RHO, STE, E, SM, PHI, SCRATC)          00003150
0014  WRITE (KP, 120)          00003170
0015  STOP          00003180
0016  END          00003190
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FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          12/59/42
0001  DIMENSION PHI(120,2),RHO(120,2),STE(120,2),F(2),SM(2),PA(25)
0002  DIMENSION SCRATC(15060)
0003  COMMON/TSRBS/A(2920)
0004  COMMON/TSOBS/Z(2920)
0005  COMMON/FPAR/EPS1,EPS2,MIT,NDIMS,NLOG,IPDEST,IPRES,ILRES,IRPNCH
0006  COMMON/ISPAR/MAX11,MBO,NP,NOB,WRD,NSD,NSEA,INC(6),IOPA(25)
0007  COMMON/DCPAR/MSD,NAC,NCHI,NCS5,NAPL,IWTPA,IWTPSP
0008  COMMON/NAMES/SERIES(20)
0009  COMMON/PUNCH/KPUNCH
0010  DATA KP, KR, KPUN /6,5,7/
0011  FORMAT(2F10.4,5I5)
0012  FORMAT(8F10.4)
0013  FORMAT(6E11.4)
0014  FORMAT(20A4)
0015  FORMAT(16I5)
0016  KPUNCH=KPUN
0017  READ (KR,100) NOB,NMODEL
0018  READ (KR,102) SERIES
0019  READ (KR,104) Z(K),K=1,NOB)
0020  DO 107 NP,PROB=1,NMODEL
0021  READ (KR,100) NLOG,NRD,NSD,NSEA,(INC(K),K=1,6)
0022  NP=0
0023  DO 101 K=1,6
0024  NP=NP+INC(K)
0025  READ (KR,100) (IOPA(K),K=1,NP)
0026  READ (KR,106) (PA(K),K=1,NP)
0027  NPO=NP+1
0028  IF(NPO.GT.25) GO TO 1025
0029  DO 1021 K=NPO,25
0030  IOPA(K)=0
0031  PA(K)=0
0032  READ (KR,108) EPS1,EPS2,MIT,IPDEST,IPRES,ILRES,IRPNCH
0033  READ (KR,100) NAC,NPAC,NEDAC,MCSE,NAPL,IWTPA,NCHI,IWTPSP
0034  NDIMS=7*NP+NP*NP+2*NOB+NP*NOB
0035  CALL ESTIM (NPROB,PA,RHO,STE,E,SM,PHI,NAC,NPAC,SCRATC)
0036  CONTINUE
0037  PRINT 94
0038  FORMAT(1H1)
0039  STOP
0040  END
0004000
00004010
00004020
00004030
00004040
00004050
00004060
00004070
00004080
00004090
00004100
00004110
00004120
00004130
00004140
00004150
00004160
00004170
00004180
00004190
00004200
00004210
00004220
00004230
00004240
00004250
00004260
00004270
00004280
00004290
00004300
00004310
00004320
00004330
00004340
00004350
00004360
00004370
00004380
00004390
00004400
00004410

```

FORTRAN IV G LEVEL 21

MAIN

DATE = 77065

12/59/42

C 108
106
104
102
100
C

99

101

1021
1025

107
94

```

FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          14/13/50
0001          DIMENSION X(3000),Z(3000)          00005000
0002          COMMON /EK/ TITLE(20),LPRINT,TITLE1(20) 00005010

```

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.....

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```

MAIN PROGRAM FOR ARIMA MODEL RESIDUAL CHECKS.

```

```

DESCRIPTION OF PARAMETERS.
TITLE - INPUT 80 CHARACTER TITLE, 20 - 4 BYTE WORDS.
LPRINT - INPUT INSTALLATION CODE FOR LINE PRINTER.
LREAD - INPUT INSTALLATION CODE FOR CARD READER.
TITLE1 - NOT REQUIRED BY THIS PROGRAM.
X N - INPUT ARRAY OF MODEL RESIDUALS.
N - INPUT LENGTH OF ARRAY X.

```

```

THIS PROGRAM REQUIRES SUBROUTINES
DIST, MOMEN, RAND, SORTX, STANDX.

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```

.....

```

```

0003          LPRINT=5
0004          LPRINT=6
0005          LPRINT=6
0006          LPRINT=6
0007          LPRINT=6
0008          LPRINT=6
0009          LPRINT=6
0010          LPRINT=6
0011          LPRINT=6
0012          LPRINT=6
0013          LPRINT=6
0014          LPRINT=6
0015          LPRINT=6
0016          LPRINT=6
0017          LPRINT=6
0018          LPRINT=6
0019          LPRINT=6
0020          LPRINT=6
0021          LPRINT=6
0022          LPRINT=6
0023          LPRINT=6

74          LPRINT=5
75          LPRINT=6
76          LPRINT=6
C          LPRINT=6
90          LPRINT=6
100         LPRINT=6
110         LPRINT=6
120         LPRINT=6
C          LPRINT=6

LPRINT=5
LPRINT=6
LPRINT=6
LPRINT=6
DO 74 I=1,N
Z(I)=X(I)
CALL MOMEN(N,Z)
DO 75 I=1,N
Z(I)=X(I)
CALL DIST(N,0,Z)
DO 76 I=1,N
Z(I)=X(I)
CALL RAND(N,X,Z)
WRITE (LPRINT,120)
FORMAT (20A4)
FORMAT (I5)
FORMAT (7E11.4)
FORMAT (1H1)
STOP
END

```



```

10TH READ - STATEMENT, VALUES IN STATEMENT 106.
PA - PARAMETER, VALUES IN THE SAME SEQUENCE AS IN IOPA.
11TH READ - STATEMENT, FORMAT STATEMENTS 104.
Z - STOCHASTIC COMPONENT, LAST SERIES BEFORE THE FIRST DAY TO BE FORECAST-
    INCLUDED AS INDICATED BY NDAYO.
12TH READ - STATEMENT, FORMAT STATEMENTS 104.
ZN - OBSERVED FLOWRATE SERIES VALUES FOR LAST DAY BEFORE THE
    FIRST DAY TO BE FORECAST-CHECKED, AS INDICATED BY NDAYO.
13TH READ - STATEMENT, FORMAT STATEMENTS 104.
Y - OBSERVED FLOWRATE TIME SERIES VALUES FOR ALL THE NDAYCK DAYS
    OF FORECASTS TO BE CHECKED, NDAYCK*NPERDY IN NUMBER.

THIS PROGRAM REQUIRES SUBROUTINES....
CFCSI, FCHEK, FLOFST, NCHOST, WOMEN, PLOT, SORTX, TSMOD, TSFCST ( CAN BE A DUMMY
AS NOT CALLED... IF TSFCST IS NOT A DUMMY, THEN UTFCSI, PRACHK, CPROXY ARE
ALSO REQUIRED. ).

MINIMUM DIMENSIONS.
ZN (NPERDY), ZP (2*NPERDY, 1), CUL (1, 1), U (1), PA (25), NT (1), DMPDMN (NDIC),
DMPDSD (NDIC), DIPDMN (NPERDY), DIPDSB (NPERDY), STOFST (NPERDY), DMFCST (2),
DMFCST (2*NPERDY, DY), D (NPERDY), AC (NPERDY), H (NPERDY), FREQ (100, NPERDY),
SERIES (20), INC (6), IOPA (25), TITLE (20), S (24), S1 (24),
X (NDAYCK*NPERDY, NPERDY), Y (NDAYCK*NPERDY), SCRATC (NOB+2*NPERDY),
Z (NOB+2*NPERDY), A (NOB+2*NPERDY).

DATA STATEMENT KP, KR, KPUN... INSTALLATION SPECIFIC CODES FOR LINE PRINTER,
CARD READER, AND CARD PUNCH.
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FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          14/14/31
0001 DIMENSION ZN(24), ZP(48), CLL(1,1), CUL(1,1), U(1), PA(25), NT(1) 00006000
0002 DIMENSION DMPDMN(364), DMPDSD(364), DIPDMN(24), DIPDSD(24), STOEST(24) 00006010
+ DIMENSION(2), DIFCST(48), D(24), G(24), AC(24) 00006020
0003 DIMENSION SCRATC(150), H(24), FREQ(100,24), S(24), X(300,24) 00006030
0004 COMYON // FLACI // NDAYO // NDAYCK // Y(300) 00006040
0005 COMEON // NAMEF // SERIES(20) 00006050
0006 COMMON // FLEO // NDIC // NDOC // NTINT // STSDDM // STSDDI 00006060
0007 COMMON // TSRES // A(150) 00006070
0008 COMMON // TSOBS // Z(150) 00006080
0009 COMMON // ISPAE // MAX(11) 00006090
0010 COMMON // DK // TITLE(20) // LPR // TITLE1(20) 00006100
0011 COMMON // SS // S1(24) 00006110
0012 DATA KP, KP, KP, KPUN // 6, 5, 7 // 00006120
DATA S(1), S(2), S(3), S(4), S(5), S(6), S(7), S(8), S(9), S(10), S(11), S(12) 00006130
+), S(13), S(14), S(15), S(16), S(17), S(18), S(19), S(20), S(21), S(22), S(23) 00006140
+), S(24) // 4H 1, 4H 2, 4H 3, 4H 4, 4H 5, 4H 6, 4H 7, 4H 8, 4H 9, 4H 10, 4H 11, 4H 12, 4H 13, 4H 14, 4H 15, 4H 16, 4H 17, 4H 18 00006150
+ 4H 19, 4H 20, 4H 21, 4H 22, 4H 23, 4H 24 / 00006160
0014 FORMAT(7E11.4) 00006170
0015 FORMAT(8F10.4) 00006180
0016 FORMAT(8F5.2) 00006190
0017 FORMAT(20A4) 00006200
0018 FORMAT(16I5) 00006210
0019 LPR=KP 00006220
0020 READ (KR,102) SERIES,PERDY,NDIC,NDAYO,NDAYCK 00006230
0021 READ (KR,110) NOB,NPDMN(I),I=1,NDIC 00006240
0022 READ (KR,110) (DMPDSD(I),I=1,NDIC) 00006250
0023 READ (KR,110) (DIPDMN(I),I=1,NPERDY) 00006260
0024 READ (KR,110) (DIPDSD(I),I=1,NPERDY) 00006270
0025 READ (KR,110) STSDDM,STSDDI 00006280
0026 READ (KR,110) NRD,NSB,NSEA,(INC(K),K=1,6) 00006290
0027 NP=0 00006300
0028 DO 301 K=1,6 00006310
0029 NP=NP+INC(K) 00006320
0030 READ (KR,100) (IOPA(K),K=1,NP) 00006330
0031 READ (KR,106) (PA(K),K=1,NP) 00006340
0032 READ (KR,104) (Z(K),K=1,NOB) 00006350
0033 READ (KR,104) (ZN(K),K=1,NPERDY) 00006360
0034 KKK=NDAYCK*NPERDY 00006370
0035 READ (KR,104) (Y(I),I=1,KKK) 00006380
0036 DO 296 I=1,NPERDY 00006390
0037 S1(I)=S(I) 00006400
0038 CALL FCHK(ZP,CLL,CUL,PA,NT,ZN,U,SCRATC,DMPDMN,DMPDSD, 00006410
+DIPDMN,DIPDSD,STOEST,DMFCST,DIFCST,H,NPERDY,D,G,AC,FREQ,X,KKK) 00006420
0039 END 00006430
0040 00006440
0041 00006450
0042 00006460
0043 00006470
0044 00006480

```



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FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          14/15/06
0033 READ (KR, 100) NOB, NMODEL, NPERDY, NDIC          00007480
0034 NOPIG=NOB          00007490
0035 READ (KR, 102)          00007500
0036 READ (KR, 110)          00007510
0037 READ (KR, 110)          00007520
0038 READ (KR, 110)          00007530
0039 READ (KR, 110)          00007540
0040 READ (KR, 110)          00007550
0041 READ (KR, 110)          00007560
0042 READ (KR, 100)          00007570
0043 READ (KR, 100)          00007580
0044 READ (KR, 110)          00007590
0045 READ (KR, 110)          00007600
0046 READ (KR, 104)          00007610
0047 NO=1          00007620
0048 READ (KR, 104)          00007630
0049 NPO=NIN+1          00007640
0050 IF (NPO.GT.24) GO TO 311          00007650
0051 DO 310 K=NPO,24          00007660
0052 ZN(K)=0.0          00007670
0053 MLOG=NLOG          00007680
0054 HR=24/NPERDY          00007690
0055 MN=2*NPERDY          00007700
0056 DO 607 NPROB=1, NMODEL          00007710
0057 READ (KR, 100) NRD, NSD, NSEA, (INC(K), K=1,6)          00007720
0058 NP=0          00007730
0059 DO 301 K=1,6          00007740
0060 NP=NP+INC(K)          00007750
0061 READ (KR, 100)          00007760
0062 READ (KR, 106)          00007770
0063 NPO=NP+1          00007780
0064 IF (NPO.GT.25) GO TO 305          00007790
0065 DO 303 K=NPO,25          00007800
0066 IOPA(K)=0          00007810
0067 IOPA(K)=0.0          00007820
0068 READ (KR, 100) ICI, IPDFST, IWTFF          00007830
0069 CALL FLOFST(NPROB, NF, ZF, CLL, CUL, PA, NT, ZN, J, SCRATC, DMPDMN, DMPDSD,          00007840
+DIPDMN, DIPDSD, STOEST, DMFCST, DIFCST, H, NPERDY, D, G, AC)          00007850
0070 NOB=NOB+1          00007860
0071 IF (NININT.NE.0) GO TO 313          00007870
0072 NOB1=NOB+1          00007880
0073 NOBN=NOB+NPERDY          00007890
0074 PRINT 134, (Z(I), I=NOB1, NOBN)          00007900
          00007910
          00007920
          00007930
          00007940
          00007950
C          OPTIONAL OUTPUT... REMOVE C FROM WRITE STATEMENT TO HAVE FLOWRATE
C          STOCHASTIC COMPONENT FOR COMPLETE DAY (NPERDY VALUES) PUNCHED
C          ONTO CARDS ON THE LAST RUN OF THE DAY FOR THIS PROGRAM.
C          ADD PUNCHED CARDS TO INPUT STOCHASTIC COMPONENT Z, AND

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DATE = 77065 14/15/06

MAIN

21

FORTRAN IV G LEVEL

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0075      C      DELETE OLDEST DAY OF Z VALUES.
0076      C      WRITE(KPUN,104) (Z(I),I=NOB1,NOBN)
0077      C
0078      C      PRINT 130, DMFCST(1), DMFCST(2)
0079      C
0080      C      OPTIONAL OUTPUT... REMOVE C FROM WRITE STATEMENT TO HAVE DMFCST(1)
0081      C      (REQUIRED ON NEXT INPUT) PUNCHED ONTO CARD ON EVERY RUN OF
0082      C      THIS PROGRAM.
0083      C      WRITE (KPUN,110) DMFCST(1)
0084      C
0085      C      PRINT 131, (DMFCST(I), I=1,MN)
0086      C      CALL OPER8 (NPERDY,H,HD)
0087      C      PRINT 120, SERIES
0088      C      PRINT 122, HR, (H(I), I=1,NPERDY)
0089      C      PRINT 124, HR, PUMPRT(1)
0090      C      IF (LL.EQ.0) GO TO 396
0091      C      PRINT 126, RCSTRT
0092      C      PRINT 128, (RCRATE(I), I=1,LL)
0093      C      CONTINUE
0094      C      CONTINUE
0095      C      STOP
0096      C      END

```

```

00007960
00007970
00007980
00007990
00008000
00008010
00008020
00008030
00008040
00008050
00008060
00008070
00008080
00008090
00008100
00008110
00008120
00008130
00008140
00008150
00008170

```

.....
FLOW EQUALIZATION BASIN DESIGN PROGRAM.
.....

GENERATES WATER FLOWRATE TIME SERIES WITH THE DESIRED ARIMA STOCHASTIC MODEL PARAMETERS AND PERIODIC COMPONENTS, AND SIMULATES ACTUAL BASIN OPERATION TO DETERMINE BASIN PERFORMANCE. CAN ALSO ACCEPT OBSERVED FLOWRATES.

THIS PROGRAM IS TO BE USED IN CONJUNCTION WITH FLOW FORECASTING AND FLOW EQUALIZATION BASIN CONTROL PROGRAM.

EXPLANATION OF PARAMETERS NOT IN FLOW FORECASTING AND FLOW EQUALIZATION BASIN CONTROL PROGRAM. SEE ARIMA.

NRANS - INPUT NO. OF CONSECUTIVE DAYS OF FLOWRATES TO BE GENERATED AND TESTED IN DESIGN.
NVOLS - INPUT NO. OF DIFFERENT MAX. EQUALIZATION BASIN VOLUMES TO BE TESTED IN DESIGN.
RVAR - INPUT PARAMETER, SEE ARIMA.
STOCCAP - INPUT MAX. AVAILABLE STORAGE OF THE NVOLS BASINS.
VINST - INPUT INITIAL STORAGE OF THE NVOLS BASINS TO BEGIN DESIGN RUN.
IRC - INPUT INDICATOR OF USE OF RECYCLING CAPABILITY OPTION, ZERO IF NO, 1 IF YES.

IXS - INPUT SEED, RANDOM NUMBER, 9 OR LESS DIGIT INTEGER.
IFF - OBSERVED FLOWRATE TESTING OPTION, ZERO IF GENERATED FLOWRATES TO BE TESTED, 1 IF OBSERVED FLOWRATES TO BE INPUT AND TESTED.
ILGS - LISTING OF GENERATED SERIES OPTION, ZERO IF NO, NONZERO IF YES. THE LISTING OF GENERATED FLOWRATES INPUT INTERVALS UP TO AND INCLUDING ALL THE FLOWRATE SERIES FOR MBO. MBO IS AN INTEGER MULTIPLE OF THE LONG TERM PERIODIC CYCLE. MBO IS AN INTEGER MULTIPLE OF NPERDY SUCH THAT MBO.NGT.MBO.

Y - IF OBSERVED FLOWRATES INPUT, Y IS THE OBSERVED FLOWRATE SERIES IF BEGINNING THE FLOWRATES BEFORE THE FIRST DAY OF THE LONG TERM CYCLE. CFCST, = OBS + NSD*NSFA + MAX. 1. ORDER OF REGULAR AR MODEL + MAX. ORDER OF SEASONAL AR MODEL + 1.
MBO - IF OBSERVED FLOWRATES INPUT, MBO IS THE MAX. BACKORDER OF MODEL.

THIS PROGRAM REQUIRES SUBROUTINES: OPFE8, RANDUM, STANDX, TSMOD, TSFCST (CAN BE ARIMA, CFCST, FLOEST, GAUSSM, NCHOSE, OPFE8, THEN UTEFCST, PRACK, CPROXY ARE ALSO REQUIRED.).

MINIMUM DIMENSIONS
ZRN(NPERDY), ZP(2*NPERDY, 1), CLL(1, 1), CUL(1, 1), U(1), PA(25), NT(1), DMPDMN(NDIC), DMPDST(2*NPERDY), DIPDMM(NPERDY), G(NPERDY), AC(NPERDY), HD(NPERDY), DMFCST(2), D(NPERDY), RANS(MBO), H(NPERDY), HD(NPERDY), HD(NPERDY), Y(NDAYS*NPERDY+MBO), A(NDAYS*NPERDY+MBO), H(NPERDY), HD(NPERDY), HD(NPERDY), RCMAX(NVOLS), FLOWMN(NVOLS), PF(NDAYS*NPERDY, C(200), CF(200), VINST(9), STOCCAP(9), PUMPR(9), RCRAT(9), MBO.NGT.MBO, WHERE MBO IS THE MAX. BACKORDER OF MBO.NGT.MBO), WHERE MBO IS THE MAX. BACKORDER OF THE ARIMA MODEL.

UNITS EXPRESSED IN THIS PROGRAM ARE MG AND MGD. HOWEVER ANY VOLUMETRIC UNIT CAN BE SUBSTITUTED AS LONG AS VOLUMETRIC FLOWRATES ARE EXPRESSED IN THOSE UNITS PER DAY.
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FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          15/42/41
0034 READ (KR,102)
0035 READ (KR,110)
0036 READ (KR,110)
0037 READ (KR,110)
0038 READ (KR,110)
0039 READ (KR,110)
0040 READ (KR,110)
0041 NP=0
0042 DO 30 K=1,6
0043 NP=NP+INC(K)
0044 READ (KR,100)
0045 READ (KR,106)
0046 READ (KR,100)
0047 READ (KR,110)
0048 READ (KR,110)
0049 READ (KR,110)
0050 READ (KR,100)
0051 READ (KR,109)
0052 READC1=NDIC+1
0053 NDIC1=NDAYS+1
0054 NOH=NDAYS1*NPERDY
0055 IF (I*FF.EQ.0) GO TO 160
0056 READ (KR,100) MAX11,MBO
0057 GO TO 162
0058 NOB=NDAYS*NPERDY
0059 CALL ARIMA(IXS,RVAR,RMN,NTRANS,PA)
0060 MBON=MBO/NPERDY
0061 MBON=(MBO+1)*NPERDY
0062 IF (I*FF.EQ.0) GO TO 165
0063 READ (KR,112) (Z(I),I=1,NOB)
0064 PRINT 675, SERIES
0065 PRINT 687
0066 GO TO 597
0067 II=NTRANS+MBO-MBON-NPERDY
0068 DO 169 I=1,MBON
0069 II=I+1
0070 Z(I)=NTRANS+MBO-NPERDY
0071 DO 170 I=1,NOH
0072 II=I+1
0073 Y(I)=Y(II)
0074 DO 176 I=1,NPERDY
0075 II=I+1
0076 Y(II)=Y(I)
0077 DO 176 I=1,NPERDY
0078 D(I)=STSDDI/DIPDS(I)
0079 AC(I)=D(I)*DIPDM(I)
0080
0081
SERIES
(DMPDMN(I),I=1,NDIC)
(DMPDSD(I),I=1,NDIC)
(DIPDMN(I),I=1,NPERDY)
(DIPDSD(I),I=1,NPERDY)
STSDDI
NRD,NSD,NSEA,(INC(K),K=1,6)
(IOPA(K),K=1,NP)
(PA(K),K=1,NP)
(NTRANS,NDAYS,NVOLS)
RVAR,PMN
(STOCAP(K),K=1,NVOLS)
(VINST(K),K=1,NVOLS)
I*FF,ILGS
IXS

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```

00009480
00009490
00009500
00009510
00009520
00009530
00009540
00009550
00009560
00009570
00009580
00009590
00009600
00009610
00009620
00009630
00009640
00009650
00009660
00009670
00009680
00009690
00009700
00009710
00009720
00009730
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00009900
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00009930
00009940
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FOETRAN IV G LEVEL 21

DATE = 77065

MAIN

15/42/41

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0082 00009960
0083 00009970
0084 00009980
0085 00009990
0086 00010000
0087 00010010
0088 00010020
0089 00010030
0090 00010040
0091 00010050
0092 00010060
0093 00010070
0094 00010080
0095 00010090
0096 00010100
0097 00010110
0098 00010120
0099 00010130
0100 00010140
0101 00010150
0102 00010160
0103 00010170
0104 00010180
0105 00010190
0106 00010200
0107 00010210
0108 00010220
0109 00010230
0110 00010240
0111 00010250
0112 00010260
0113 00010270
0114 00010280
0115 00010290
0116 00010300
0117 00010310
0118 00010320
0119 00010330
0120 00010340
0121 00010350
0122 00010360
0123 00010370
0124 00010380
0125 00010390
0126 00010400
0127 00010410
0128 00010420
0129 00010430

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```

177  IF (NDOC.EQ.0) NDOC=NDIC
      IF (NDOC.GE.NDICI) NDOC=NDIC-NDIC
      IF (NDOC.GE.NDICI) GO TO 177
      AD=STSDDM/DMPSD(NDOC)
      ADD=AD*DHPDM(NDOC)
      DO 178 I=1,NPERDY
      JI=JI+1
      G(I)=Y(JI)+ADD*AC(I)
      AN=AN-AD/D(I)
      GN=GN-G(I)/D(I)
      DM=GN/AN
      IF (K.EQ.1) GO TO 179
      SUMY3=SUMY3+DM
      SUMY4=SUMY4+DM*DM
      DO 180 I=1,NPERDY
      KI=KI+1
      Y(KI)=(G(I)-AD*DM)/D(I)
      IF (K.EQ.1) GO TO 181
      SUMY2=SUMY2+Y(KI)*Y(KI)
      Y(KI)=Y(KI)+DM
      IF (Y(KI).LE.0) Y(KI)=0.01
      CONTINUE
      PRINT 675, SERIES
      PRINT 676, NDAYS, IXS
      IF (ILGS.EQ.0) GO TO 591
      NP1=NPERDY+1
      PRINT 677, (Y(I),I=NP1,NOH)
      PRINT 665
      PRINT 664
      LO=0
      SUMY2=SUMY2/NOH
      SUMY3=SUMY3/NDAYS1
      SUMY4=(SUMY4-NDAYS1*SUMY3*SUMY3)/NDAYS1
      SUM5=SUMY2+SUMY4
      PRINT 666, SUMY3, SUMY4, SUMY2, SUM5, IXS
      IF (LO.EQ.1) GO TO 599
      PRINT 667
      LO=1

```

FORTRAN IV G LEVEL 21 MAIN DATE = 77065 15/42/41

```

0130 SUMY2=0.0
0131 SUMY3=0.0
0132 SUMY4=0.0
0133 DO 909 K=2,NDAYS1
0134 JJ=(K-1)*NPERDY
0135 SUM=0.0
0136 DO 907 I=1,NPERDY
0137 JJ=JJ+1
0138 SUM=SUM+Y(JJ)
0139 DX=SUM/NPERDY
0140 SUMY3=SUMY3+DM
0141 SUMY4=SUMY4+DM*DM
0142 JJ=JJ-NPERDY
0143 DO 908 I=1,NPERDY
0144 JJ=JJ+1
0145 DMM=Y(JJ)-DM
0146 SUMY2=SUMY2+DMM*DMM
0147 CONTINUE
0148 GO TO 595
0149 DO 600 K=1,NVOLS
0150 FLOWMN(K)=0.0
0151 FCMAX(K)=0.0
0152 NOF(K)=0
0153 DO 601 I=1,NPERDY
0154 ZN(I)=Y(I)
0155 WOEIG=NOB
0156 NDOC=NDIC
0157 NINT=NPERDY
0158 MPEOB=0
0159 CALL FLOFST(999,NF,ZP,CLL,CUL,PA,NT,ZN,U,SCRATC,DMPDMM,DMPDSD,
+DIPDMN,DIPDSD,STOEST,DMPDST,DIFCST,H,NPERDY,D,G,AC)
0160 CALL OPER8(NPERDY,H,HD)
0161 KO=1
0162 JO=0
0163 YB=Y(NPERDY+1)
0164 DO 606 K=1,NVOLS
0165 PF(KO,K)=PUMPT(K)
0166 VINST(K)=VINST(K)+(YB+RCRATE(K)-PUMPT(K))/NPERDY
0167 IF(VINST(K).LE.STOCAP(K))GO TO 604
0168 PF(KO,K)=PF(KO,K)+(VINST(K)-STOCAP(K))*NPERDY
0169 NOF(K)=NOF(K)+1
0170 IF(VINST(K).GT.0.0)GO TO 606
0171 PF(KO,K)=PF(KO,K)+VINST(K)*NPERDY
0172 VINST(K)=0.0
0173 VINST(K)=0.0
0174 RCMAX(K)=AMAX1(RCMAX(K),RCRATE(K))
0175 CONTINUE
0176
0177
0178
0179
0180
0181
0182
0183
0184
0185
0186
0187
0188
0189
0190
0191
0192
0193
0194
0195
0196
0197
0198
0199
0200
0201
0202
0203
0204
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FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          15/42/41
0177      II=NPERDY
0178      DO 608 I=1,NOB
0179      II=I+1
0180      Z(I)=Z(II)
0181      MM=NPERDY
0182      DO 640 M=1,NDAYS
0183      NDOC=M
0184      IF (NDOC.GE.NDIC1) NDOC=NDOC-NDIC
0185      IF (NDOC.GE.NDIC1) GO TO 612
0186      DO 615 I=1,NPERDY
0187      ZN(I)=Y(MM+I)
0188      DO 622 I=1,NPERDY
0189      MM=MM+1
0190      IF (MM.EQ.NOH) GO TO 622
0191      NNTIN=I
0192      CALL FLOFST(999,NF,ZP,CLL,CUL,PA,NT,ZN,U,SCRATC,DMPDMN,DMPDSD,
+DIPDMN,DIG
NOB=NORIG
CALL OPER8(NPERDY,H,HD)
YB=Y(MM+1)
KO=KO+1
DO 620 K=1,NVOLS
PF(KO,K)=PUMPT(K)+(YB+RCFATE(K)-PUMPT(K))/NPERDY
VINST(K)=VINST(K)+(YB+RCFATE(K)-PUMPT(K))/NPERDY
IF (VINST(K).LE.STOCAP(K)) GO TO 618
PF(KO,K)=PF(KO,K)+(VINST(K)-STOCAP(K))*NPERDY
VINST(K)=STOCAP(K)
NPF(K)=NPF(K)+1
IF (VINST(K).GT.0.0) GO TO 620
PF(KO,K)=PF(KO,K)+VINST(K)*NPERDY
VINST(K)=0.0
VCMAX(K)=AMAX1(RCMAX(K),RCRATE(K))
CONTINUE
II=NPERDY
DO 625 I=1,NOB
II=I+1
Z(I)=Z(II)
DO 631 K=1,NVOLS
SUM=0.0
DO 627 I=1,NPERDY
SUM=SUM+PF(JO+I,K)
DM=SUM/NPERDY
FLOWN(K)=FLOWN(K)+DM
DO 629 I=1,NPERDY
PF(JO+I,K)=PF(JO+I,K)-DM
CONTINUE
JO=JO+NPERDY
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FORTRAN IV G LEVEL 21          MAIN          DATE = 77065          15/42/41
0224      PRINT 7677
0225      PRINT 675, SERIES
0226      PRINT 676
0227      AKO=KO
0228      DO 680 K=1, NVOLS
0229      CALL STNEX (KO, PF(1,K), AM, ASD)
0230      VARRED=(SUMY2-ASD*ASD)/SUMY2*100.
0231      FLOWM=FLOWM(K)/SUMY3/NDAYS
0232      ANOF=NOF(K)/AKO
0233      IF (IEC.EQ.0) RCMAX(K)=0.0
0234      PRINT 978, STOCAP(K), ANOF, RCMAX(K), FLOWM, ASD, VARRED
0235      PRINT 977
0236      CONTINUE
0237      STOP
0238      END
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APPENDIX B

COMPUTER PROGRAM SOURCE LISTINGS - SUBROUTINES

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TSFCST	236
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FORTRAN IV G LEVEL 21          ACCP          DATE = 77065          12/58/53
0001      SUBROUTINE ACOR(SERIES,Z,NOB,NAC,NPAC,NDF,RHO,SEE,F,SM,PHI,C) 00010000
C      UNIVERSITY OF WISCONSIN COMPUTING CENTER, BOX AND JENKINS ARIMA MODELLING
C      SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
0002      DIMENSION SERIES(20),Z(1),RHO(NAC,1),SEE(NAC,1),E(1),SM(1) 00010010
0003      DIMENSION PHI(NPAC,1),C(1),SAVE(7),TITLE(6) 00010020
0004      COMMON/ACPAR/HRD,NSD,NSEA,NAPL,NCHI,MCSE,ILDAC,IPDID,MPRINT,IWTPA, 00010030
+ IWIPSP 00010040
0005      DATA SAVE(1),SAVE(2),SAVE(3),SAVE(4),SAVE(5),SAVE(6),SAVE(7) /4HNR 00010050
+ D,4HNSD,4HNSEA,4HNPAC,4HNAC,4HNAPL,4HNCHI/ 00010060
0006      DATA TITLE(1),TITLE(2),TITLE(3),TITLE(4),TITLE(5),TITLE(6) /4HTHE 00010070
+ ,4HOBSE,4HRVED,4H SER,4HIES ,4H 00010080
C      J=0 00010090
0007      IF(NPAC .GE. 0) GO TO 81 00010100
0008      PRINT 64,SAVE(1),NRD 00010110
0009      PRINT 67,J 00010120
0010      NED=J 00010130
0011      IF(NSD .GE. 0) GO TO 84 00010140
0012      PRINT 64,SAVE(2),NSD 00010150
0013      PRINT 67,J 00010160
0014      KSD=J 00010170
0015      IF(NSEA .GE. 0) GO TO 87 00010180
0016      PRINT 64,SAVE(3),NSEA 00010190
0017      NSP=J 00010200
0018      IF(NPAC .GE. 0) GO TO 90 00010210
0019      PRINT 67,J 00010220
0020      IF(NPAC .GE. 0) GO TO 90 00010230
0021      PRINT 64,SAVE(4),NPAC 00010240
0022      PRINT 67,J 00010250
0023      NPAC=J 00010260
0024      IF(NAC .GT. 0) GO TO 71 00010270
0025      PRINT 64,SAVE(5),NAC 00010280
0026      PRINT 69 00010290
0027      IF(NCHI .LE. NAC) GO TO 72 00010300
0028      PRINT 64,SAVE(7),NCHI 00010310
0029      PRINT 67,NAC 00010320
0030      NCHI=NAC 00010330
0031      IF(NSEA .GE. 0) GO TO 76 00010340
0032      PRINT 64,SAVE(3),NSEA 00010350
0033      PRINT 67,NSD 00010360
0034      PRINT 69 00010370
0035      PRINT 69 00010380
0036      PRINT 69 00010390
0037      PRINT 69 00010400
0038      RETURN 00010410
0039      IF(MIN .GT. 0) GO TO 116 00010420
0040      PRINT 79,J,MIN 00010430
0041      PRINT 69 00010440
0042      PRINT 69 00010450

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FCRTRAN IV G LEVEL 21          ACOR          DATE = 77065          12/58/53
0042 RETURN
0043 IF(NAPL .GT. 0 .AND. NAPL .LE. 12) GO TO 118
0044 J=12
0045 PRINT 64,SAVE(6),NAPL
0046 PRINT 67,J
0047 NAPL=LDAC .EQ. 0) GO TO 125
0048 IF(JLE 119,SERIES,NOB
0049 PRINT 111
0050 PRINT 111,SERIES,NOB
0051 DO 122 I=1,NOB,8
0052 IHI=MINO(NOB,I+7)
0053 PRINT 123,I,IHI,(Z(J),J=I,IHI)
0054 IF(IPLDID .EQ. 0) GO TO 128
0055 CALL I PLOT (SERIES,Z,NOB,0,0,0,RMIN,RMAX,RMID,.80,TITLE)
0056 DO 128 J=1,NOB
0057 C(J)=Z(J)
0058 NOBD=NOB
0059 IF(NSD .EQ. 0) GO TO 3
0060 DO 2 I=1,NSD
0061 NOBD=NOB-NSEA
0062 DO 2 J=1,NOBD
0063 L=J+NSEA
0064 C(J)=C(L)-C(J)
0065 NRD1=NRD+1
0066 DO 16 I=1,NRD1
0067 IF(L=NOBD-1) GO TO 11
0068 MIN=NOBD-NAC
0069 MIP(MIN .GT. 0) GO TO 13
0070 LL=L-1
0071 PRINT 69
0072 PRINT 69
0073 DO 15 J=1,NOBD
0074 C(J)=C(J+1)-C(J)
0075 DIV=NOBD
0076 SUM=0.0
0077 DO 12 J=1,NOBD
0078 SUM=SUM+C(J)
0079 E(L)=SUM/DIV
0080 DENOM=CPRXY(C,E(L),C,F(L),NOBD)
0081 DO 14 K=1,K
0082 M=NOBD - K
0083 RHO(K,L)=CPRXY(C(I),E(L),C(K+1),E(L),M)/DENOM
0084 SM(L)=SQRT(DENOM/(DIV*(DIV-1.0)))
0085 IF(MCSE .EQ. 0) GO TO 27
0086 DO 24 L=1,NRD1
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FORTRAN IV G LEVEL 21          ACOE          DATE = 77065          12/58/53
0090  LL=L-NOB-LL
0091  DIV=L-1
0092  STEP(1,K)=2*REC
0093  STEP(K,L)=STEP(K-1,L)+2.0*RHO(K-1,L)**2
0094  STEP(1,L)=(1.0/DIV)**.5
0095  STEP(K,L)=(1.0/DIV)**.5
0096  DO 23 K=2,NAC
0097  SLE(K,L)=(STEP(K,L)/DIV)**.5
0098  CONTINUE
0099  IF(MPRINT-EO.0) GO TO 42
0100  MIN=XOB-NSEA
0101  PRINT 127
0102  PRINT 110, SERIES, NOB
0103  IF(NSD .GT. 0) PRINT 113, NSEA, NSD
0104  DO 40 L=1,NED1
0105  CALL PPLC(SERIES, RHO, NAC, E, SM, MIN, NAPL, STE, MCSE, L, 1, 1, C)
0106  PZ=ABS(E(L)/SM(L))
0107  PRINT 41, PZ
0108  IF(NDF .LE. 0) GO TO 40
0109  CHI=0.0
0110  DO 38 K=1, NCHI
0111  CHI=CHI+RHO(K,L)**2
0112  CHI=CHI*FLOAT(MIN)
0113  PRINT 43, CHI, NDF
0114  MIN=MIN-1
0115  IF(MINPA .EQ. 0) GO TO 53
0116  DO 47 L=1, NED1
0117  CALL PPLC(SERIES, RHO, NAC, E, SM, MIN, NAPL, STE, MCSE, L, 1, 2, C)
0118  IF(NPAC .EQ. 0) GO TO 96
0119  DO 58 L=1, NED1
0120  CALL PACOR(NPAC, PHI(1,L), NAC, RHO(1,L), C)
0121  IF(MPRINT-EO.0) GO TO 70
0122  MIN=XOB-NSEA*NSD
0123  PRINT 55
0124  PRINT 110, SERIES, NOB
0125  IF(NSD .GT. 0) PRINT 113, NSEA, NSD
0126  DO 68 L=1, NED1
0127  CALL PPLC(SERIES, PHI, NPAC, E, SM, MIN, NAPL, STE, 0, L, 2, 1, C)
0128  MIN=MIN-1
0129  IF(MINPA .EQ. 0) GO TO 96
0130  DO 75 L=1, NED1
0131  CALL PPLC(SERIES, PHI, NPAC, E, SM, MIN, NAPL, STE, 0, L, 2, 2, C)
0132  IF(IWCPSP .EQ. 0) GO TO 99
0133  XNOB=XNOB
0134  VAR=SM(1)*SM(1)*(XNOB-1.)
0135  DO 97 I=1, NAC
0136  RHO(I,1)=RHO(I,1)*VAR
0137  CALL SPECT(SERIES, RHO(1,1), NAC, VAR, XNOB)

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FORTRAN IV G LEVEL 21          ACOR          DATE = 77065          12/58/53
0138 CONTINUE          00011420
0139 RETURN          00011430
0140 C          00011440
0141 43          00011450
0142 64          00011460
0143 65          00011470
0144 67          00011480
0145 69          00011490
0146 73          00011500
0147 79          00011510
0148 110          00011520
0149 111          00011530
0150 113          00011540
0151 119          00011550
0152 123          00011560
0153 127          00011570
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//10X, 27HMEAN DIVIDED BY ST. ERROR = R12.5)
//10X, 54H TO TEST WHETHER THIS SERIES IS WHITE NOISE, THE VA
//10X, 51H SHOULD BE COMPARED WITH A CHI-SQUARE VARIABLE W
+LUE, E3, 19H DEGREES OF FREEDOM)
+FORMAT(//10X, 30H IN SUBROUTINE ACOR, THE VALUE ,A4, = , I4, 11H I
+S ILLLEGAL)
+FORMAT(//10X, 24HPARTIAL AUTOCORRELATIONS)
+FORMAT(//10X, 21H IT HAS BEEN RESET TO I4)
+FORMAT(//10X, 38H NO AUTOCORRELATIONS WILL BE CALCULATED)
+FORMAT(//10X, 22H THIS IS BECAUSE NSD = I4, 61H INDICATING THAT SEASON
+AL DIFFERENCE OF ORIGINAL DATA DESIRED)
+FORMAT(//10X, 61H THE EFFECTIVE NUMBER OF OBSERVATIONS FOR CALCULA
TION OF LAST I1, 31H DIFFERENCE AUTOCORRELATION IS , I4)
+FORMAT(//10X, 7H DATA - , 20A4, 5X, I5, 15, 13H OBSERVATIONS)
+FORMAT(//10X, 56HD DIFFERENCING - ORIGINAL SERIES IS YOUR DATA TIMES
+1-B**I2, 3H)** I2)
+FORMAT(//10X, 9X, 12H DATA LISTING)
+FORMAT(//10X, 14, 1H - , I4, 1X, 8E12.6)
+FORMAT(//10X, 9X, 16H AUTOCORRELATIONS)
END

```

FORTRAN IV G LEVEL 21 APIMA DATE = 77065 14/15/34 00012000
0001 SUBROUTINE ARIMA (IXS, RVAR, RMN, NTRANS, PA)

.....
GENERATES SERIES OF INDEPENDENT RANDOM NORMAL NUMBERS OF DESIRED MEAN AND
VARIANCE AND TRANSFORMS THEM TO STOCHASTIC TIME SERIES HAVING DESIRED ARIMA
MODEL CHARACTERISTICS. APIMA IS COMPATIBLE WITH THE BOX AND JENKINS ARIMA
MODEL SUBROUTINES.

DESCRIPTION OF PARAMETERS.
IXS - INPUT SEED NUMBER, 9 OR LESS DIGIT ODD INTEGER PROCESS.
RVAR - INPUT VARIANCE OF RANDOM NORMAL SHOCKS, USUALLY 0.0.
RMN - INPUT MEAN OF TRANSITIONAL ARIMA SERIES VALUES COMPUTED TO NULLIFY
NTRANS - INPUT NO. OF TRANSITIONAL ARIMA SERIES VALUES COMPUTED TO NULLIFY
EFFECT OF INITIALS SUGGESTED.
A - RESULTING SERIES OF RANDOM NORMAL SHOCKS, MUST BE DIMENSIONED
Y - IN CALLING PROGRAM TO AT LEAST HOB+NTRANS+MBO, MUST BE DIMENSIONED
NOB - IN CALLING PROGRAM TO AT LEAST NOB+NTRANS+MBO.
MBO - MAX. DESIRED NUMBER OF GENERATED VALUES.
MAX11 - INPUT BACKORDER OF ARIMA MODEL, COMPUTED IN ARIMA.
MPROB - CONSTANT COMPUTED IN ARIMA.
C, CF - NOT REQUIRED BY ARIMA.
PA, NP, NRD - MODEL WEIGHTING COEFFICIENTS DEFINED IN ARIMA.
INSD, NSEA, INC, IOPA - INPUT ARIMA MODEL PARAMETERS AS DEFINED
IN BOX AND JENKINS ARIMA SUBROUTINES.

.....
0002 DIMENSION PA (1), T (200), V (200) 00012010
0003 COMMON /TSPAR/ MAX11, MBO, NP, NOB, NRD, NSD, NSEA, INC (6), IOPA (1) 00012020
0004 COMMON /TSONE/ C (200), CF (200), MPROB 00012030
0005 COMMON /TSGEN/ Y (1) 00012040
0006 COMMON /TSRES/ A (1) 00012050
0007 MAX1=NRD+NSD*NSEA 00012060
0008 KK=INC (1) 00012070
0009 IF (INC (1).NE.0) MAX1=MAX1+IOPA (KK) 00012080
0010 KK=KK+INC (2) 00012090
0011 IF (INC (2).NE.0) MAX1=MAX1+IOPA (KK) 00012100
0012 MAX11=MAX1+1 00012110
0013 KK=KK+INC (3)+INC (4)+INC (5) 00012120
0014 MAX2=0 00012130
0015 IF (INC (5).NE.0) MAX2=IOPA (KK) 00012140
0016 IF (INC (6).NE.0) MAX2=MAX2+IOPA (NP) 00012150
0017 MBO=MAX0 (MAX1, MAX2) 00012160
0018 IF (MBO.LE.200.OR.MBO.GT.0) GO TO 5 00012170
.....
C

```

FORTRAN IV G LEVEL 21          ARIMA          DATE = 77065          14/15/34
0019      PRINT 110, MBO
0020      FORMAT(' IN SUBROUTINE ARIMA THE VALUE OF MBO =',I5,/, ' MAX ALLOWAB
+LE IS 200 AND MIN ALLOWABLE IS 1.,/')
0021      GO TO 180
0022      KK=INC(1)+INC(2)+INC(3)
0023      RMEAN=0.0
0024      IF (INC(3).NE.0) RMEAN=PA(KK)
0025      KK=KK+INC(4)
0026      CONST=0.0
0027      IP (INC(4).EQ.1) CONST=PA(KK)
0028      LDIF=NSD*NSEA+NRD
0029      DO 3 J=1, MBO
0030      T(J)=0.0
0031      CF(J)=0.0
0032      IF (LDIF.EQ.0) GO TO 43
0033      DO 13 I=1, MBO
0034      V(I)=0.0
0035      IF (NRD.EQ.0) GO TO 18
0036      EXPAND (1-B)**NRD AND STORE COEFFICIENTS IN C
0037
0038      DO 16 K=1, NSD
0039      C(K) = (-1)**K * NCHOSE(NRD,K)
0040      IF (NSD.EQ.0) GO TO 43
0041
0042      EXPAND (1-B**NSEA)**NSD AND STORE COEFFICIENTS IN T
0043      DO 21 K=1, NSD
0044      LOC=K*NSEA
0045      T(LOC) = (-1)**K * NCHOSE(NSD,K)
0046
0047      MULTIPLY TWO POLYNOMIALS TOGETHER AND STORE FINAL COEFFICIENTS IN
0048      MAX=NSEA*NSD
0049      DO 25 I=NSEA, MAX, NSEA
0050      V(I)=T(I)
0051      IF (NRD.EQ.0) GO TO 32
0052      DO 31 I=1, NRD
0053      V(I)=V(I)+C(I)
0054      DO 39 ISD=NSEA, MAX, NSEA
0055      LOC=ISD+IRD
0056      V(LOC)=V(LOC)+T(ISD)*C(IRD)
0057      DO 42 I=1, LDIF
0058      C(I)=V(I)
0059      T(I)=0.0
0060
0061      00012190
0062      00012200
0063      00012210
0064      00012220
0065      00012230
0066      00012240
0067      00012250
0068      00012260
0069      00012270
0070      00012280
0071      00012290
0072      00012300
0073      00012310
0074      00012320
0075      00012330
0076      00012340
0077      00012350
0078      00012360
0079      00012370
0080      00012380
0081      00012390
0082      00012400
0083      00012410
0084      00012420
0085      00012430
0086      00012440
0087      00012450
0088      00012460
0089      00012470
0090      00012480
0091      00012490
0092      00012500
0093      00012510
0094      00012520
0095      00012530
0096      00012540
0097      00012550
0098      00012560
0099      00012570
0100      00012580
0101      00012590
0102      00012600
0103      00012610
0104      00012620
0105      00012630
0106      00012640
0107      00012650
0108      00012660

```

FORTRAN IV G LEVEL 21 ARIMA DATE = 77065 14/15/34

```

00567 EXPAND MODEL. STORE AUTOREGRESSIVE COEFFICIENTS IN C, MOVING
00568 AVERAGE COEFFICIENTS IN CP.
00569 C
00570 C
00571 C
00572 C
00573 C
00574 C
00575 C
00576 C
00577 C
00578 C
00579 C
00580 C
00581 C
00582 C
00583 C
00584 C
00585 C
00586 C
00587 C
00588 C
00589 C
00590 C
00591 C
00592 C
00593 C
00594 C
00595 C
00596 C
00597 C
00598 C
00599 C
01000 C

MIN=1
MAX=0
DO 60 J=1,6
IF (INC(J).EQ.0) GO TO 60
MAX=MAX+INC(J)
GO TO (98,99,60,60,60,47,48),J
IF (LDIF) 105,105,105,105,99,99,47,48,J
DO 101 I=1,LDIF
T(I)=C(I)
DO 115 M=MIN,MAX
K=IOPA(M)
PTEM=PA(K)
T(K)=T(K)-PTEM
IF (LDIF.EQ.0) GO TO 115
DO 113 I=1,LDIF
KI=K+I
T(KI)=T(KI)-C(I)*PTEM
CONTINUE
LDIF=LDIF+K
DO 120 I=1,LDIF
C(I)=T(I)
T(I)=0.0
GO TO 60
DO 130 M=MIN,MAX
K=IOPA(M)
T(K)=-PA(M)
CF(K)=T(K)
MDIF=K
GO TO 60
IF (INC(5).EQ.0) GO TO 47
DO 140 M=MIN,MAX
K=IOPA(M)
PTEM=PA(M)
CF(K)=CF(K)-PTEM
DO 140 I=1,MDIF
KI=K+I
CF(KI)=CF(KI)-T(I)*PTEM
MIN=MIN+INC(J)
DO 66 J=1,MBO
CF(J)=-CF(J)
C(J)=-C(J)
IX=IXS
RSD=SQRT(RVAR)
DO 160 I=1,MBO
CALL GAUSSM(IX,RSD,RMN,A(I))

```

000112670
000112680
000112690
000112700
000112710
000112720
000112730
000112740
000112750
000112760
000112770
000112780
000112790
000112800
000112810
000112820
000112830
000112840
000112850
000112860
000112870
000112880
000112890
000112900
000112910
000112920
000112930
000112940
000112950
000112960
000112970
000112980
000112990
00013000
00013010
00013020
00013030
00013040
00013050
00013060
00013070
00013080
00013090
00013100
00013110
00013120
00013130
00013140

```

0101  FORTRAN IV G LEVEL 21          APIMA          DATE = 77065          14/15/34
0102  160          Y(I)=A(I)
0103  NN=MBO+NERANS+NOB          00013150
0104  MBO1=MBO+1          00013160
0105  DO 168 I=MBO1,NN          00013170
0106  CALL GAUSSM(IX,RSD,RMN,A(I))          00013180
0107  YC=CCNST          00013190
0108  DO 166 J=1,MBO          00013200
0109  KJ=I-J          00013210
0110  YC=YC+C(J)*Y(KJ)-CF(J)*A(KJ)          00013220
0111  Y(I)=YC+A(I)+RMEAN          00013230
0112  RETURN          00013240
          END          00013250
          00013260

```



```

FORTRAN IV G LEVEL 21          CPCST          DATE = 77065          14/14/31
0001 SUBROUTINE CFCST (NF, ZP, PA, E)
0002 DIMENSION PA (1), ZP (1, 1), R (1)
0003 INTEGER FF
0004 COMMON /TSRES/ A (1)
0005 COMMON /TSOBS/ Z (1)
0006 COMMON /ISPAC/ MAX11, MBO, MP, NOB, NRD, NSD, NSEA, INC (6), IOPA (1)
0007 COMMON /TSONE/ C (200), CF (200), MPROB
0008 COMMON /TSAVER/ RMEAN, CONST
0009 FF=NOB+1
0010 LF=NOB+NF
0011 MAX1=MAX11-1
0012 NNR=NOB-MAX1
0013 IF (MAX1.EQ.0) GO TO 10
0014 DO 9 J=1, MAX1
0015 A (J)=0.0
0016 DO 11 J=FF, LF
0017 A (J)=0.0
0018 CALL TSMOD (999, PA, R, NDR)
0019 IF (INC (3).EQ.6) GO TO 51
0020 DO 4 J=1, NOB
0021 Z (J)=Z (J)-RMEAN
0022 DO 5 J=1, NOB
0023 A (K)=0.0
0024 Z (K)=CONST
0025 DO 54 J=1, MBO
0026 KJ=K-J
0027 Z (K)=Z (K)+C (J)*Z (KJ)-CF (J)*A (KJ)
0028 CONTINUE
0029 DO 62 J=FF, LF
0030 Z (J)=Z (J)+RMEAN
0031 L=J+1-FF
0032 ZP (L, 1)=Z (J)
0033 DO 144 I=1, NOB
0034 Z (I)=Z (I)+RMEAN
0035 RETURN
0036 END

```

```

00014000
00014010
00014020
00014030
00014040
00014050
00014060
00014070
00014080
00014090
00014100
00014110
00014120
00014130
00014140
00014150
00014160
00014170
00014180
00014190
00014200
00014210
00014220
00014230
00014240
00014250
00014260
00014270
00014280
00014290
00014300
00014310
00014320
00014330
00014340
00014350
00014360

```

C

9

11

48

51

54

58

62

144

```

FORTRAN IV G LEVEL 21          DIST          DATE = 77065          14/13/50          00015000
0001          SUBROUTINE DISI(N,K,X)

```

```

C.....
SUBROUTINE TO COMPUTE THE PROBABILITY DENSITY FUNCTION, CUMULATIVE
PROBABILITY DISTRIBUTION AND PERFORM THE CHI-SQUARE AND KOIMOGOROV-
SMIRNOV TESTS AGAINST A NORMAL AND A LOGNORMAL DISTRIBUTION.
ADAPTED FROM KITE, G., 'CRUSTAL MOVEMENT AROUND THE GREAT LAKES',
PH.D. THESIS, U. OF OTTAWA, 1972.
DESCRIPTION OF PARAMETERS.
X - INPUT SUBJECT ARRAY. VALUES IN THE SUBJECT ARRAY X, MUST BE AN ODD
N - INPUT NUMBER OF CLASS INTERVALS TO BE USED, I.E. IS 0, THEN K WILL BE
K - INTEGER, IF K IS NOT SPECIFIED (I.E. IS 0), THEN K WILL BE
   COMPUTED USING A SIMPLIFIED VERSION OF EQUATION 30.72
   PAGE 433, THE ADVANCE IN THEORY OF STATISTICS, VOL. 2,
   KENDALL AND STUART, 1961.
TITLE - INPUT CHARACTER TITLE. 20 - 4 BYTE WORDS.
A - INPUT INTEGER INSTALLATION CODE FOR LINE PRINTER.
TITLE1 - NOT REQUIRED BY DIST.
C.....

```

```

0002          INTEGER A.....
0003          COMMON /BK/ TITLE(20), A, TITLE1(20).....
0004          DIMENSION Y(100), Z(100), DEL(100), POS(100), W(100), D(100), S(100), X(100).....
C.....
0005          XN=N.....
0006          XBAR=0.0.....
0007          STDV=0.0.....
0008          CALL STANDX(N,X,XBAR,STDV).....
0009          IF (K.GT.0) GO TO 20.....
0010          IF (N.LT.450) GO TO 10.....
0011          K=2.0*(0.8622*(N-1))*0.4.....
0012          K=K*2-1.....
0013          IF (K.GE.100) K=99.....
0014          GO TO 20.....
0015          K=15.....
0016          CONTINUE.....
0017          XK=K.....
0018          KH=K/2.....
0019          ZXXK=1.0/XK.....
0020          C0=2.515517.....
0021          C1=0.802853.....
0022          C2=0.010328.....

```

```

PORTRAN IV G LEVEL 21          DIST          DATE = 77065          14/13/50
0023  D1=1.432788
0024  D2=0.189269
0025  D3=0.001308
0026  DO 30 J=1,KH
0027  XJ=J
0028  O=XJ*AXK
0029  B=1.0/O**2
0030  B=SQRT(ALOG(B))
0031  C=R-(C0+C1*B+C2*B**2)/(1.0+D1*B+D2*B**2+D3*B**3)
0032  Z(J)=C
0033  CONTINUE
0034  KH1=KH+1
0035  KH2=K-1
0036  JJ=KH
0037  DO 40 J=KH1,KH2
0038  Z(J)=Z(JJ)
0039  JJ=JJ-1
0040  CONTINUE
0041  DO 50 J=1,KH
0042  Z(J)=-Z(J),KH2
0043  DO 60 J=1,KH2
0044  S(J)=Z(J)
0045  S(J)=XBAE+Z(J)*STDX
0046  CONTINUE
0047  DO 80 J=1,KH2
0048  Y(J)=0.0
0049  DO 70 I=1,N
0050  IF (X(I).LE.Z(J)) Y(J)=Y(J)+1.0
0051  CONTINUE
0052  CONTINUE
0053  Y(K)=XN
0054  WRITE (A,280) TITLE
0055  WRITE (A,310)
0056  WRITE (A,300)
0057  WRITE (A,320)
0058  DO 90 J=1,K
0059  W(J)=Y(J)*100.0/XN
0060  DO 100 J=1,KH2
0061  IF (J.EQ.40) WRITE (A,280)
0062  IF (J.EQ.80) WRITE (A,280)
0063  WRITE (A,330) Z(J),W(J)
0064  DEL(1)=W(1),KH2
0065  DO 110 J=2,KH2
0066  DEL(J)=W(J)-W(J-1)
0067  POS(J)=(Z(J)+Z(J-1))/2.0
0068  CONTINUE
0069  DEL(K)=100.-W(KH2)
0070  WRITE (A,280)
0071
0001 15240
0002 15250
0003 15260
0004 15270
0005 15280
0006 15290
0007 15300
0008 15310
0009 15320
0010 15330
0011 15340
0012 15350
0013 15360
0014 15370
0015 15380
0016 15390
0017 15400
0018 15410
0019 15420
0020 15430
0021 15440
0022 15450
0023 15460
0024 15470
0025 15480
0026 15490
0027 15500
0028 15510
0029 15520
0030 15530
0031 15540
0032 15550
0033 15560
0034 15570
0035 15580
0036 15590
0037 15600
0038 15610
0039 15620
0040 15630
0041 15640
0042 15650
0043 15660
0044 15670
0045 15680
0046 15690
0047 15700
0048 15710

```

```

FORTRAN IV G LEVEL 21          DIST          DATE = 77065          14/13/50
0071 WRITE (A,310) TITLE          00015720
0072 WRITE (A,340)          00015730
0073 WRITE (A,350)          00015740
0074 WRITE (A,360) Z(1),DEL(1) 00015750
0075 DO 120 J=2,KH2          00015760
0076 IF (J.EQ.40) WRITE (A,280) 00015770
0077 IF (J.EQ.80) WRITE (A,280) 00015780
0078 WRITE (A,370) Z(J-1),Z(J),POS(J),DEL(J) 00015790
0079 CONTINUE          00015800
0080 WRITE (A,380) Z(KH2),DEL(K) 00015810
0081 SUM=0.0          00015820
0082 DO 130 J=1,K          00015830
0083 DEL(J)=(DEL(J)*XN)/100.0 00015840
0084 SUM=SUM+DEL(J)**2 00015850
0085 CONTINUE          00015860
0086 CHI=((XK/XN)*SUM)-XN 00015870
0087 IDF=K-3          00015880
0088 DO 140 J=1,K          00015890
0089 XJ=J          00015900
0090 W(J)=W(J)/100.0 00015910
0091 G=XJ/XK          00015920
0092 F=W(J)-G          00015930
0093 D(J)=ABS(F)          00015940
0094 CONTINUE          00015950
0095 CALL SORTX(K,D)          00015960
0096 SK=D(1)          00015970
0097 WRITE (A,280)          00015980
0098 WRITE (A,400)          00015990
0099 WRITE (A,310) TITLE IDF,SK,N 00016000
0100 WRITE (A,390) CHI,STDY 00016010
0101 WRITE (A,410) XBAR,STDX 00016020
0102 CHECK IF NEGATIVE VALUE EXISTS IN THE ARRAY X. 00016030
C DO 150 I=1,N          00016040
150 IF (X(I).LT.0.0) GO TO 180 00016050
C CONTINUE          00016060
C CHECK IF THE SMALLEST VALUE IS ZERO, IF SO, REPLACE IT WITH 0.0001 00016070
DO 170 I=1,N          00016080
170 IF (X(I).EQ.0.0) GO TO 160 00016090
X(I)=0.0001          00016100
CONTINUE          00016110
GO TO 210          00016120
C FIND THE LARGEST NEGATIVE NUMBER IN THE ARRAY. 00016130
SMALL=0.0          00016140
DO 190 I=1,N          00016150
190 IF (X(I).LT.SMALL) SMALL=X(I) 00016160
CONTINUE          00016170
          00016180
          00016190

```

```

PORTRAN IV G LEVEL 21          DIST          DATE = 77065          14/13/50
0116 WRITE (A,440) SMALL
0117 SMALL=ABS(SMALL)
0118 DO 200 I=1,N
0119 X(I)=X(I)+SMALL
0120 IF (X(I).EQ.0.0) X(I)=0.0001
0121 X(I)=ALOG(X(I))
0122 CONTINUE
0123 GO TO 230
0124 DO 220 I=1,N
0125 X(I)=ALOG(X(I))
0126 CONTINUE
0127 CALL STANDX(N,X,XBAR,STDY)
0128 DO 240 J=1,KH2
0129 Z(J)=(XBAR+S(J)*STDY)
0130 DO 250 J=1,KH2
0131 Y(J)=0.0
0132 DO 250 I=1,N
0133 IF (X(I).LE.Z(J)) Y(J)=Y(J)+1.0
0134 CONTINUE
0135 Y(K)=XN
0136 DO 260 J=1,K
0137 XJ=J
0138 W(J)=Y(J)/XN
0139 G=XJ/XK
0140 F=W(J)-G
0141 D(J)=ABS(F)
0142 CALL SORTX(K,D)
0143 SK=D(1)
0144 W(1)=Y(1)*2
0145 SUM=W(1)*2
0146 DO 270 J=2,K
0147 W(J)=Y(J)-Y(J-1)
0148 SUM=SUM+W(J)*2
0149 CHI=((XK/XN)*SUM)-XN
0150 WRITE (A,420) CHI,IDF,SK,N
0151 RETURN
0152
C
0153 FORMAT(1H1)
0154 FORMAT(15X,////,CUMULATIVE PROBABILITY DISTRIBUTION OF A ,
0155 +,TIME SERIES,///)
0156 FORMAT(9X,20A4,21X,'PERCENT PROBABILITY',//,
0157 +46X,'OBTAINING THE LESS THAN OR',//,
0158 +46X,'EQUAL TO Z',//,
0159 FORMAT(19X,E10.4,22X,E10.4)

```

```

00016200
00016210
00016220
00016230
00016240
00016250
00016260
00016270
00016280
00016290
00016300
00016310
00016320
00016330
00016340
00016350
00016360
00016370
00016380
00016390
00016400
00016410
00016420
00016430
00016440
00016450
00016460
00016470
00016480
00016490
00016500
00016510
00016520
00016530
00016540
00016550
00016560
00016570
00016580
00016590
00016600
00016610
00016620
00016630
00016640
00016650
00016660
00016670

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FOURFRAN IV G LEVEL 21          ESTIM          DATE = 77065          12/59/42          00017000
SURROUTINE ISIY(NPROB, PA, BHO, SRE, E, SM, PHI, NAC, NPAC, SCRATC) 00017000
UNIVERSITY OF WISCONSIN COMPUTING CENTER, BOX 480, JENKINS ARIMA MODELLING
SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
DIMENSION PA(1), BHO(NAC, 1), STI(NAC, 1), PHI(NPAC, 1), SCRATC(1), E(1)
COMMON /SRES/ A(1), SW(4), TTILE(6), DITE(9), RESTIT(20), GTIT(6)
COMMON /ISORS/ Z(1)
COMMON /ISPAR/ MAX(11), MBO, MRD, MSD, MSEA, INC(6), IOPA(1)
COMMON /SERIES/ SER(1), EPS2, MIT, NDIMS, NLOG, IPDFT, IPPES, ILRES, IRPNCH
COMMON /PARAMS/ EPAR(1), NRDAC, KCHI, MCSE, NAPI, INTDPA, INTDSP
COMMON /DCPAR/ N1, NNSDAC, N4, N2, N3, ILDAC, IPDID, MPRINT, N5, N6
COMMON /ACPAR/ N1, NNSDAC
COMMON /HAY/ LTPES
COMMON /HUNCH/ KPUNCH
DATA PLAM, ENU / .10, 10.0 /
DATA TTILE(1), SW(2), SW(3), SW(4), TITLE(3) /4H OBSV, 4H HRVED, 4H SER, 4H SER/
DATA SW(1), SW(2), SW(3), SW(4), HIES, 4H HIES, 4H HIES, 4H HIES /
DATA RESTIT(1), RESTIT(2), RESTIT(3), RESTIT(4), RESTIT(5), RESTIT(6), RESTIT(7), RESTIT(8) /4H TIT, 4H TIT, 4H TIT, 4H TIT, 4H TIT, 4H TIT, 4H TIT, 4H TIT /
+ M, 4H HODIT /
DATA DTIT(1), DTIT(2), DTIT(3), DTIT(4), DTIT(5), DTIT(6), DTIT(7), DTIT(8) /4H 1, 4H 2, 4H 3, 4H 4, 4H 5, 4H 6, 4H 7, 4H 8 /
+ 8), DTIT(9) /4H 1, 4H 2, 4H 3, 4H 4, 4H 5, 4H 6, 4H 7, 4H 8 /
+ 4H 9
DATA GTIT(1), GTIT(2), GTIT(3) /4H RESI, 4H DUAL, 4H S /
NSDAC=0
NSEAAC=0
ILDAC=0
IPDID=0
MPRINT=1
N1=NRDAC
N2=MCSE
N3=NAPI
N4=NINTDPA
N5=INTDSP
LTPES=ILRES
*****
IMPORTANT CHANGE -- NOB IS LENGTH OF SERIES
NDR IS NUMBER OF OBSERVATIONS USED IN ESTIMATION
(I.E. NOB ADJUSTED FOR DIFFERENCING)
*****
CALL PRACHK (NPROB, NDR, MAX1, PA, 1, SCRATC, 1)
00017450

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```

FORTRAN IV G LEVEL 21          ESTIM          DATE = 77065          12/59/42
0032 IF (MAX11.EQ.(-1)) RETURN
0033 IZ=7*NP+NP*NP+2*NOB+NP*NOB
0034 IE (NDIMS,GE,NSIZE) GO TO 3
0035 PRINT 10001,NDIMS,NSIZE
0036 GO TO 89
0037 IF(NP.GE.1.AND.NP.LE.50) GO TO 40
0038 PRINT 2
0039 GO TO 89
0040 IF(MIT.EQ.1.AND.MIT.LE.999) GO TO 50
0041 ITEMP=50
0042 PRINT 42,MIT,ITEMP
0043 ITEMP=ITEMP
0044 IE(NDR.NP).GT.0) GO TO 55
0045 PRINT 53,NP,NDR
0046 GO TO 89
0047 TEME=10
0048 DO 5 I=1, NP
0049 IF (ABS(PA(I)).GT. 1.E-05) GO TO 5
0050 PRINT 10000,I,TEMP
0051 PA(I)=TEMP
0052 CONTINUE
0053
0054
0055
0056
0057
0058
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0060
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0075

THE FIRST NP LOCATIONS OF SCRATIC ARE USED FOR THE ARRAY 'DIFF'. RE-
QUIRED BY UWHAUS, THE SECOND NP FOR 'SIGNS' REQUIRED BY UWHAUS.
DO 7 J=1,2
JJ=J-1
M=I+JJ*NP
SCRATIC(M)=.01+FLOAT(JJ)*(-.01)
IF(NLOG.EQ.0) GO TO 10
DO 8 J=1,NOB
IF(Z(J).LE..0000) GO TO 300
GO TO 10
PRINT 305
GO TO 89
DO 12 J=1,MAX1
A(J)=0.0
IF(IPDES.EQ.0) GO TO 14
ITITLE(4)=SW(2)
ITITLE(5)=SW(3)
ITITLE(6)=SW(4)
ITITLE(3)=SW(1)
ITITLE(5)=SW(0)
ITITLE(4)=SW(3)
ITITLE(5)=SW(4)
ITITLE(6)=SW(2)

```

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FORTRAN IV G LEVEL 21          ESTIM          DATE = 77065          12/59/42
0117 83  FORMAT(7E11,4,I3)          00018420
0118 305  FORMAT(////10X,52HLOG OF DATA REQUESTED, BUT SOME DATA POINTS NEGA 00018430
      +LIVE)          00018440
0119 10000  FORMAT(////10X,53HIN SUBROUTINE ESTIM, THE INITIAL GUESS FOR PAPAM 00018450
      +ETER,12,10X,51HWAS ZERO. IT HAS BEEN RESET TO P3,2) 00018460
0120 10001  FORMAT(////10X,59HIN SUBROUTINE ESTIM, THE DIMENSION OF THE 00018470
      +H ARRAY WAS, I7,10X,26HWHILE THE REQUIRED SIZE IS,I7) 00018480
0121  END          00018490
```

FORTRAN IV G LEVEL 21 FCHEK DATE = 77065 14/14/31
 0001 SUBROUTINE FCHEK(ZP, CLL, CUL, PA, NZ, U, SCRAFC, DMPDMS, DMPDSD, 00019000
 +DIPDMN, DIPDSD, STOEST, DMFCST, DMFCST, H, NPERDY, D, G, AC, FEQ, X, KKK) 00019010

.....
 SUBROUTINE TO COMPUTE FLOWRATE FORECAST ERRORS FOR ALL LFAD TIMES UP TO
 24 HOURS, AND THEIR STATISTICS AND FREQUENCY DISTRIBUTIONS.
 THIS SUBROUTINE IS USED WITH THE FLOWRATE FORECASTING CHECKING MAIN PROGRAM.
 DESCRIPTION OF PARAMETERS... SEE FLOWRATE FORECASTING CHECKING MAIN PROGRAM.

0002 DIMENSION ZN(1), ZP(1, 1), CLL(1, 1), CUL(1, 1), U(1), PA(1), NT(1) 00019020
 0003 DIMENSION SCRAFC(1), DMPDSD(1), DIPDMN(1), DIPDSD(1), STOEST(1), 00019030
 0004 +DMFCST(1), DMFCST(1), D(1), G(1), AC(1) 00019040
 0005 DIMENSION H(1), GTIT(6) 00019050
 0006 DIMENSION FREQ(100, NPERDY), BOUND(100), FINV(100), X(KKK, NPERDY) 00019060
 0007 COMMON // FLACS, NDAYO, NDAYCK, Y(1) 00019070
 0008 COMMON // KLMES, SERIES(20) 00019080
 0009 COMMON // NDIC, NDOC, NTINT, STSDDM, STSDDI 00019090
 0010 COMMON // TSRES, A(1) 00019100
 0011 COMMON // TSORS, Z(1) 00019110
 0012 COMMON // TSONE, C(200) 00019120
 0013 COMMON // TSPAL, MAX11, MBO, NP, NOB, NRD, NSD, NSEA, INC(6), IOPA(1) 00019130
 0014 COMMON // TSAVE, RMHEAN, CONST 00019140
 0015 COMMON // BK, TITLE(20), LPR, TITLE1(20) 00019150
 0016 COMMON // SS, S(1) 00019160
 0017 DATA GTIT(2), GTIT(3), GTIT(4), GTIT(5), GTIT(6) /4HPDS, 4HAHEA, 4HD FC 00019170
 +, 4HST E, 4HRRCE/ 00019180
 0018 00019190
 0019 00019200

FORMAT(14X, I3, 3X, 2E15.4) 00019210
 FORMAT(14X, I3, 3X, 2E15.4) 00019220
 +, E15.4, //, 6A4, //, PROBABILITY DENSITY DISTRIBUTION 00019230
 +, E15.4, //, 5X, CLASS WIDTH =, E15.4, //, 5X, LOWER BOUND = 00019240
 +, E15.4, //, 5X, UPPER BOUND =, E15.4, //, 5X, IN THE UNITS OF THE FORECAS 00019250
 +, ED VARIABLE: //, 10X, CLASS NO. CLASS LOW PT. REL FREQUENCY, // 00019260
 FORMAT(14X, I3, 3X, 2E15.4) 00019270
 +, E15.4, //, 5X, 8E12.4, //, 5X, 8E12.4) 00019280
 +, E15.4, //, 5X, 8E12.4, //, 5X, 8E12.4) 00019290
 +, E15.4, //, 5X, 8E12.4, //, 5X, 8E12.4) 00019300
 +, E15.4, //, 5X, 8E12.4, //, 5X, 8E12.4) 00019310
 +, E15.4, //, 5X, 8E12.4, //, 5X, 8E12.4) 00019320
 +, E15.4, //, 5X, 8E12.4, //, 5X, 8E12.4) 00019330
 +, E15.4, //, 5X, 8E12.4, //, 5X, 8E12.4) 00019340
 +, E15.4, //, 5X, 8E12.4, //, 5X, 8E12.4) 00019350

0023 NORIG=NOB 00019360
 0024 NDB=NOB/NPERDY 00019370
 0025 ND1=NDAYO-NDB 00019380
 0026 IF (ND1.LT.1) ND1=NDIC+ND1 00019390
 0027 IF (ND1.LT.1) GO TO 241 00019400

FORTRAN IV G LEVEL 21 FCHEK DATE = 77065 14/14/31

```

0028 JJ=0
0029 KK=0
0030 DO 250 J=1,NDB
0031 SUM=0.
0032 DO 246 I=1,NPERDY
0033 JJ=JJ+1
0034 SUM=SUM+Z(JJ)
0035 DM=SUM/NPERDY
0036 DMSTO=(DM-DMPDMN(ND1))/DMPDSD(ND1)*STSDDM
0037 DO 248 I=1,NPERDY
0038 KK=KK+1
0039 Z(KK)=DMSTO+(Z(KK)-DM-DIPDMN(I))/DIPDSD(I)*STSDDI
0040 ND1=ND1+1
0041 IF (ND1.EQ.NDIC+1) ND1=1
0042 DO 298 I=1,20
0043 TITLE(I)=SERIES(I)
0044 DO 299 I=16,20
0045 TITLE(I)=GIT(I-14)
0046 MAX1=NRD+NSD*NSEA
0047 KK=IKC(1)
0048 IF (INC(1).NE.0) MAX1=MAX1+IOPA(KK)
0049 KK=KK+INC(2)
0050 IF (INC(2).NE.0) MAX1=MAX1+IOPA(KK)
0051 MAX1=MAX1+1
0052 KK=KK+INC(3)+INC(4)+INC(5)
0053 MAX2=0
0054 IF (INC(5).NE.0) MAX2=IOPA(KK)
0055 IF (INC(6).NE.0) MAX2=MAX2+IOPA(NP)
0056 MBO=MAX0(MAX1,MAX2)
0057 KK=INC(1)+INC(2)+INC(3)
0058 RMEAN=0.0
0059 IF (INC(3).NE.0) RMEAN=PA(KK)
0060 KK=KK+INC(4)
0061 CONST=0.0
0062 IF (INC(4).EQ.1) CONST=PA(KK)
0063 NDOC=NDAY0
0064 NTINT=NPERDY
0065 MN=2*NPERDY
0066 MPROB=0
0067 CALL FLOEST(999,NE,ZP,CLI,CUL,PA,NT,ZN,U,SCRATC,DMPDMN,DMPDSD,
0068 +DIPDMN,DIPDSD,STOEST,DMFCST,DIFCST,H,NPERDY,D,G,AC)
0069 NOB=NOB+IG
0070 II=NPERDY
0071 DO 306 I=1,NOB
0072 II=II+1
0073 Z(I)=Z(II)
0074 MM=0

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306

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POFTRAN IV G LEVEL 21          FCHEK          DATE = 77065          14/14/31
0075 DO 410 M=1, NDAYCK          00019840
0076 NDCC=NDAYO+N              00019850
0077 IF (NDCC.GE.NDICI1) NDCC=NDCC-NDIC 00019860
0078 DO 310 K=1, NPERDY GO TO 308      00019870
0079 ZN(K)=Y(MX+K)           00019880
0080 DO 406 I=1, NPERDY          00019890
0081 MM=MM+1                  00019900
0082 NT=NT+1                  00019910
0083 CALL FLOFSI(999,NF,ZP,CLL,CUL,PA,NT,ZN,U,SCRATC,DMPDMN,DMPDSD, 00019920
0084 +DIPDMN,DIPDSD,SFOEST,DMFCST,DIFCST,H,NPERDY,D,G,AC) 00019930
0085 RCB=NOZIG                 00019940
0086 DO 404 J=1, NPERDY          00019950
0087 X(MM+J)=H(J)             00019960
0088 CCONTINUE                 00019970
0089 II=NPERDY                 00019980
0090 DO 408 I=1, NOB           00019990
0091 II=II+1                   00020000
0092 Z(II)=Z(II)              00020010
0093 CONTINUE                  00020020
0094 KK=KKK-NPERDY           00020030
0095 AKK=KK                    00020040
0096 DO 420 I=1, NPERDY          00020050
0097 J=I                         00020060
0098 DO 418 K=1, KK            00020070
0099 X(K,I)=X(K,I)-Y(J)        00020080
0100 CCONTINUE                 00020090
0101 PRINT 501, NPERDY         00020100
0102 PRINT 113, NPERDY         00020110
0103 DO 421 I=1, KK           00020120
0104 PRINT 114, I, X(I,J), J=1, NPERDY 00020130
0105 NINTS=2.0*(6.8622*(KK-1))*0.4 00020140
0106 IF (NINTS.GT.1)          00020150
0107 NINTS=NINTS               00020160
0108 IF (NINTS.GT.100) NINTS=100 00020170
0109 ANI=NINTS                 00020180
0110 ANI=NINTS-1               00020190
0111 BOUND0=0.0                00020200
0112 BOUND1=0.0                00020210
0113 DO 454 I=1, NPERDY       00020220
0114 CALL SORTX(KK,X(1,I))    00020230
0115 BOUND0=AMAX1(BOUND0,X(1,I)) 00020240
0116 BOUND1=AMIN1(BOUND1,X(KK,I)) 00020250
0117 CWIDTH=(BOUND0-BOUND1)/ANI 00020260
0118 DO 456 I=1, NI           00020270
0119 AI=I                        00020280
0120 BOUND(I)=BOUND0-AI*CWIDTH 00020290
0121 BOUND(NINTS)=BOUND1      00020300
                                00020310

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FORTRAN IV G LEVEL 21          FCHEK          DATE = 77065          14/14/31
0122 DO 460 I=1,NPERDY          00020320
0123 DO 458 J=1,NINTS          00020330
0124 FREQ(J,I)=0.             00020340
0125 CONV=INUE              00020350
0126 FMAX=0.                00020360
0127 DO 466 I=1,NPERDY     00020370
0128 J=1                     00020380
0129 DO 465 K=1,KK          00020390
0130 IF (X(K,I)-GE. BOUND(J)) GO TO 465
0131 IF (FREQ(J,I)-FMAX) 464,464,463
0132 FMAX=FREQ(J,I)
0133 J=J+1
0134 GO TO 461
0135 FREQ(J,I)=FREQ(J,I)+1.0
0136 IF (FREQ(J,I).GT.FMAX) FMAX=FREQ(J,I)
0137 KFMAX=(FMAX/AKK)*10.0
0138 FMAX=(KFMAX+1.0)/10.
0139 DO 470 I=1,NPERDY
0140 J=NINTS
0141 DO 468 K=1,NINTS
0142 FINV(J)=FREQ(K,I)/AKK
0143 J=J-1
0144 GTITLE(1)=S(I)
0145 GTITLE(15)=GFIT(1)
0146 PRINT 501,TITLE
0147 PRINT 502,(GLIE(K),K=1,6),CWIDTH,BOUND1,BOUND0
0148 JJ=NINTS
0149 DO 469 K=1,NINTS
0150 PRINT 503,K,BOUND(JJ),FINV(K)
0151 JJ=JJ-1
0152 CALL HOPEN(KK X(1,I))
0153 CALL PLOT(SERIES,FINV,NINTS,0,1,0,0.0,FMAX,RMID,DUM,GFIT)
0154 RETURN
0155 END

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00020650

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0001
FORTRAN IV G LEVEL 21          FLOPST          DATE = 77065          14/14/31
SUBROUTINE FLOPST(NPROB,NF,ZP,CLL,CUL,PA,NT,ZN,U,SCRATC,DMPDMN,      00021000
+DMPDSD,DIPDMN,DIPDSD,SIOEST,DIFCST,H,NPERDY,D,G,AC)      00021010

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.....
FLOWRATE FORECASTING PROGRAM COMBINING PERIODIC AND STOCHASTIC COMPONENTS
AND COMPUTING 24 HOUR AHEAD FLOWRATE FORECASTS, DAILY MEAN AND DIURNAL
FLUCTUATION FORECASTS FOR MAXIMUM OF 48 HOURS FROM PRESENT TIME TO THE END
OF THE NEXT DAY.
THIS PROGRAM IS COMPATIBLE WITH BOX AND JENKINS ARIMA SUBROUTINES.
1. FLOWRATE FORECASTING AND FLOW EQUALIZATION BASIN CONTROL PROGRAM, WITH
NPROB, LT, NPERDY, EQ, 999, AND CALLS TSFCST.
2. FCHEK, WITH NPROB, EQ, 999, AND CALLS CFCST.
3. FLOW EQUALIZATION BASIN DESIGN PROGRAM, WITH NPROB, EQ, 999, AND CALLS CFCST.
DESCRIPTION OF PARAMETERS. SEE ANY OF 1, 2, 3, ABOVE.
MINIMUM DIMENSIONS... FLOPST COMPATIBLE WITH 1., 2., 3., ABOVE.
.....

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0002 DIMENSION ZN(1), ZP(1,1), CLL(1,1), CUL(1,1), U(1), PA(1), NT(1)      00021020
0003 DIMENSION SCRATC(1), DMPDSD(1), DIPDMN(1), DIPDSD(1), STOEST(1),      00021030
0004 +DIFCST(1), D(1), G(1), AC(1)      00021040
0005 DIMENSION H(1)      00021050
0006 COMMON /FLO/ NDIC, NDOC, NTINT, STSDDM, STSDDI      00021060
0007 COMMON /TSOBS/ Z(1)      00021070
0008 COMMON /TSPAF/ MAX11, MBO, NP, NOB, NRD, NSD, NSEA, INC(6), IOPA(1)      00021080
0009 IF (NTINT.LT.NPERDY) GO TO 330      00021100
0010 SUM=0.0      00021110
0011 DO 320 I=1,NPERDY      00021120
0012 SUM=SUM+ZN(I)      00021130
0013 DMNEW=SUM/NPERDY      00021140
0014 STODM=(DMNEW-DMPDMN(NDOC))*STSDDM/DMPDSD(NDOC)      00021150
0015 DO 322 I=1,NPERDY      00021160
0016 NOB=NOB+1      00021170
0017 Z(NOB)=STODM+(ZN(I)-DMNEW-DIPDMN(I))*STSDDI/DIPDSD(I)      00021180
0018 NDOC=NDOC+1      00021190
0019 IF (NDOC.GE.NDIC+1) NDOC=1      00021200
0020 NTINT=0      00021210
0021 NF=2*NPERDY      00021220
0022 NT(1)=NOB      00021230
0023 IF (NPROB.NE.999) GO TO 324      00021240
0024 CALL CFCST(NF,ZP,PA,SCRATC)      00021250
0025 GO TO 340      00021260
0026 CALL TSFCST(NPROB,NF,ZP,CLL,CUL,PA,NT,ZN,U,SCRATC)      00021270
0027 GO TO 340      00021280
0028

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FCRIPAN IV G LEVEL 21          FLOFST          DATE = 77065          14/14/31
0028 STODM=(DMFCST(I)-DMPDMN(NDOC))*STSDDM/DMPDSD(NDOC)          00021300
0029 DO 331 I=1,NFINI          00021310
0030 NDB=NOB+1          00021320
0031 STOEI(I)=STODM+(ZN(I)-DMFCST(I)-DIPDMN(I))*STSDDI/DIPDSD(I)          00021330
0032 Z(NOB)=STOPST(I)          00021340
0033 KI=2*KPEFDY-NINT          00021350
0034 NI(I)=NOB          00021360
0035 IF (HPROB.NE.999) GO TO 332          00021370
0036 CALL CFCST(NF,ZP,PA,SCRATC)          00021380
0037 GO TO 333          00021390
0038 CALL ISFCST(NPROB,NF,ZP,CLL,CUL,PA,NT,ZN,U,SCRATC)          00021400
0039 JJ=2*NPERDY          00021410
0040 DO 334 I=1,NF          00021420
0041 J=I-1          00021430
0042 ZP(JJ-J,1)=ZP(NF-J,1)          00021440
0043 DC 336          00021450
0044 ZP(I,1)=STOEST(I)          00021460
0045 JII=0          00021470
0046 KO 352 J=1,2          00021480
0047 AX=0          00021490
0048 GNDOCJ1=(NDOC+J-1)          00021500
0049 NDOCJ1=GNDOCJ1          00021510
0050 IF (NDOCJ1.GE.NDLC+1) NDOCJ1=1          00021520
0051 DO 348 I=1,NPERDY          00021530
0052 JI=JI+1          00021540
0053 IPE(I,FO,2) GO TO 342          00021550
0054 IPE(I,NINT)          00021560
0055 AC(I)=STSDDM/DMPDSD(NDOCJ1)          00021570
0056 D(I)=STSDDI/DIPDSD(I)          00021580
0057 G(I)=ZP(JI,1)+AC(I)*DMPDMN(NDOCJ1)+D(I)*DIPDMN(I)          00021590
0058 GO TO 346          00021600
0059 AC(I)=1          00021610
0060 D(I)=ZN(I)          00021620
0061 G(I)=ZN(I)          00021630
0062 AN=AN-AC(I)/D(I)          00021640
0063 GN=GN-G(I)/D(I)          00021650
0064 DMFCST(J)=GN/AN          00021660
0065 DO 350 I=1,NPERDY          00021670
0066 KIF=KI+1          00021680
0067 DIFCST(KI)=(G(I)-AC(I)*DMFCST(J))/D(I)          00021690
0068 CONTINUE          00021700
0069 J=NINT          00021710
0070 K=1          00021720
0071 DO 353 I=1,NPERDY          00021730
0072 J=J+1          00021740
0073 H(I)=DMFCST(K)+DIFCST(J)          00021750
0074 IF (J.EQ.NPERDY) K=2          00021760
0075 CONTINUE          00021770
0076 RETURN          00021780
0077 END          00021790
0078          00021800

```

FORTRAN IV G LEVEL 21
 0001
 SUBROUTINE FOUR (NFP,ND,MM,X) DATE = 77065 12/58/12 00022000

PERFORMS FOURIER ANALYSIS OF A DISCRETELY TABULATED FUNCTION.
 COMPUTES THE COEFFICIENTS OF THE DESIRED NUMBER OF TERMS IN THE FOURIER
 SERIES $F(P) = XM + \sum(A(K) \cos(2*PI*K*T/FUNDPERIOD) + B(K) \sin(2*PI*K*T/FUNDPERIOD))$
 WHERE $K = 1, 2, \dots, MM$ AND $T = 1, 2, \dots, ND$. OF DATA POINTS
 TO APPROXIMATE A GIVEN SET OF DISCRETELY TABULATED VALUES OF A FUNCTION.

SUBROUTINE PREPARED FOR FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.

DESCRIPTION OF PARAMETERS REQUIRED AS INPUT
 NFP - THE NUMBER OF CONSECUTIVE FUNDAMENTAL PERIODS INCLUDED IN THE INPUT
 DATA. MUST BE AN INTEGER.
 ND - THE TOTAL NUMBER OF INPUT DATA VALUES. MUST BE AN INTEGER MULTIPLE
 OF NFP.
 MM - THE NUMBER OF THE HIGHEST HARMONIC OF THE FUNDAMENTAL PERIOD
 TO WHICH COEFFICIENTS ARE DESIRED. MM MUST BE LESS THAN OR EQUAL
 TO $ND/NFP/2$.
 X TITLE - AN 80 CHARACTER TITLE MUST BE SUPPLIED TO THE SUBROUTINE IN THE
 COMMON BLOCK /BK/. AS WELL AS
 THE PRINTER CODE LP. TITLE1 IS A DUMMY NOT REQUIRED BY FOUR AND
 NOT REQUIRED ON INPUT.

SUBROUTINE FOUR IS DIMENSIONED FOR A MAXIMUM OF 400 HARMONICS AND ANY NUMBER
 OF VALUES OF X, DIMENSIONED IN THE CALLING PROGRAM.

0002 DIMENSION /BK/ X(1), A(400), B(400), C2(400), THETA(400), PERVAR(400) 00022010
 0003 COMMON /BK/ TITLE(20), LP, TITLE1(20) 00022020
 0004 FORMAT(11,'FOURIER ANALYSIS BY TRADITIONAL METHOD') 00022030
 0005 FORMAT(//,20A4) 00022040
 0006 PRINT(//,ZD50 HARMONIC..... SERIES MEAN =,F10.4, 4X,'SERIES VA 00022050
 +PIANCE =,F10.4) = XBAR + SUM(A(H)COS(2PIHT/TP) + B(H)SIN(2PIHT/ 00022060
 TP)) 00022070
 0008 FORMAT(//,' HARMONIC A.,14X,'B',10X,'AMPLITUDE',9X,'PHASE',3X 00022080
 +,PERCENT OF SERIES VARIANCE',F15.2) 00022090
 0009 FORMAT(3X,13.4E15.4,F15.2) 00022100
 0010 PRINT(//,'PERCENT CONTRIBUTED BY THE ABOVE HARMONICS',23X,F15.2) 00022110
 0011 FORMAT(//,' ERROR IN MM') 00022120
 0012 WRITE (LP,10) TITLE 00022130
 0013 WRITE (LP,12) TITLE 00022140
 00022150
 00022160
 00022170

```

FORTRAN IV G LEVEL 21          FOUF          DATE = 77065          12/58/12
0014  NDPFPD=ND/NFP
0015  IF (MM.LE.(NDPFPD/2)) GO TO 36
0016  WRITE (LP,26)
0017  RETURN
0018  END=ND
0019  I=ND
0020  I=ND
0021  ANDEGA=2.*3.141593/ANDEFP
0022  I=ND
0023  I=ND
0024  CALL STANDEX (ND,X,XMEAN,XSTD)
0025  XVAR=XSTD*XSID
0026  DO 37 I=1,ND
0027  X(I)=X(I)-XMEAN
0028  I=I+1
0029  I=ND
0030  BK=0.
0031  OMEGA=OMEGA*AI
0032  DO 38 J=1,ND
0033  TJ=J
0034  AK=X(J)*COS(OMEGA*TJ)
0035  BK=BK+X(J)*SIN(OMEGA*TJ)
0036  A(I)=TWO*ND*AK
0037  B(I)=TWO*ND*BK
0038  C2(I)=A(I)*A(I)+B(I)*B(I)
0039  THETA(I)=ATAN(-A(I)/B(I))
0040  PERVAR(I)=C2(I)/2./XVAR*100.
0041  IF (I).GE.(NDPFPD/2)) PERVAR(I)=C2(I)/XVAR*100.
0042  C2(I)=SQR(C2(I))
0043  WRITE (LP,14) XMEAN,XVAR
0044  WRITE (LP,16)
0045  WRITE (LP,18)
0046  SUM=0.
0047  DO 44 I=1,MM
0048  SUM=SUM+PERVAR(I)
0049  WRITE (LP,20) I,A(I),B(I),C2(I),THETA(I),PERVAR(I)
0050  WRITE (LP,22) SUM
0051  RETURN
0052  END

```

```

00022180
00022190
00022200
00022210
00022220
00022230
00022240
00022250
00022260
00022270
00022280
00022290
00022300
00022310
00022320
00022330
00022340
00022350
00022360
00022370
00022380
00022390
00022400
00022410
00022420
00022430
00022440
00022450
00022460
00022470
00022480
00022490
00022500
00022510
00022520
00022530
00022540
00022550
00022560

```

```

FORTRAN IV G LEVEL 21          CPROXY          DATE = 77065          12/58/53
0001      FUNCTION CPROXY(X,XBAR,Y,YBAR,N)          00023000
C          UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
C          SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
C          DIMENSION X(1),Y(1)
C          S=0.0
C          DO 10 I=1,N
C             S=S+(X(I)-XBAR)*(Y(I)-YBAR)
C          CPROXY=S
C          RETURN
C          END
0002
0003
0004
0005
0006
0007
0008

```

```

FORTRAN IV G LEVEL 21          ILOC          DATE = 77065          12/58/53
0001      FUNCTION ILOC(I,J)          00023100
C          UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
C          SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
C          ILOC=J+I*(I-1)/2
C          RETURN
C          END
0002
0003
0004

```

```

FORTRAN IV G LEVEL 21          NCHOSE          DATE = 77065          12/58/53
0001      FUNCTION NCHOSE(N,K)          00023150
C          UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
C          SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
C          IF(K)2,4,6,N,K
C          PRINT 12,N,K
C          FORMAT(//,'10X',I10,' AT A TIME',/10X,'UNDEFINED. RESULT SET TO ZERO')
C          + I10,' THINGS',I10,' AT A TIME',/10X,'UNDEFINED. RESULT SET TO ZERO')
C          NCHOSE=0
C          RETURN
C          NCHOSE=1
C          RETURN
C          IF(N-K)2,4,8
C          KK=MIN0(K,N-K)
C          NN=1
C          DO 10 I=1,KK
C             KI=I-1
C             NN=(NN*(N-K1))/I
C          NCHOSE=NN
C          RETURN
C          END
0002
0003
0004
0005
0006
0007
0008
0009
0010
0011
0012
0013
0014
0015
0016
0017

```

```

FORTRAN IV G LEVEL 21          GASS60          DATE = 77065          12/59/42
0001  SUBROUTINE GASS60 (ITYPE,NO,A,B,C)          00024000
C    UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
C    SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.          00024020
C          DIMENSION A(NQ),B(NQ),C(NQ,NQ)          00024030
NP=NO          00024040
NR=NR/10          00024050
LOW=1          00024060
LUP=10          00024070
IF(NR) 15,20,30          00024080
IF(LUP) .GT. LUP) RETURN          00024090
PRINT 500,(J,J=LOW,LUP)          00024100
GO TO C(40,60),ITYPE          00024110
PRINT 600,(A(J),J=LOW,LUP)          00024120
GO TO 100          00024130
PRINT 600,(B(J),J=LOW,LUP)          00024140
GO TO 40          00024150
DO 90 I=LOW,LUP          00024160
PRINT 720,I,(C(J,I),J=LOW,I)          00024170
IF(LUP) LUP+1          00024180
DO 95 I=LOW2,NR          00024190
PRINT 720,I,(C(J,I),J=LOW,LUP)          00024200
LUP=LUP+10          00024210
NR=NR-1          00024220
GO TO 10          00024230
RETURN          00024240
C          15          00024250
C          500          00024260
C          600          00024270
C          720          00024280
C          00024290
C          00024300
C          00024310
C          00024320
FORMAT (/10X,I8,9I12)
FORMAT (10X,10E12.4)
FORMAT (/16X,I3,1X,F7.4,9F12.4)
END

```

FORTRAN IV G LEVEL 21 GAUSS DATE = 77065 14/15/34
0001 SUBROUTINE GAUSS (IX,S,AM,V) 00025080

.....
COMPUTES A NORMALLY DIST'D. RANDOM NUMBEP WITH GIVEN MEAN AND STD. DEVIATION
DESCRIPTION OF PARAMETERS
IX - MUST CONTAIN AN ODD INTEGER WITH 9 OR LESS DIGITS ON FIRST ENTRY
TO GAUSS. THEREAFTER IT WILL CONTAIN A UNIFORMLY DIST'D. INTEGER
RANDOM NUMBER GENERATED BY THE SUBROUTINE FOR USE ON THE NEXT ENTRY
TO THE SUBROUTINE.
S - THE DESIRED STD. DEVIATION OF THE NORMAL DIST'N.
AM - THE DESIRED MEAN OF THE NORMAL DIST'N.
V - THE VALUE OF THE COMPUTED NORMAL RANDOM VARIABLE.

SOURCE: ADAPTED FROM IBM SCIENTIFIC SUBROUTINE PACKAGE
METHOD: R.W. HAMMING, NUMERICAL METHODS FOR SCIENTISTS AND ENGINEERS,
MCGRAW-HILL, N.Y., 1962, PAGES 34 AND 389.

```
0002 A=0.0  
0003 DO 50 I=1,12  
0004 CALL RANDUM (IX,IY,Y)  
0005 IX=IY  
0006 A=A+Y  
0007 V=(A-6.0)*S+AM  
0008 RETURN  
0009 END  
50  
00025090  
00025100  
00025110  
00025120  
00025130  
00025140  
00025150  
00025160
```

```

FORTRAN IV G LEVEL 21          HAUS59          DATE = 77065          12/59/42
0001
SUBROUTINE HAUS59(NPROB, NCR, Y, NP, TH, DIFZ, SIGNS, EPS1, EPS2,
1 XIT, FLAM, FNU, SDEVI, TD, F(1), F(1), F(1), D, DELZ,
C Q, P, PHI, TD, F(1), F(1), F(1), D, DELZ,
C UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
C SURROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
0002 26230
0003 26240
0004 26240
0005 26240
0006 26250
0007 26250
0008 26270
0009 26280
0010 26280
0011 26290
0012 26300
0013 26300
0014 26310
0015 26320
0016 26330
0017 26330
0018 26340
0019 26350
0020 26350
0021 26360
0022 26370
0023 26380
0024 26390
0025 26400
0026 26410
0027 26420
0028 26430
0029 26440
0030 26440
0031 26450
0032 26460
0033 26470
0034 26480
0035 26500
0036 26500
0037 26510
0038 26520
0039 26530
0040 26540
0041 26550
0042 26560
0043 26570
0044 26580
0045 26590
0046 26600
0047 26610
0048 26620
0049 26630
0050 26640
0051 26650
0052 26660
0053 26670
0054 26680

```

P. J. PACK VERSION OF NOVEMBER 27, 1971

```

DIMENSION TH(1), DIFZ(1), SIGNS(1), Y(1), Q(1), R(1), E(1)
DIMENSION PHI(1), F(1), R(1), A(1), D(1), DELZ(1)
COMMON /DWH/ SDEV, MAX11
COMMON /HAU/ LTRSS

```

GA=FLAM

```

NIT=1
ASSIGN 225 TO IRAN
ASSIGN 265 TO JORDAN
IF(EPS1) 5, 10, 10

```

```

5 10
10 40, 40, 30
40 60, 60, 50
60 270 TO IRAN

```

```

50 265 TO IRAN
GO TO 70
30 80, 80, 70
80 270 TO JORDAN

```

```

SSQ=0.0
CALL TSMOD(NPROB, TH, F, NOB)
DO 90 I=1, NOB
R(I)=Y(I)-F(I)
SSQ=SSQ+R(I)*R(I)
PRINT 1003, SSQ

```

BEGIN ITERATION

C 100

```

GA=FNU
INITCNT=0
PRINT 1004, NIT
JS=1-NOB
DO 130 J=1, NP
TEMP = TH(J)
P(J)=DIFZ(J)*TH(J)
TH(J)=IH(J)+P(J)
Q(J)=0.0

```

```

JS=JS+NOB
CALL TSMOD(NPROB, TH, DELZ(JS), NOB)
IJ=JS-1
DO 120 I=1, NOB
IJ=IJ+1
DELZ(IJ)=DELZ(IJ)-F(I)

```

CALL TSMOD(NPROB, TH, DELZ(JS), NOB)

DO 120 I=1, NOB

IJ=IJ+1

DELZ(IJ)=DELZ(IJ)-F(I)

```

FORTRAN IV G LEVEL 21          HAUS59          DATE = 77065          12/59/42
0041 Q(J)=Q(J)+DELZ(IJ)*R(I)
0042 Q(J)=Q(J)/P(J)
0043 TH(J)=TEMP
0044 DO 150 I=1,NP
0045 DO 151 J=1,I
0046 SUM=0.0
0047 KJ=NOB*(J-1)
0048 KI=NOB*(I-1)
0049 DO 160 K=1,NOB
0050 KI=KI+1
0051 KJ=KJ+1
0052 SUM=SUM+DELZ(KI)*DELZ(KJ)
0053 TEMP=SUM/(P(I)*P(J))
0054 J=J+NP*(I-1)
0055 IJ=I+NP*(J-1)
0056 D(IJ)=TEMP
0057 D(IJ)=D(IJ)
0058 D(IJ)=SORT(D(JI))
0059 CONTINUE
0060 DO 153 I=1,NP
0061 IJ=I-NP
0062 DO 153 J=1,I
0063 IJ=IJ+NP
0064 A(IJ)=D(IJ)/(E(I)*E(J))
0065 J=J+NP*(I-1)
0066 A(JI)=A(IJ)
0067 II=-NP
0068 DO 155 I=1,NP
0069 P(I)=O(I)/E(I)
0070 PHI(I)=P(I)
0071 II=NP+1+II
0072 A(II)=A(II)+GA
0073 I=1
0074 CALL MATIN(A, NP, P, I, DET)
0075 STEP=1.0
0076 SUM1=0.0
0077 SUM2=0.0
0078 SUM3=0.0
0079 DO 231 I=1,NP
0080 SUM1=P(I)*PHI(I)+SUM1
0081 SUM2=P(I)*P(I)*SUM2
0082 SUM3=PHI(I)*PHI(I)+SUM3
0083 PHI(I)=P(I)
0084 TEMP=SUM1/SQRT(SUM2*SUM3)

```

Q=XT*B (STEEPEST DESCENT)

A= SCALED MOMENT MATRIX

P/E = CORRECTION VECTOR

```

00026630
000266700
00026710
00026720
00026730
00026740
00026750
00026760
00026770
00026780
00026790
00026800
00026810
00026820
00026830
00026840
00026850
00026860
00026870
00026880
00026890
00026900
00026910
00026920
00026930
00026940
00026950
00026960
00026970
00026980
00026990
00027000
00027010
00027020
00027030
00027040
00027050
00027060
00027070
00027080
00027090
00027100
00027110
00027120
00027130
00027140
00027150
00027160

```

```

FORTRAN IV G LEVEL 21          HAUS59          DATE = 77065          12/59/42
0095      AMIN1(TEMP, 1.0)
0096      TEMP=5.295*ARCOS(TEMP)
0097      DO I=1, NP
0098      P(I)=PHI(I)*STEP/E(I)
0099      CORR(I)=PHI(I)+P(I)
0100      CORR(I)=CORR(I)*STEP
0101      PRINT 2006, (TB(I), I=1, NP)
0102      DO I=1, NP
0103      P(I)=SIGN(I), 221, 222
0104      IF (SIGN(I), TH(I)) *SIGN(1.0, TB(I)) 663, 221, 221
0105      CORR(I)=CORR(I)+P(I)
0106      SUMB=0.0
0107      DO I=1, NP
0108      SUMB=SUMB+P(I)*R(I)
0109      IF (SUMB.NE.0) SUMB=SUMB/2.0
0110      SIGN=SIGN(SUMB, NP/2.0)
0111      IF (SIGN.NE.1) SIGN=-SIGN
0112      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0113      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0114      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0115      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0116      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0117      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0118      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0119      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0120      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0121      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0122      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0123      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0124      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0125      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0126      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0127      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0128      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0129      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0130      IF (SIGN.EQ.1) SIGN=SIGN*SIGN
0131      IF (SIGN.EQ.1) SIGN=SIGN*SIGN

```

END ITERATION

```

000271170
000271180
000271190
000271200
000271210
000271220
000271230
000271240
000271250
000271260
000271270
000271280
000271290
000271300
000271310
000271320
000271330
000271340
000271350
000271360
000271370
000271380
000271390
000271400
000271410
000271420
000271430
000271440
000271450
000271460
000271470
000271480
000271490
000271500
000271510
000271520
000271530
000271540
000271550
000271560
000271570
000271580
000271590
000271600
000271610
000271620
000271630
000271640

```

```

FOETPAN IV G LEVEL 21          HAUS59          DATE = 77065          12/59/42
0132 DO 282 I=1,NOB          00027650
0133 IV=I+MAX(1,I-1)          00027650
0134 IF=I*(I)+F(I)          00027670
0135 PR=I*200,I,I,F(I),E(I),DV 00027680
0136 SSO=SUMR          00027690
0137 IDP=NOB-NP          00027700
0138 IDPRINT 1015          00027710
0139 I=0          00027720
0140 CALL MATIN(D,NP,P,I,DET) 00027730
0141 DO 7692 I=1,NP          00027740
0142 IF=I+NP*(I-1)          00027750
0143 E(I)=SQRT(D(I,I))          00027760
0144 DO 340 I=1,NP          00027770
0145 J=I+NP*(I-1)-1          00027780
0146 IJ=I+NP*(I-2)          00027790
0147 DO 340 J=I,NP          00027800
0148 J=J+1          00027810
0149 A(J,I)=D(J,I)/(E(I)*E(J)) 00027820
0150 IJ=IJ+NP          00027830
0151 R(I,I)=A(S60(3,NP,TEMP,TEMP,A) 00027840
0152 (I,I) GAS 341, 414, 341) 00027850
0153 IF(I,DE) 341          00027860
0154 SDEV=SSO/IDP          00027870
0155 SDE=SQRT(SDEV)          00027880
0156 DO 391 I=1,NP          00027890
0157 P(I)=TH(I,I)+2.0*E(I)*SDEV 00027900
0158 TB(I)=TH(I,I)-2.0*E(I)*SDEV 00027910
0159 PRINT 1033,NPROB          00027920
0160 REIUEN          00027930
C          00027940
0161 FORMAT(//10X,24HINITIAL SUM OF SQUARES =,E12.4) 00027950
0162 FORMAT(//45X,13HITERATION NO.,I4) 00027960
0163 FORMAT(//10X,31HPARAMETER VALUES VIA REGRESSION) 00027970
0164 + R LEAST THAN E12.4) 00027980
0165 + S LEAST THAN E12.4) 00027990
0166 + R LEAST THAN E12.4) 00028000
0167 + S LEAST THAN E12.4) 00028010
0168 + R LEAST THAN E12.4) 00028020
0169 + S LEAST THAN E12.4) 00028030
0170 FORMAT(//10X,36HCORELATION MATRIX OF THE PARAMETERS) 00028040
0171 FORMAT(//10X,27HEND OF ESTIMATION FOR MODEL I3) 00028050
0172 FORMAT(//10X,33HSUM OF SQUARES AFTER REGRESSION =,E15.7) 00028060
0173 FORMAT(//9X,I4,6X,E12.4) 00028070
0174 + R LEAST THAN E12.4) 00028080
0175 + S LEAST THAN E12.4) 00028090
0176 + R LEAST THAN E12.4) 00028100
0177 + S LEAST THAN E12.4) 00028110
0178 + R LEAST THAN E12.4) 00028120
0179 + S LEAST THAN E12.4) 00028130

```

```

FORTRAN IV G LEVEL 21          MATIN          DATE = 77065          12/59/42
0001      SUBROUTINE MATIN (A,NVAR,B,NR,DET)          00029000
C      UNIVERSITY OF WISCONSIN COMPUTING CENTRE    BOX AND JENKINS ARIMA MODELLING
C      SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.          00029000
C          DIMENSION A(NVAR, 1), B(NVAR, 1)          00029010
C          PIVOTM=A(1,1)          00029020
C          DET=1.0          00029030
C          DO 350 ICOL=1, NVAR          00029040
C             PIVOT=A(ICOL,ICOL)          00029050
C             PIVOTM=AMIN1(PIVOT, PIVOTM)          00029060
C             DET=PIVOT*DET          00029070
C          DIMENSION A(NVAR, 1), B(NVAR, 1)          00029080
C          PIVOTM=A(1,1)          00029090
C          DET=1.0          00029100
C          DO 370 L=1,NB          00029110
C             DIVIDE PIVOT ROW BY PIVOT ELEMENT          00029120
C             A(ICOL, ICOL)=1.0          00029130
C             PIVOT=A(ICOL, ICOL)/PIVOT          00029140
C             DO 350 L=1,NVAR          00029150
C                A(ICOL, L)=A(ICOL, L)*PIVOT          00029160
C             IF(NB.EQ.0) GO TO 371          00029170
C             DO 370 L=1,NB          00029180
C                B(ICOL, L)=B(ICOL, L)*PIVOT          00029190
C             REDUCE NON-PIVOT ROWS          00029200
C             DO 550 L1=1,NVAR          00029210
C                IF(L1.EQ.ICOL) GO TO 550          00029220
C                T=A(L1,ICOL)          00029230
C                A(L1,ICOL)=0.0          00029240
C                DO 450 L=1,NVAR          00029250
C                   A(L1, L)=A(L1, L) - A(ICOL, L)*T          00029260
C                IF(NB.EQ.0) GO TO 550          00029270
C                DO 500 L=1,NB          00029280
C                   B(L1, L)=B(L1, L) - B(ICOL, L)*T          00029290
C                CONTINUE          00029300
C            RETURN          00029310
C            END          00029320
C            END          00029330
C            END          00029340
C            END          00029350

```

```

0001  FORTRAN IV G LEVEL 21          MOMEN          DATE = 77065          14/13/50          00030000
      SUBROUTINE MOMEN(N,X)

```

```

.....
      SUBROUTINE TO CALCULATE AND PRINT THE FIRST FOUR ABSOLUTE AND CENTRAL
      MOMENTS OF A VECTOR OF REAL VARIATES, AS WELL AS VARIANCE, STD. DEVIATION,
      COEFF. OF VARIATION, SKENNESS COEFF. AND KURTOSIS.
      SUBROUTINE PREPARED FOR FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.

```

```

.....
      DESCRIPTION OF PARAMETERS.
      TITLE - INPUT 80 CHARACTER TITLE 20 - 4 BYTE WORDS.
      LPRINT - INPUT INSTALLATION CODE FOR LINE PRINTER.
      LTITLE1 - NOT REQUIRED BY MOMEN.
      X N - INPUT ARRAY OF REAL VARIATES.
      N - INPUT LENGTH OF ARRAY X.

```

```

0002  DIMENSION ABSMOM(4), CENMOM(4), X(N)
0003  COMMON /BK/ TITLE(20), LPRINT, TITLE1(20)
0004  XN=N
0005  WRITE (LPRINT,406) TITLE
0006  WRITE (LPRINT,408)
0007  DO 102 J=1,4
0008  XSUM=0.
0009  DO 100 I=1, N
0010  T=X(I)
0011  XSO=T.
0012  DO 99 K=1, J
0013  XSO=XSO*T
0014  XSUM=XSUM+XSO
0015  ABSMOM(J)=XSUM/XN
0016  WRITE (LPRINT,404) J, ABSMOM(J)
0017  CONTINUE
0018  XBAR=ABSMOM(1)
0019  WRITE (LPRINT,401)
0020  DO 202 J=1,4
0021  XSUM=0.
0022  DO 200 I=1, N
0023  T=X(I)-XBAR
0024  XSO=T.
0025  DO 199 K=1, J
0026  XSO=XSO*T
0027  XSUM=XSUM+XSO
0028  CENMOM(J)=XSUM/XN
0029  WRITE (LPRINT,404) J, CENMOM(J)
0030  CONTINUE

```

```

.....
000300010
000300020
000300030
000300040
000300050
000300060
000300070
000300080
000300090
000300100
000300110
000300120
000300130
000300140
000300150
000300160
000300170
000300180
000300190
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000300210
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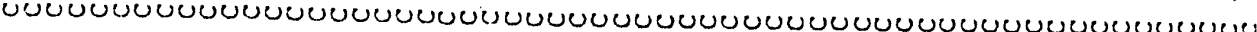

SUBROUTINE OPER8

WASTEWATER FLOW EQUALIZATION BASIN CONTROL PROGRAM.

TAKES INPUT FORECASTS H FOR NEXT 24 HOURS.
 CALCULATES AVERAGE FLOW FORECAST FOR NEXT 24 HOURS, AND SETS THIS AS THE
 INITIAL BASIN OUTFLOW PUMP RATE.
 CHECKS IF VOLUME IN STORAGE TO INCREASE INITIALLY, COMPUTES PROJECTED
 STORAGE VOLUME IN STORAGE TO INCREASE INITIALLY, COMPUTES PROJECTED
 AVAILABLE FLOW AT END OF PEAK PERIOD AND COMPARES WITH REMAINING
 - IF VOLUME IN STORAGE TO INCREASE INITIALLY, COMPUTES PROJECTED
 AVAILABLE FLOW AT END OF PEAK PERIOD, PUMP RATE IS INCREASED TO HAVE BASIN FILLED
 EXACTLY AT END OF PEAK PERIOD.
 - IF NO OVERFLOW AT END OF PEAK PERIOD, PUMP RATE IS LEFT UNCHANGED.
 - IF VOLUME IN STORAGE TO INCREASE INITIALLY (OR REMAIN CONSTANT),
 COMPUTES PROJECTED STORAGE DECREASE TO END OF LOW FLOW PERIOD AND
 COMPARES WITH REMAINING STORAGE VOLUME. LEFT AT END OF LOW FLOW PERIOD
 - IF STORAGE VOLUME IS INCREASED TO HAVE BASIN EMPTIED EXACTLY AT END OF LOW
 FLOW PERIOD.
 - IF PUMP RATE COMPLETE STORAGE VOLUME USAGE IS PROJECTED, AND RECYCLE
 OPTION IS SPECIFIED, RECYCLE RATES ARE CALCULATED TO SUPPLEMENT
 THE INFLOW WHEN THE LAST STOKED VOLUME IS PROJECTED TO BE PUMPED OUT.
 INTERVAL

SUBROUTINE PREPARED FOR FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.

DESCRIPTION OF PARAMETERS.
 NPERDY - INPUT NUMBER OF OPERATING INTERVALS PER DAY.
 H - INPUT ARRAY OF FLOW FORECASTS FOR NEXT 24 HOURS, ORDER BY IN NUMBER.
 HD - RESULTING ARRAY OF DIURNAL FLUCTUATIONS ABOUT THE FORECASTED
 NVOLS - 24 HOUR AHEAD MEAN NPERDY EQUALIZATION BASIN UNDER CONSIDERATION,
 1 INPUT NUMBER OF DIFFERENT EQUALIZATION BASINS.
 VINST - DESIGN ESTIMATING OF USE, FOR ONE WWTP, AND MINIMUM 2 TO MAXIMUM 9 FOR
 STOCAP - INPUT ARRAY REPRESENTING PRESENT STORAGE VOLUME IN EACH OF THE
 IFC - NVOLS BASINS REPRESENTING MAXIMUM STORAGE CAPACITY OF EACH OF THE
 HR - INPUT PARAMETER INDICATING IF RECYCLING OPTION SPECIFIED,
 RCSTRT - 0 IF NO CONSTANT LENGTH OF OPERATING INTERVAL, HOURS.
 LL - RESULTING INDICATOR OF RECYCLING BEING PROJECTED, REQUIRED BY
 PUMPRT - CALLING PROGRAM, OF BASIN OUTFLOW PUMP RATES FOR EACH OF THE
 RCRATE - RESULTING ARRAY OF REQUIRED RECYCLING RATES...
 - FOR EVERY DAY BASIN CONTROL PROGRAM - REQ'D RECYCLING RATES
 - FOR SUCCEEDING OPERATION INTERVALS UNTIL RECYCLING NO LONGER REQ'D
 - FOR DESIGN PROGRAM - REQ'D RECYCLING RATES FOR THE NEXT
 OPERATION INTERVAL, FOR EACH OF THE NVOLS BASINS.



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FCRIRAN IV G LEVEL 21          OPR8          DATE = 77065          14/15/34
0001  SUBROUTINE OPER8(NPERDY,H,HD)
0002  DIMENSION H(1),HD(1)
0003  COMMON /FOOP/,HE,NVOLS,RCSTRT,LL,RCRATE(24),VINST(9),STOCAP(9),
      +PUMPR(9),IPC
0004  SUM=0.0
0005  DO 353 I=1,NPERDY
0006  SUM=SUM+H(I)
0007  PUMPAV=SUM/NPERDY
0008  DO 354 I=1,NPERDY
0009  HD(I)=H(I)-PUMPAV
0010  LL=0
0011  DO 355 K=1,NVOLS
0012  RCRATE(K)=0.0
0013  PUMPR(K)=PUMPAV
0014  SUM=0.0
0015  IF (HD(1)) 362,362,356
0016  DO 358 I=1,NPERDY
0017  IF (HD(I).LE.0.0) GO TO 360
0018  XI=I
0019  SUM=SUM+HD(I)
0020  SUM=SUM/NPERDY
0021  DO 361 K=1,NVOLS
0022  EXCESS=(VINST(K)+SUM-STOCAP(K))/XI*NPERDY
0023  IF (EXCESS.GT.0.) PUMPR(K)=PUMPR(K)+EXCESS
0024  CONTINUE
0025  RETURN
0026  DO 364 I=1,NPERDY
0027  IF (HD(I).GT.0.0) GO TO 365
0028  XI=I
0029  SUM=SUM-HD(I)
0030  SUM=SUM/NPERDY
0031  IF (IRC.EQ.0) GO TO 397
0032  IF (NVOLS.EQ.1) GO TO 368
0033  DO 367 K=1,NVOLS
0034  EXCESS=(VINST(K)-SUM)/XI*NPERDY
0035  IF (EXCESS.GT.0.) GO TO 366
0036  XIV=-VINST(K)/HD(1)*NPERDY
0037  IF (XIV.EQ.0) RCRATE(K)=(1.0-XIV)*(-HD(1))
0038  GO TO 367
0039  PUMPR(K)=PUMPR(K)+EXCESS
0040  CONTINUE
0041  RETURN
0042  EXCESS=(VINST(1)-SUM)/XI*NPERDY
0043  IF (EXCESS.LI.0.) GO TO 369
0044  PUMPR(1)=PUMPR(1)+EXCESS
0045  RETURN
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FORTRAN IV G LEVEL 21
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OPER8
DATE = 77065
14/15/34

LEXVOL=VINST(1)
DO 376 I=1,NPERDY
VR=REMVOL+HD(I)/NPERDY
IF (VP-0.0) 372,372,370
REMVOL=VR
GO TO 376
J=I-1
XI=J
XXI=HD(I)
GO TO 378
CONTINUE
RCSTRT=XI*HR
NLEFT=NPERDY-J
J=J+1
ACRATE(1)=(1.0+REMVOL/XXI*NPERDY)*(-XXI)
DO 394 I=2,NLEFT
J=J+1
RCRATE(I)=-HD(J)
IF (RCRATE(I)) 393,393,394
LL=I-1
GO TO 396
CONTINUE
RETURN
DO 399 K=1,NVOLS
EXCESS=(VINST(K)-SUM)/XI*NPERDY
PUMPRT(K)=PUMPRT(K)+EXCESS
RETURN
END

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FORTRAN IV G LEVEL 21          PACOR          DATE = 77065          12/58/53          00032000
0001          SUBROUTINE PACOR(NPAC,PCOR,NAC,2,P)          00032020
C          UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING          00032030
C          SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.          00032040
C          00032050
C          DIMENSION P(1),P(1),PCOE(1)          00032060
C          P(1)=P(1)          00032070
PCOR(1)=R(1)          00032080
IF(NPAC.LE.NAC) GO TO 5          00032090
P=FMAGAL(10X,21HT) HAS BEEN REPTD TO I430H BECAUSE THIS IS THE          00032100
+ NUMBER OF 10X,25HAUTOCORRELATIONS SUPPLIED)          00032110
NPAC=100 L=2,NPAC          00032120
S1=0.0          00032130
S2=0.0          00032140
L1=LLOC(L1,0)          00032150
DO 10 J=1,L1          00032160
  IJ=IJ+1          00032170
  LS1=S1+P(IJ)*R(LJ)          00032180
  S2=S2+P(IJ)*P(IJ)          00032190
PCOR(L)=(R(L)-S1)/(1.-S2)          00032200
P(IJ)=PCOR(L)          00032210
IF(L.EQ.0) NPAC) GO TO 100          00032220
I2=ILOC(L1,0)          00032230
I3=ILOC(L1,1)          00032240
DO 20 J=1,L1          00032250
  I2=I2+1          00032260
  I3=I3-1          00032270
P(I2)=P(I2)-PCOR(L)*P(I3)          00032280
CONTINUE          00032290
RETURN          00032300
END          00032310
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FORTRAN IV G LEVEL 21          PLOT          DATE = 77065          12/58/53
0001          SUBROUTINE PLOT(SERIES,Z,NPP,IWTPA,ISMAM,ISMD,DMIN,DMAX,DMID,SCWD)
+          FILE)
C          UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
C          SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
0002          DIMENSION Z(1),TITLE(6),SERIES(20),P(101)
C          DATA X,B,D/1HX,1H,1H./
0003          RMIN=DMIN
0004          RMAX=DMAX
0005          IF(I=ISMAM .NE. 0) GO TO 20
0006          RMAX=Z(1)
0007          RMAX=Z(1)
0008          DO 5 J=2,NPP
0009          IF(Z(J) .LE. RMIN) RMIN=Z(J)
0010          IF(Z(J) .GE. RMAX) RMAX=Z(J)
0011          IF(I=IWTPA .EQ. 0) GO TO 10
0012          IF(ABS(RMAX-X) .GT. ABS(RMIN)) RMIN=-RMAX
0013          IF(ABS(RMIN) .GT. ABS(RMAX)) RMAX=-RMIN
0014          IF(I=ISMID .EQ. 0) GO TO 20
0015          IF(D=SCWD) RMIN=(RMAX+RMIN)*.5/SCWD
0016          RMINX=RMIN+EPS
0017          RMAXX=RMAX-EPS
0018          RMID=(RMAX+RMIN)/2.0
0019          RPP=(RMAX-NE. 0 .OR. ISMAM .NE. 0) GO TO 22
0020          IF(I=ISMID .EQ. 0) GO TO 22
0021          RMID=DMID
0022          IF(I=RMID) .GT. (RMAX-RMIN)} RMIN=2.0*RMID-RMAX
0023          IF(I=RMID) .LT. (RMIN-RMIN)} RMAX=2.0*RMID-RMIN
0024          IF(I=EPS)=(RMAX-RMIN)* (1.0-SCWD)*.5/SCWD
0025          RMINX=EPS
0026          RMAXX=EPS
0027          RPP=EPS
0028          RPP=EPS
0029          RPP=EPS
0030          RPP=EPS
0031          RPP=EPS
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0040          RPP=EPS
0041          RPP=EPS
0042          RPP=EPS
0043          RPP=EPS
0044          RPP=EPS

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PROGRAM IV G LEVEL 21          PLCT          DATE = 77065          12/58/53
NS=NS
IF (IS-US) .GT. .5) NS=NS+1
IF (NS .LT. 1 .OR. NS .GT. 51) GO TO 188
DO 38 K=NS,51
  P(K)=X
  GO TO 48
  NS=(Z(J)-PMID)/SQV+51.0
  USE=NS
  IF (IS-US) .GT. 0.5) NS=NS+1
  IF (NS .GT. 101 .OR. NS .LT. 51) GO TO 188
  DO 44 K=51,NS
    P(K)=X
    P(K)=J, (P(K), K=1, 101), Z(J)
    DO 68 J=1, NPP
      DO 56 K=1, 101
        P(K)=B
        NS=(Z(J)-PMIN)/SQV+1.0
        USE=NS
        IF (IS-US) .GT. .5) NS=NS+1
        IF (NS .LT. 1 .OR. NS .GT. 101) GO TO 188
        IF (NS)=X
        P(P(1)) .NE. X .AND. ISMID .EQ. 0) P(1)=D
        IF (P(51)) .NE. X .AND. ISMID .NE. 6) P(51)=D
        IF ((J/10)*10) .EQ. J) GO TO 62
        PRINT 59, (P(K), K=1, 101), Z(J)
        GO TO 66
        P(INPP) 40, J, (P(K), K=1, 101), Z(J)
        PRINT 67
        PRINT 67
        COME TO 100
        GO TO 192
        PRINT 192
        RETURN
        FORMAT (1H1, 16X, 20A4) OF 6A4, / IS, F11.4 /
        FORMAT (/17X, 18HGRAPH INTERVAL ERROR EXIT)
        FORMAT (/17X, 25HGRAPH INTERVAL ERROR EXIT)
        FORMAT (2X, E11.4, 39X, E11.4, 37X, E11.4, 3X, 6HVALUES, /7X, 10(10H.+++++))
        FORMAT (1H, 57X, A1)
        FORMAT (1X, I4, 2X, 101A1, E12.5)
        FORMAT (7X, I4, E12.5)
        FORMAT (7X, 1H.)
        FORMAT (///10X, 27HERROR IN MINIMUM OR MAXIMUM)
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FOIRAN IV G LEVEL 21          PRACHK          DATE = 77065          12/59/42
0001  SUBROUTINE REACHK(NPROB,NDS,MAX1,PA,NCALL,SCRATC,NSUB) 00034000
C     UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
C     SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
DIMENSION PA(1),SCRATC(1),T(6),PT(6,6),TEMP(3),D(4),VARS(9)
COMMON/ISCBS/ Z(1)
COMMON/ISPAR/MAX11,MRO,NP,NOB,NRD,NSD,NSEA,INC(6),IOPA(1)
COMMON/NAMES/SERIES(26)
COMMON/EPAR/ EPS1,EPS2,MIT,NDINS,NLOG,IPDEST,IPRES
COMMON/UMH/ SUMR,INUM
EQUIV ALERCE (TEMP(1),NPD)
DATA VARS(1),VARS(2),VARS(3),VARS(4),VARS(5),VARS(6),VARS(7),VARS(8),VARS(9)
+ 8),VARS(9) /4HINC1,4HINC2,4HINC3,4HINC4,4HINC5,4HINC6,4HINC7,4HNSD,00034110
+ 4HNSD,00034120
DATA D(1),D(2),D(3),D(4) /4HRIGH,4HT,4HLEFT,4H /
DATA NZT(1),NCNF,0,1 /
DATA T(1),T(2),T(3),T(4),T(5),T(6) /4HBEGI,4HNNIN,4HG,4HESTI,4H /
+ MATI,4HD /
DATA PI(1),PI(2),PT(1,3),PT(1,4),PT(1,5),PT(1,6) /4HREGU,4HLAR,00034150
+ 4HREGU,4HLAR,00034160
DATA AUTO(1),HREG,4HESI,4HVE /
+ DATA PT(2,1),PT(2,2),PT(2,3),PT(2,4),PT(2,5),PT(2,6) /4HSEAS,4HONA,00034180
+ L,4H ADI,4HREG,4HESI,4HIVE /
DATA PT(3,1),PT(3,2),PT(3,3),PT(3,4),PT(3,5),PT(3,6) /4HMEAN,4H,00034190
+ 4H PT(4,1),PT(4,2),PT(4,3),PT(4,4),PT(4,5),PT(4,6) /4HTREN,4HD C,00034210
+ 4HNSIA,4HNT,4H /
DATA PI(5,1),PT(5,2),PT(5,3),PT(5,4),PT(5,5),PT(5,6) /4HREGU,4HLAR,00034240
+ 4HMOVI,4HNG A,4HVERA,4HGE /
DATA PT(6,1),PT(6,2),PT(6,3),PT(6,4),PT(6,5),PT(6,6) /4HSEAS,4HONA,00034250
+ L,4H MOV,4HNG,4HVER,4HAGE /
C GO TO (5,72,96),NCALL
KK=0
DO 8 J=1,6
IF(INC(J),GE,0) GO TO 8
PRINT 11,VARS(J),INC(J)
INC(J)=NZERO
KK=KK+INC(J)
DO 18 J=1,3
IF(TEMP(J),GE,0) GO TO 18
L=J+6
PRINT 11,VARS(L),TEMP(J)
IF(INC(3),NE,1) GO TO 15
PRINT 12,NZERO
TEMP(J)=KZERO
GO TO 18
PRINT 21
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12/59/42

DATE = 77065

PPACHK

FORTRAN IV G LEVEL 21

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0036 GO TO INUE 95
0037 CONTINUE
0038 IF (NSD .EQ. 0) GO TO 27
0039 IF (NSEA .GE. 1) GO TO 27
0040 PRINT 11, VARS(9), NSEA
0041 PRINT 24, VARS(8), NSD
0042 PRINT 21
0043 GO TO XC(3) -1) 30, 36, 45
0044 IF (NRD .GT. 0 .OR. NSD .GT. 0) GO TO 48
0045 PRINT 11, VARS(3), INC(3)
0046 PRINT 33
0047 PRINT 21
0048 PRINT 21
0049 GO TO 95
0050 IF (NRD .EQ. 0 .AND. NSD .EQ. 0) GO TO 48
0051 PRINT 11, VARS(3), INC(3)
0052 PRINT 39
0053 PRINT 12, NZERO
0054 PRINT (3) = NZERO
0055 KK = KK - 1
0056 K1 = INC(1) + INC(2)
0057 IF (K1 .EQ. KK) GO TO 48
0058 K1 = K1 + 1
0059 DO 42 I = K1, KK
0060 PA(I) = PA(I + 1)
0061 IOPA(I) = IOPA(I + 1)
0062 GO TO 48
0063 PRINT INC(3)
0064 SAV = INC(3)
0065 KP = NZERO
0066 IF (NRD .EQ. 0 .AND. NSD .EQ. 0) KP = NONE
0067 PRINT 12, KP
0068 INK(3) = KP
0069 KK = KK - SAV + KP
0070 IF (INC(4) .LE. 1) GO TO 51
0071 PRINT 11, VARS(4), INC(4)
0072 PRINT 12, NONE
0073 INK(4) = NONE
0074 KK = KK - INC(4) + 1
0075 NP = KK
0076 DO 57 J = 1, NP
0077 IF (IOPA(J) .GE. 0) GO TO 57
0078 PRINT 54, J, IOPA(J)
0079 PRINT 21
0080 GO TO 95
0081 CONTINUE
0082 MAX1 = NRD + NSD * NSEA
0083 KK = INC(1)

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PCBIRAN IV G LEVEL 21          PRACHK          DATE = 77065          12/59/42
0084 IF (INC(1) .NE. 0) MAX1=MAX1+IOPA(KK)
0085 KK=KK+INC(2)
0086 IF (INC(2) .NE. 0) MAX1=MAX1+IOPA(KK)
0087 MAX11=MAX1+1
0088 INDU*=MAX11
0089 NDB=NDB-MAX1
0090 IF (NDB .GT. 0) GO TO 63
0091 PRINT 21 ,D(3),D(4)
0092 GO TO 95
0093
0094 KK=KK+INC(3)+INC(4)+INC(5)
0095 MAX2=0
0096 IF (INC(5) .NE. 0) MAX2=IOPA(KK)
0097 IF (INC(6) .NE. 0) MAX2=MAX2+IOPA(NP)
0098 MBO=MAX0(MAX1,MAX2)
0099 IF (NOB .GT. MAX2) GO TO 66
0100 PRINT 60 ,D(1),D(2)
0101 PRINT 21
0102 GO TO 95
0103 IF (MBO .LE. 200) GO TO 70
0104 PRINT 69 ,MBO
0105 PRINT 21
0106 GO TO 95
0107 PRINT 75 ,SERIES,NOB
0108 PRINT 78 ,NRD,NSD,NSEA
0109 IF (NTLOG .EQ. 0) GO TO 80
0110 PRINT 79
0111 PRINT 81
0112 PRINT 81
0113 LL=(NSUB-1)*3+1
0114 LL=LL+2
0115 PRINT 84 , (T(J),J=L,LL)
0116 PRINT 1
0117 MAX=0
0118 DO 90 J=1,6
0119 K=INC(J)
0120 IF (K .EQ. 0) GO TO 90
0121 MAX=MAX+K
0122 DO 87 L=MIN,MAX
0123 PRINT 93 ,L, (PT(J,M),M=1,6), IOPA(L),PA(L)
0124 PRINT 81
0125 PRINT 81
0126 PRINT 81
0127 PRINT 99 ,NPROB
0128 PRINT 81
0129 PRINT 75 ,NRD,NSD,NSEA
0130 PRINT
0131

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00034940
00034950
00034960
00034970
00034980
00034990
00035000
00035010
00035020
00035030
00035040
00035050
00035060
00035070
00035080
00035090
00035100
00035110
00035120
00035130
00035140
00035150
00035160
00035170
00035180
00035190
00035200
00035210
00035220
00035230
00035240
00035250
00035260
00035270
00035280
00035290
00035300
00035310
00035320
00035330
00035340
00035350
00035360
00035370
00035380
00035390
00035400
00035410

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FORMAN IV G LEVEL 21          PEACHK          DATE = 77065          12/59/42
0132 IF(MLOG .EQ. 0) GC TO 100
0133 PRINT 79
0134 PRINT 81
0135 PRINT 102, T(4), C(5), I(6)
0136 PRINT 81
0137 MAX=1
0138 MAX=0
0139 L1=3*NP
0140 L2=6*NP
0141 DO 108 J=1,6
0142 K=INC(J)
0143 IF(K .EQ. 0) GO TO 108
0144 MAX=MAX+K
0145 DO 105 L=MIN,MAX
0146 K1=L1+L
0147 K2=L2+L
0148 PRINT 81
0149 PRINT MIN+K
0150 PRINT 114
0151 PRINT 81
0152 VOP=SUMB**2
0153 IRSS=NDF-NP
0154 IRSS=VOE*ELOAT(IDF)
0155 PRINT 117,RSS, IDF, VOR
0156 PRINT 120,NDR, SUMB
0157 RETURN
0158 MAX1=-1
0159 MAXTUPN
0160
0161 FORMAT(///10X,39HPARAMETER CHECK REVEALS THAT THE VALUE ,A4,3H =
+ I4,11H IS ILLEGAL)
0162 FORMAT(10X,21HIT PROGRAM HAS BEEN RESET TO I1)
0163 FORMAT(10X,33HPROGRAM CANNOT CORRECT THIS ERROR)
0164 FORMAT(10X,16HTHIS IS BECAUSE ,A4,3H = ,I4,44H INDICATING THAT SEA-
+ SONAL DIFFERENCE DESIRED)
0165 FORMAT(10X,54HTHIS IS BECAUSE THERE IS NO DIFFERENCING IN THIS MOD
+ EL)
0166 FORMAT(10X,51HTHIS IS BECAUSE THERE IS DIFFERENCING IN THIS MODEL)
0167 FORMAT(///10X,44HPARAMETER CHECK REVEALS THAT THE VALUE IOPA(,I2,
+ 4H) = I4,11H IS ILLEGAL)
0168 FORMAT(///10X,55HTHE SERIES IS TOO SHORT TO ESTIMATE THE SPECIFIC
+ ED MODEL,///10X,26HCHECK BACKORDERING ON THE ,A4,A4)
0169 FORMAT(///10X,63HPARAMETER CHECK REVEALS THAT THE MAXIMUM BACKORD
+ ER IN MODEL IS ,I4,14,22HMAXIMUM ALLOWED IS 200)
0170 FORMAT(///10X,7HDATA - ,20A4,5X, I5,13H OBSERVATIONS)
0171 FORMAT(///10X,15HDIFFERENCES OF ORDER - ,I2,
+ 33H SEASONAL DIFFERENCES OF ORDER - ,I2)
00035420
00035430
00035440
00035450
00035460
00035470
00035480
00035490
00035500
00035510
00035520
00035530
00035540
00035550
00035560
00035570
00035580
00035590
00035600
00035610
00035620
00035630
00035640
00035650
00035660
00035670
00035680
00035690
00035700
00035710
00035720
00035730
00035740
00035750
00035760
00035770
00035780
00035790
00035800
00035810
00035820
00035830
00035840
00035850
00035860
00035870
00035880
00035890

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FCSTRAN IV G LEVEL 21          PRACHK          DATE = 77065          12/59/42
0172  FORMAT(//10X,25HLOG OF ORIGINAL DATA USED)          00035900
0173  FORMAT(//10X,115(1H READING))          00035910
0174  FORMAT(//10X,2(9HPARAMETER,8X,3A4, /11X,6HNUMBER,  00035920
+17X,4H TYPE,18X,5HORDER,12X,5HVALUE),E11.5)          00035930
0175  FORMAT(//13X,12,10X,6A4,8X,4(2,10X,MODEL,13)          00035940
0176  FORMAT(//10X,2(9HPARAMETER,8X,3A4,21X,11H95 PER  00035950
+CEFFICIENCY,11X,6HNUMBER,17X,4H TYPE,18X,5HORDER,12X,11HLOWER,  00035960
+ LIMIT,11X,11HUPPER,14X,8X,12,10X,E11.5,11X,E11.5)  00035970
0178  FORMAT(//13X,12,10X,6A4,8X,12,10X,E11.5,11X,E11.5)  00035980
0179  FORMAT(//10X,29(OTHER INFORMATION AND RESULTS)  00035990
0180  FORMAT(//10X,23HRESIDUAL SUM OF SQUARES,6X,E11.5,2X,I5,5H D.F.,14X,  00036000
+20HRESIDUAL MEAN SQUARE,15X,E11.5)          00036010
0181  FORMAT(//10X,19HNUMBER OF RESIDUALS,16X,I5,26X,23HRESIDUAL STANDARD  00036020
+ ERROR,12X,E11.5)          00036030
0182  END          00036040

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FORTRAN IV G LEVEL 21          PPPLC          DATE = 77065          12/58/53
0001
0002 SUBROUTINE PPPLC(SERIES,P,NPP,P,SN,MIN,NAPL,STE,MCSE,L,IT,IMPOP,C) 00037000
0003 UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AMD JENKINS ARIMA MODELLING
0004 C. SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER. 00037010
0005 DIMENSION P(NPP,1),E(1),SM(1),STE(NPP,1),C(1),S1(5),S2(6),S3(3) 00037020
0006 DIMENSION SERIES(20),GIT(6) 00037030
0007 DATA S1(1),S1(2),S1(3),S1(4),S1(5) /4HOBSE,4HPVED,4HDIFF,4HEREN,4H 00037040
0008 DATA S2(1),S2(2),S2(3),S2(4),S2(5),S2(6) /4HIES,4HCE 1,4HCE 2,4HCE 00037050
0009 DATA S3(1),S3(2),S3(3) /4HACF,4HPACE,4H / 00037060
0010 IF(IMPOP.EQ.2) GO TO 41 00037070
0011 IF(L.NE.1) GO TO 29 00037080
0012 PRINT=90,E(1),SM(1),MIN 00037090
0013 GO TO 32 00037100
0014 L=L-1 91,LL,F(L),SM(L),MIN 00037110
0015 PRINT=91,PP,NAPL 00037120
0016 DO 37 KK=1,NAPL 00037130
0017 JJ=MIN(KK,NAPL-1,NPP) 00037140
0018 IF(KK.EQ.92,93,94) NAPL=EQ,1) GO TO 35 00037150
0019 PRINT=92,93,94,PP,(P(K,L),K=KK,94) 00037160
0020 GO TO 36 95,96,97,PP,(P(K,L),K=KK,94) 00037170
0021 PRINT=95,96,97,PP,(P(K,L),K=KK,94) 00037180
0022 IF(MCSE.EQ.0) GO TO 37 00037190
0023 PRINT=93,(STE(K,L),K=KK,94) 00037200
0024 RETURN 00037210
0025 DO 44 KK=1,NPP 00037220
0026 C(KK)=P(KK,L) 00037230
0027 IF(LL.GT.1) GO TO 45 00037240
0028 GIT(1)=S1(1) 00037250
0029 GIT(2)=S1(2) 00037260
0030 GIT(3)=S1(3) 00037270
0031 GIT(4)=S1(4) 00037280
0032 GIT(5)=S1(5) 00037290
0033 GIT(6)=S1(6) 00037300
0034 GIT(1)=S2(1) 00037310
0035 GIT(2)=S2(2) 00037320
0036 GIT(3)=S2(3) 00037330
0037 GIT(4)=S2(4) 00037340
0038 GIT(5)=S2(5) 00037350
0039 GIT(6)=S2(6) 00037360
0040 GO TO 47 00037370
0041 GIT(1)=S3(1) 00037380
0042 GIT(2)=S3(2) 00037390
0043 GIT(3)=S3(3) 00037400
0044 GIT(4)=S3(4) 00037410
0045 GIT(5)=S3(5) 00037420
0046 GIT(6)=S3(6) 00037430
0047 CALL PLOT(SERIES,C,NPP,5,5,0,-1,0,1,0,DUM,DENOM,GIT) 00037440
0048 RETURN 00037450

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FORTRAN IV G LEVEL 21          PPIC          DATE = 77065          12/58/53
0043      C 90      FORMAT(//10X,15HORIGINAL SERIES,/10X,20HMEAN OF THE SERIES =,F12.5,
+S,/10X,20HST. ERROR OF MEAN =,E12.5,/10X,24HNUMBER OF OBSERVATIONS,
+S =,I6)
0044      91      FORMAT(//10X,11HDIFFERENCE ,I2,/10X,20HMEAN OF THE SERIES =,E12.5,
+S,/10X,20HST. ERROR OF MEAN =,E12.5,/10X,24HNUMBER OF OBSERVATIONS,
+S =,I6)
0045      92      FORMAT (/10X,I3,1H-,I3,5X,12(F5.2,2X))
0046      93      FORMAT (/12X,5HS1.E.,5X,12(F5.2,2X))
0047      95      FORMAT (/10X,I3,9X,F5.2)
0048      END
00037460
00037470
00037480
00037490
00037500
00037510
00037520
00037530
00037540
00037550
00037560
```



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FORTRAN IV G LEVEL 21          RAND          DATE = 77065          14/13/50
0020 F4=0.0
0021 I=1 N(25)
0022 IF (S(I)) -F025) 10,60,60
0023 IF (S(I)) -F050) 20,50,50
0024 IF (S(I)) -F075) 30,40,40
0025 FIRSTI=4
0026 F4=F4+1.0
0027 GO TO 70
0028 FIRSTI=3
0029 F3=F3+1.0
0030 GO TO 70
0031 FIRSTI=2
0032 F2=F2+1.0
0033 FIRSTI=1
0034 F1=F1+1.0
0035 CONTINUE
0036 IF (FIRSTI.EQ.1) GO TO 80
0037 IF (FIRSTI.NE.SECOND) ICOUNT=ICOUNT+1
0038 SECOND=FIRSTI
0039 RI=ICOUNT
0040 SMCU=F1**2+F2**2+F3**2+F4**2
0041 SMCU=F1**3+F2**3+F3**3+F4**3
0042 RM1=(I*(T+1.))-SMCU/T
0043 STDV1=SQRT((SMCU*(SMCU+T*(T+1.))-2.*T*SMCU-T**3)/((T**2)*(T-1.)))
0044 STDV1=((R1+0.5)-RM1)/STDV1
0045
CC
CC
CC
CC
CC
90
100
110
120
0046 SM=0.0
0047 SP=0.0
0048 DO 120 I=2,N
0049 K=I-1
0050 IF (S(I)) -S(K) 100,110,90
0051 SN=SN+1
0052 FIRSTI=-1
0053 GO TO 110
0054 SP=SP+1
0055 FIRSTI=1
0056 CONTINUE
0057 IF (FIRSTI.EQ.2) GO TO 120
0058 IF (FIRSTI.NE.SECOND) ICOUNT=ICOUNT+1
0059 SECOND=FIRSTI
0060 RR2=ICOUNT
0061 RM2=(2.*T-1.)/3.0
0062 STDV2=SQRT((16.*T-29.)/90.)
0038270
0038280
0038290
0038300
0038310
0038320
0038330
0038340
0038350
0038360
0038370
0038380
0038390
0038400
0038410
0038420
0038430
0038440
0038450
0038460
0038470
0038480
0038490
0038500
0038510
0038520
0038530
0038540
0038550
0038560
0038570
0038580
0038590
0038600
0038610
0038620
0038630
0038640
0038650
0038660
0038670
0038680
0038690
0038700
0038710
0038720
0038730
0038740

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FORTRAN IV G LEVEL 21          RAND          DATE = 77065          14/13/50
0063          STNV2=((R2+0.5)-RM2)/STDV2
C          TEST NO. 3 BEGINS
C          THIS TEST SHOWS IF THERE IS A PREDOMINANCE OF UPWARD OR DOWNWARD C
C          MARGES
IF (SN-SP) 130,140,140
SMIN=SN
GO TO 150
SMA=SP
COMLINEUE
RM3=(E-1,0)/2.0
SPRV3=SORI((SMIN+0.5))/STDV3
WRITE((NOPUT,270))
WRITE((NOPUT,260))
WRITE((NOPUT,160))
WRITE((NOPUT,240))
WRITE((NOPUT,220))
WRITE((NOPUT,250))
WRITE((NOPUT,230))
WRITE((NOPUT,170))
I=1
WRITE (NOPUT,180) I,STNV1,R1,RM1,STDV1
I=I+1
WRITE (NOPUT,180) I,STNV2,R2,RM2,STDV2
I=I+1
WRITE (NOPUT,180) I,STNV3,SMIN,RM3,STDV3
WRITE (NOPUT,200)
WRITE (NOPUT,210)
C
160          FORMAT (9X,78HTHTEST SERIAL CORRELATION TESTS USING RUNS, OR CLUSTE
170          1,12X,AND A STANDARD DEVIATION)
180          1,12X,AND A STANDARD DEVIATION)
190          1,12X,AND A STANDARD DEVIATION)
200          1,12X,AND A STANDARD DEVIATION)
210          1,12X,AND A STANDARD DEVIATION)
220          1,12X,AND A STANDARD DEVIATION)
230          1,12X,AND A STANDARD DEVIATION)
240          1,12X,AND A STANDARD DEVIATION)
250          1,12X,AND A STANDARD DEVIATION)
260          1,12X,AND A STANDARD DEVIATION)
270          1,12X,AND A STANDARD DEVIATION)
280          1,12X,AND A STANDARD DEVIATION)
290          1,12X,AND A STANDARD DEVIATION)
300          1,12X,AND A STANDARD DEVIATION)
310          1,12X,AND A STANDARD DEVIATION)
320          1,12X,AND A STANDARD DEVIATION)
330          1,12X,AND A STANDARD DEVIATION)
340          1,12X,AND A STANDARD DEVIATION)
350          1,12X,AND A STANDARD DEVIATION)
360          1,12X,AND A STANDARD DEVIATION)
370          1,12X,AND A STANDARD DEVIATION)
380          1,12X,AND A STANDARD DEVIATION)
390          1,12X,AND A STANDARD DEVIATION)
400          1,12X,AND A STANDARD DEVIATION)
410          1,12X,AND A STANDARD DEVIATION)
420          1,12X,AND A STANDARD DEVIATION)
430          1,12X,AND A STANDARD DEVIATION)
440          1,12X,AND A STANDARD DEVIATION)
450          1,12X,AND A STANDARD DEVIATION)
460          1,12X,AND A STANDARD DEVIATION)
470          1,12X,AND A STANDARD DEVIATION)
480          1,12X,AND A STANDARD DEVIATION)
490          1,12X,AND A STANDARD DEVIATION)
500          1,12X,AND A STANDARD DEVIATION)
510          1,12X,AND A STANDARD DEVIATION)
520          1,12X,AND A STANDARD DEVIATION)
530          1,12X,AND A STANDARD DEVIATION)
540          1,12X,AND A STANDARD DEVIATION)
550          1,12X,AND A STANDARD DEVIATION)
560          1,12X,AND A STANDARD DEVIATION)
570          1,12X,AND A STANDARD DEVIATION)
580          1,12X,AND A STANDARD DEVIATION)
590          1,12X,AND A STANDARD DEVIATION)
600          1,12X,AND A STANDARD DEVIATION)
610          1,12X,AND A STANDARD DEVIATION)
620          1,12X,AND A STANDARD DEVIATION)
630          1,12X,AND A STANDARD DEVIATION)
640          1,12X,AND A STANDARD DEVIATION)
650          1,12X,AND A STANDARD DEVIATION)
660          1,12X,AND A STANDARD DEVIATION)
670          1,12X,AND A STANDARD DEVIATION)
680          1,12X,AND A STANDARD DEVIATION)
690          1,12X,AND A STANDARD DEVIATION)
700          1,12X,AND A STANDARD DEVIATION)
710          1,12X,AND A STANDARD DEVIATION)
720          1,12X,AND A STANDARD DEVIATION)
730          1,12X,AND A STANDARD DEVIATION)
740          1,12X,AND A STANDARD DEVIATION)
750          1,12X,AND A STANDARD DEVIATION)
760          1,12X,AND A STANDARD DEVIATION)
770          1,12X,AND A STANDARD DEVIATION)
780          1,12X,AND A STANDARD DEVIATION)
790          1,12X,AND A STANDARD DEVIATION)
800          1,12X,AND A STANDARD DEVIATION)
810          1,12X,AND A STANDARD DEVIATION)
820          1,12X,AND A STANDARD DEVIATION)
830          1,12X,AND A STANDARD DEVIATION)
840          1,12X,AND A STANDARD DEVIATION)
850          1,12X,AND A STANDARD DEVIATION)
860          1,12X,AND A STANDARD DEVIATION)
870          1,12X,AND A STANDARD DEVIATION)
880          1,12X,AND A STANDARD DEVIATION)
890          1,12X,AND A STANDARD DEVIATION)
900          1,12X,AND A STANDARD DEVIATION)
910          1,12X,AND A STANDARD DEVIATION)
920          1,12X,AND A STANDARD DEVIATION)
930          1,12X,AND A STANDARD DEVIATION)
940          1,12X,AND A STANDARD DEVIATION)
950          1,12X,AND A STANDARD DEVIATION)
960          1,12X,AND A STANDARD DEVIATION)
970          1,12X,AND A STANDARD DEVIATION)
980          1,12X,AND A STANDARD DEVIATION)
990          1,12X,AND A STANDARD DEVIATION)

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FORTRAN IV G LEVEL 21          SORTX          DATE = 77065          14/13/50          00040000
0001          SUBROUTINE SORTX (N,X)
C.....
C          SUBROUTINE TO SORT AN ARRAY X OF N REAL VARIATES INTO DESCENDING ORDER.
C          SUBROUTINE PREPARED FOR FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
C.....
C          DIMENSION X (1)
C          K = (N-1)
C          DO 10 L = 1, K
C          M = (N-L)
C          DO 10 J = 1, M
C          IF (X(J) .GE. X (J+1)) GO TO 10
C          XTEMP = X (J)
C          X (J) = X (J+1)
C          X (J+1) = XTEMP
C          CONTINUE
C          RETURN
C          END
10
0002
0003
0004
0005
0006
0007
0008
0009
0010
0011
0012
0013
```

FORTRAN IV G LEVEL 21 SPECT DATE = 77065 12/58/53 00041000

SUBROUTINE SPECT(SERIES,P,KMAX,VAR,XNOB)
SUBROUTINE TO CALCULATE SMOOTHED SPECTRUM ESTIMATES OF A TIME SERIES USING
BARTLETT, HANNING, AND PARZEN LAG WINDOWS.

DESCRIPTION OF INPUT PARAMETERS.
SERIES- AN 80 CHARACTER TITLE BROKEN INTO 20 - 4 BYTE WORDS.
P - A VECTOR CONTAINING THE TABULATED COVARIANCE ESTIMATES FOR THE
TIME SERIES AT LAGS OF 1,2,3,...,KMAX.
KMAX - THE NUMBER OF COVARIANCE VALUES IN P. SUBROUTINE IS DIMENSIONED
FOR KMAX LESS THAN OR EQUAL TO 400. THE DIMENSIONS OF P, SPC11,
SPCT2, AND SPC13 SHOULD BE GREATER THAN OR EQUAL TO KMAX/2+1.
XNOB - THE NUMBER OF DATA VALUES IN THE SERIES.
VAR - THE SERIES VARIANCE.

0002 DIMENSION F(201), SPC11(201), SPCT2(201), SPC13(201), R(1)
0003 DIMENSION SERIES(20), TITLE(6), GTIT(6)
0004 DATA TITLE(1), TITLE(2), TITLE(3), TITLE(4) /4HSMO0,4TH S,4HPECT,4HR
+UM- /
0005 DATA GTIT(1), GTIT(2), GTIT(3), GTIT(4), GTIT(5), GTIT(6) /4HBA0T,4HLET
+T,4H HAN,4HNING,4H PAR,4HZEN /
0006 WR(K,X) = 1.-K/X
0007 WP1(K,X) = 0.5*(1.+COS(A*K/X))
0008 WP2(K,X) = 1.-6.*(K/X)**2+6.*(K/X)**3
0009 N1 = 2*KMAX/2+1
0010 XMAX = KMAX
0011

SPECTRAL ANALYSIS
SMOOTHED SPECTRUM USING DIFFERENT LAG WINDOWS
DO 100 I=1,N1
F(I) = (I-1.) / XMAX
PHI = 6.283185 * P(I)
SUMR1 = VAR
SUMR2 = VAR
SUMR3 = VAR
DO 101 J=1,KMAX
CONST1 = 2.*R3(J)*COS(PHI*J)
SUMR1 = SUMR1 + CONST1*WB(J,XMAX)
SUMR2 = SUMR2 + CONST1*WT(J,XMAX,3.141593)

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FORTRAN IV G LEVEL 21          SPECT          DATE = 77065          12/58/53
0022  IF (J, LE, (KMAX/2)) SUMR3=SUMR3+CONST*WP1 (J, XMAX)          00041290
0023  IF (J, GT, (KMAX/2)) SUMR3=SUMR3+CONST*WP2 (J, XMAX)          00041300
0024  CONTINUE          00041310
0025  SPCT1(I) = 2.*SUMR1          00041320
0026  SPCT2(I) = 2.*SUMR2          00041330
0027  SPCT3(I) = 2.*SUMR3          00041340
0028  CONTINUE          00041350
0029  PRINT 300, VAP          00041360
0030  PRINT 353, KMAX          00041370
0031  PRINT 354, KMIN          00041380
0032  DO I=1, N          00041390
0033  PRINT I, F(K), SPCT1(K), SPCT2(K), SPCT3(K)          00041400
0034  VAP2=2.*VAP          00041410
0035  VAP1LOG=A LOG (VA2)          00041420
0036  SUMR=0.          00041430
0037  SUMB=0.          00041440
0038  SUMC=0.          00041450
0039  N2=N-1          00041460
0040  N2=N2          00041470
0041  DO I=1, N          00041480
0042  SUMYA=SUMB+SPCT1(I)          00041490
0043  SUMYB=SUMC+SPCT2(I)          00041500
0044  SUMY=SUMYA+ (SPCT1(I) )+SPCT1(N1) *0.5          00041510
0045  SUMX=SUMB+ (SPCT2(I) )+SPCT2(N1) *0.5          00041520
0046  SUMZ=SUMC+ (SPCT3(I) )+SPCT3(N1) *0.5          00041530
0047  ASPCT1=SUMYA/AN2          00041540
0048  ASPCT2=SUMB/AN2          00041550
0049  ASPCT3=SUMC/AN2          00041560
0050  A1LOG=A LOG (ASPCT1)          00041570
0051  A2LOG=A LOG (ASPCT2)          00041580
0052  A3LOG=A LOG (ASPCT3)          00041590
0053  PRINT 310, N1          00041600
0054  DO I=1, N1          00041610
0055  IF (SPCT1(I), GT, 0.) GO TO 355          00041620
0056  IF (SPCT1(I), GT, 0.) GO TO 355          00041630
0057  GO TO 355          00041640
0058  SPCT1(I) = A LOG (SPCT1(I))          00041650
0059  IF (SPCT2(I), GT, 0.) GO TO 356          00041660
0060  IF (SPCT2(I), GT, 0.) GO TO 356          00041670
0061  GO TO 356          00041680
0062  SPCT2(I) = A LOG (SPCT2(I))          00041690
0063  IF (SPCT3(I), GT, 0.) GO TO 360          00041700
0064  IF (SPCT3(I), GT, 0.) GO TO 360          00041710
0065  SPCT3(I) = A LOG (SPCT3(I))          00041720
0066  GO TO 361          00041730
0067  SPCT3(I) = A LOG (SPCT3(I))          00041740
0068  CONTINUE          00041750
0069  PRINT 366          00041760

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FCPTFAN IV G LEVEL 21          SPECT          DATE = 77065          12/58/53
0070 2.  *XMOB/XRMAX          00041770
0071 (5)=GCHI(1)           00041730
0072 (6)=GCHI(2)           00041790
0073 CRIT(3)                00041800
0074 CRIT(4)                00041810
0075 CRIT(5)                00041830
0076 CRIT(6)                00041840
0077 CALLPLOT(SERR)        00041850
0078 CALLPLOT(SERR)        00041850
0079 CALLPLOT(SERR)        00041870
0080 CALLPLOT(SERR)        00041830
0081 CALLPLOT(SERR)        00041890
0082 C 300  *** VARIANCE SPECTRUM ANALYSIS ****          00041900
0083 310  AVERAGE SPECTRUM ESTIMATES 31X, 2 * VARIANCE, //, 10X 00041910
0084 350  NATURAL LOGARITHMS //, 10X, 4(4X, E11.4) 00041920
0085 353  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00041930
0086 357  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00041940
0087 366  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00041950
0088 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00041960
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00041970
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00041980
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00041990
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042000
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042010
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042020
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042030
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042040
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042050
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042060
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042070
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042080
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042090
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042100
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042110
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042120
0089 370  SMOOTHED SPECTRUM ESTIMATES (MAX, LAG USED) 00042130

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FORTRAN IV G LEVEL 21          STANDX          DATE = 77065          12/58/12          00040140
0001          SUBROUTINE STANDX (N,X,Y,Z)

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.....
SUBROUTINE TO COMPUTE THE ARITHMETIC MEAN Y AND STANDARD DEVIATION Z
OF A SERIES OF N REAL VARIATES X
SUBROUTINE PREPARED FOR FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
.....

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0002          DIMENSION X(N)
0003          XN=N
0004          SUM1=0.0
0005          SUM2=0.0
0006          DO 10 J=1,N
0007             XSO=X(J)*X(J)
0008             SUM1=SUM1+X(J)
0009             SUM2=SUM2+XSO
0010          Y=SUM1/XN
0011          Z=((SUM2/XN) - (Y**2)) **.5
0012          RETURN
0013          END
0014

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10

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FORTRAN IV G LEVEL 21          TSFCST          DATE = 77065          14/15/06
0001      SUBROUTINE TSFCST(NPROB,NF,ZP,CLL,CUL,PA,NT,ZN,U,SCRATC) 00045000
C          UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS APIMA MODELLING
C          SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
C          DIMENSION SCRATC(1),ZP(1,1),CLL(1,1),CUL(1,1),ZN(1),U(1),NT(00045010
+1) 00045020
C          COMMON/TSPAE/MAX11,MBO,NP,NOB,NRD,NSE,INCA,INCB,IOPA(1) 00045030
C          IF=1 00045040
C          IG=IF+NOB 00045050
C          CALL UTFCST(NPROB,NF,ZP,CLL,CUL,PA,NT,ZN,U,SCRATC(IF),SCRATC(IG)) 00045060
C          RETURN 00045070
C          END 00045080
0002 00045090
0003 00045100
0004
0005
0006
0007
0008
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FORTRAN IV G LEVEL 21          TSMOD          DATE = 77065          12/59/42
0001          SUBROUTINE TSMOD(MPROB,PA,F,NDR)          00043000
C          UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
C          SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.          00043020
0002          DIMENSION PA(1),F(1),T(200),V(200)          00043040
0003          COMMON/TS PAP/MAX,I1,MBC,NQ,NOB,NED,NSD,NSEA,INC(6),IOPA(1)          00043050
0004          COMMON/TSRES/A(1)          00043060
0005          COMMON/TSOBS/Z(1)          00043070
0006          COMMON/TSONE/C(200),CF(200),MPROB          00043080
C          IF(MBO.EQ.0) GO TO 68          00043090
0007          LDIF=NSD*NSEA+NED          00043100
0008          DO 3 J=1,MBO          00043110
0009          T(J)=0.0          00043120
0010          C(J)=0.0          00043130
0011          CF(J)=0.0          00043140
0012          IF THIS MODEL HAS BEEN USED BEFORE, THE EXPANSION OF THE DIFFERENC
TERMS WILL STILL BE STORED IN V. THE DO 10 LOOP SAVES REPEATING
THE EXPANSIONS.          00043150
0013          IF(LDIF.EQ.0) GO TO 43          00043170
0014          IF (NPROB.NE.MPROB) GO TO 15          00043180
0015          DO 10 I=1,LDIF          00043190
0016          C(I)=V(I)          00043200
0017          GO TO 43          00043210
0018          DO 13 I=1,MBO          00043220
0019          V(I)=0.0          00043230
0020          IF(NED.EQ.0) GO TO 18          00043240
C          EXPAND (1-B)**NRD AND STORE COEFFICIENTS IN C          00043250
C          DO 16 K=1,NRD          00043260
C          C(K)=(-1)**K * NCHOSE(NRD,K)          00043270
C          IF (NSD.EQ.0) GO TO 43          00043280
C          EXPAND (1-B**NSEA)**NSD AND STORE COEFFICIENTS IN T          00043290
C          DO 21 K=1,NSD          00043300
C          LOC=K*NSEA          00043310
C          T(LOC)=(-1)**K * NCHOSE(NSD,K)          00043320
C          MULTIPLY TWO POLYNOMIALS TOGETHER AND STORE FINAL COEFFICIENTS IN          00043330
C          MAX=NSTA*NSD          00043340
C          DO 25 I=NSEA,MAX,NSEA          00043350
C          V(I)=T(I)          00043360
C          IF (NRD.EQ.0) GO TO 32          00043370
C          00043380
C          00043390
C          00043400
C          00043410
C          00043420
C          00043430
C          00043440
C          00043450

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FORTRAN IV G LEVEL 21          TSMOD          DATE = 77065          12/59/42
0031 DO 31 I=1,NPD
0032 V(I)=V(I)+C(I)
0033 DO 39 ISD=NSEA,MAX,NSEA
0034 DO 39 IRD=1,NRD
0035 LOC=ISD+IRD
0036 V(LOC)=V(LOC)+T(ISD)*C(IRD)
0037 DO 42 I=1,LDIF
0038 C(I)=V(I)
0039 C(I)=0.0
C
C
C
EXPAND MODEL. STORE AUTOREGRESSIVE COEFFICIENTS IN C, MOVING
AVERAGE COEFFICIENTS IN CF.
MPCOF=MPFOB
MIN=1
MAX=0
DO 60 J=1,6,EO, 0) GO TO 60
IF (INC(J).INC(J))
MAX=MAX+INC(J)
GO TO (98,98,60,60,47,48),J
IF (LDIF) 105,105,105,99
DO 101 I=1,LDIF
T(I)=C(I)
DO 115 M=MIN,MAX
K=ICPA(M)
PIEN=PA(M)
T(K)=T(K)-PTM
IF (LDIF) 110,110,110,110,110
DO 110 I=1,LDIF
KI=K+I
T(KI)=T(KI)-C(I)*PTM
CONTINUE
LDIF=LDIF+K
DO 120 I=1,LDIF
C(I)=T(I)
GO TO 60
DO 130 M=MIN,MAX
K=ICPA(M)
CF(K)=-PA(M)
CF(K)=T(K)
MDIF=K
GO TO 60
IF (INC(5).EQ.0) GO TO 47
DO 140 M=MIN,MAX
K=ICPA(M)
PTM=PA(M)
CF(K)=CF(K)-PTM
0040 3460
0041 3470
0042 3480
0043 3490
0044 3500
0045 3510
0046 3520
0047 3530
0048 3540
0049 3550
0050 3560
0051 3570
0052 3580
0053 3590
0054 3600
0055 3610
0056 3620
0057 3630
0058 3640
0059 3650
0060 3660
0061 3670
0062 3680
0063 3690
0064 3700
0065 3710
0066 3720
0067 3730
0068 3740
0069 3750
0070 3760
0071 3770
0072 3780
0073 3790
0074 3800
0075 3810
0076 3820
0077 3830
0078 3840
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0080 3860
0081 3870
0082 3880
0083 3890
0084 3900
0085 3910
0086 3920
0087 3930

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PCBTRAN IV G LEVEL 21          TSMOD          DATE = 77065          12/59/42
0075      DO 140 I=1,MDIF
0076      KI=K+I
0077      CF(KI)=CF(KI)- T(I)*PTIM
0078      MIN=MIN+INC(J)
0079      DO 66 J=1,MBO
0080      CF(J)=-CF(J)
0081      C(J)=-C(J)
0082      COMPUTE FITTED VALUES AND RESIDUALS FOR MODEL.
0083      KK=INC(1)+INC(2)+INC(3)
0084      IF(INC(3) .EQ. 0) GO TO 72
0085      PTIME=PA(KK)
0086      DO 70 J=1,NOB
0087      Z(J)=Z(J)-PMEAN
0088      KK=KK+INC(4)
0089      CONSL=0.0
0090      IF(INC(4) .EQ. 1) CONST=PA(KK)
0091      DO 70 K=MAX11,NOB
0092      A(K)=Z(K)-CONST
0093      MAX=MIN0(K-1,MBO)
0094      IF(MAX .EQ. 0) GO TO 79
0095      DO 74 J=1,MAX
0096      KJ=K-J
0097      A(KJ)=A(K)-C(J)*Z(KJ)+CF(J)*A(KJ)
0098      CONTINC(3) .EQ. 0) GO TO 82
0099      DO 85 J=1,NOB
0100      Z(J)=Z(J)+PMEAN
0101      MAX1=MAX11-1
0102      DO 83 J=1,NDR
0103      LL=J+MAX1
0104      IF(J)=Z(LL)-A(LL)
0105      RETURN
0106      END
00043940
00043950
00043960
00043970
00043980
00043990
00044000
00044010
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FORTRAN IV G LEVEL 21          UFCST          DATE = 77065          14/15/06          00045110
0001          SUBROUTINE UFCST(NPRCE,NF,ZP,CLL,CUL,PA,NT,ZN,U,P,W)          00045130
C          UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIANA MODELLING
C          SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.          00045140
0002          DIMENSION PS(300),SDN(5),VARB(4),U(1),R(1),K(1),PA(1)          00045150
0003          DIMENSION CLL(NF,1),CUL(NF,1),ZP(NF,1),NT(1),SW(4),TITLE(6)          00045160
0004          DIMENSION GTIT(6),CH(9),ICCN(5),ZN(1)          00045170
0005          COMMON /TSRES/ A(4)          00045180
0006          COMMON /ISRES/ MAX11,MBC,NP,NOB,HRD,NSD,NSEA,INC(6),IOPA(1)          00045190
0007          COMMON /ISPAR/ SERIES(20)          00045200
0008          COMMON /ISONES/ C(200),CF(200),MPROB          00045210
0009          COMMON /ISOPAF/ NIO,NU,NLOG,ICI,IPDEFST,IWTPF          00045220
0010          DATA SDN(1),SDN(2),SDN(3),SDN(4),SDN(5) / .68,1.15,1.65,1.96,2.58 /          00045230
0011          DATA ICOR(1),ICOR(2),ICOR(3),ICOR(4),ICOR(5) / .50, .75, .90, .95, .99 /          00045240
0012          DATA VARB(1),VARB(2),VARB(3),VARB(4) / 4H NTO,4H NF,4H NY,4H ICI /          00045250
0013          DATA TITLE(1),TITLE(2),TITLE(3),TITLE(4),TITLE(5),TITLE(6) / 4H OBS,4H HEV,4H SER /          00045260
0014          DATA SW(1),SW(2),SW(3),SW(4) / 4H IES,4H HIRS,4H HLOG /          00045270
0015          DATA GTIT(1),GTIT(2),GTIT(3),GTIT(4),GTIT(5) / 4H HPC,4H HCAST,4H S AT          00045280
0016          DATA ORIGIN(1),ORIGIN(2),ORIGIN(3),ORIGIN(4),ORIGIN(5) / 4H HPC,4H HCAST,4H S AT          00045290
0017          DATA CH(1),CH(2),CH(3),CH(4),CH(5),CH(6),CH(7),CH(8),CH(9) / 4H 1          00045300
0018          +,4H 2,4H 3,4H 4,4H 5,4H 6,4H 7,4H 8,4H 9 / 4H 1          00045310
0019          IF (MAX11.EQ.(-1)) RETURN          00045320
0020          IF (MPROB.EQ.NPROB) GO TO 185          00045330
0021          CALL PRACTCK(NPROB,NDR,MAX1,PA,1,R,2)          00045340
0022          IF (MAX11.EQ.(-1)) RETURN          00045350
0023          IF (NTO.GT.0) GO TO 190          00045360
0024          J=1          00045370
0025          PRINT 181,VARB(1),NTO          00045380
0026          PRINT 189,J          00045390
0027          NTO=J          00045400
0028          PRINT 188,NOB          00045410
0029          NT(1)=NOB          00045420
0030          NE=0          00045430
0031          DO 194,IT=1,NTO          00045440
0032          IF (NT(IT).LE.NOB) GO TO 192          00045450
0033          NE=NE+1          00045460
0034          PRINT 191,IT          00045470
0035          NT(IT)=NOB          00045480
0036          IF (NT(IT).GE.MBO) GO TO 194          00045490
0037          NE=NE+1          00045500
0038          PRINT 193,IT,NT(IT)          00045510
0039          NT(IT)=MBO          00045520
0040          CONTINUE          00045530
0041          IF (NE.EQ.0) GO TO 209          00045540
0042          N=0          00045550

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FORTRAN IV G LEVEL 21          UTCST          DATE = 77065          14/15/06
0043  N=N+1
0044  NR=N+1
0045  DO (NTO, K=NR, N) GO TO 209
0046  IF (NR(N) .NE. NT(K)) GO TO 198
0047  LUP=NT(K)
0048  IF (K .GT. 1) LUP GO TO 205
0049  IF (K .EQ. 1) LUP GO TO 205
0050  NT(J)=NT(J+1)
0051  GO TO 205
0052  CONTINUE
0053  GO TO 209
0054  NTO=NTO-1
0055  GO TO 195
0056  IF (NT .GT. 0 .AND. NF .LE. 300) GO TO 220
0057  PRINT 181, VARB(2), NF
0058  PRINT 216
0059  GO TO 120
0060  LUP=NF-1
0061  IF (NU .LT. NF) GO TO 240
0062  PRINT 181, VARB(3), NU
0063  PRINT 189, LUP
0064  NU=LUP
0065  IF (ICI .GE. 1 .AND. ICI .LE. 5) GO TO 6
0066  J=4
0067  PRINT 181, VARB(4), ICI
0068  PRINT 189, J
0069  ICI=J
0070  MAXFOR=NT(1)
0071  IF (NTO .EQ. 1) GO TO 8
0072  DO (NTO, J=2, NTO)
0073  MAXFOR=MAXFOR+NT(J)
0074  MTOPNF=MAXFOR+NF
0075  MAX1=MAX1-1
0076  MDR=NCB-MAX1
0077  IF (MAX1 .EQ. 0) GO TO 9
0078  DO 14 J=1, MAX1
0079  A(J)=0.0
0080  FACT=SDV (ICI)
0081  MAX=MINO (NOB, MTOPNF)
0082  MIN=MINO (NOB+1, MTOPNF)
0083  LL=MINO (NOB, MTOPNF) GO TO 24
0084  IF (LL .GE. MTOPNF) GO TO 24
0085  DO 22 J=LL, MTOPNF
0086  A(J)=0.0
0087  IF (NLOG .EQ. 0) GO TO 18
0088  DO 17 J=1, MAXFOR
0089  IF (Z(J) .LE. .0000) GO TO 300
0090  Z(J)=ALOG(Z(J))
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00045580
00045590
00045600
00045610
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00045630
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FORTRAN IV G LEVEL 21          UTCST          DATE = 77065          14/15/06
0091  IF(MU.EO.0) GO TO 18
0092  DO 20 J=1,NU
0093  IF(ZN(J).LE.0000) GO TO 300
0094  ZN(J)=ALOG(ZN(J))
0095  GO TO 18
0096  PRINT 305
0097  PRINT 216
0098  GO TO 120
0099  DO 16 J=1,MAX
0100  W(J)=Z(J).EQ.0) GO TO 12
0101  IF(IPDFSI.EO.0) GO TO 12
0102  TITLE(4)=SW(2)
0103  TITLE(5)=SW(2)
0104  IF(NLOG.NE.0) TITLE(4)=SW(3)
0105  IF(NLOG.NE.0) TITLE(5)=SW(4)
0106  TITLE(6)=SW(2)
0107  CALL PLOT(SERIES,Z,NCS,0,0,RMIN,RMAX,RMID,.80,TITLE)
0108  IP(MPROC.EO.NE.0) GO TO 15
0109  CALL ISMOD(NPROB,PA,R,NDR)
0110  DO 19 J=1,MAX
0111  R(J)=A(J)
0112  SGM2=CPRCXY(A(MAX11),0.0,A(MAX11),0.0,NDR)/FLOAT(NDR-NP)
0113  PS(1)=C(1)-CF(1)
0114  LL=MINO(NF,MBO)
0115  DO 35 J=2,LL
0116  PS(J)=C(J)-CF(J)
0117  L=J-1
0118  DO 32 K=1,L
0119  LKK=K-1
0120  LKK=L-KK
0121  PS(J)=PS(J)+PS(K)*C(LKK)
0122  CONTINUE
0123  IF(NF.LE.MBO) GO TO 45
0124  MBOP1=MBO+1
0125  DO 42 J=MBOP1,NF
0126  PS(J)=0.0
0127  L=J-1
0128  I=J-MBO
0129  DO 38 K=I,L
0130  LKK=K-1
0131  LKK=L-KK
0132  PS(J)=PS(J)+PS(K)*C(LKK)
0133  CONTINUE
0134  KK=INC(1)+INC(2)+INC(3)
0135  RMEAN=0.0
0136  IF(INC(3).EQ.0) GO TO 51
0137  RMEAN=PA(LKK)
0138  DO 48 J=1,MAXFOR

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14/15/06

DATE = 77065

UTFCST

FORTRAN IV G LEVEL 21

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0139 Z(J)=Z(J)-PMEAN
0140 KK=KK+C(4)
0141 C(4)=C(4)
0142 IF(LINEC(4).EQ.1) CONST=PA(KK)
0143 P=LINEC(4)*PEOB
0144 CALL PRACHK(NPROB,NDR,MAX1,PA,2,R,2)
0145 PRINT 207,NF
0146 PRINT 225,NF
0147 PRINT 230,(NT(I),I=1,NT0)
0148 DO 95 I=1,NT0
0149 FF=NT(I)+1
0150 LP=NT(SGM2)
0151 VAR=SSGM2
0152 DO 58 K=FF,LF
0153 A(K)=0.0
0154 Z(K)=CONST
0155 DO 54 J=1,MBO
0156 KJ=K-J
0157 Z(K)=Z(K)+C(J)*Z(KJ)-CF(J)*A(KJ)
0158 CONTINUE
0159 DO 62 J=FF,LF
0160 Z(J)=Z(J)+RMEAN
0161 L=J+1-FF
0162 ZP(L,I)=Z(J)
0163 DO 66 J=1,NF
0164 CUL(J,IT)=ZP(J,IT)-FACT*(VAR)**.5
0165 CUL(J,IT)=ZP(J,**2)*SGM2
0166 VAR=VAR+(PS(J,**2)*SGM2)
0167 PRINT 70,NPROB,NI(IT),ICON(ICI)
0168 PRINT 74
0169 DO 78 J=1,NF
0170 K=J+NT(IT)
0171 IF(K.LE.NOB) GO TO 77
0172 IF(K.LE.NTO) AND(J.LE.NU) GO TO 71
0173 IF(IT.EQ.85) J,IT)=ZP(J,IT),CUL(J,IT)
0174 GO TO 78
0175 J,CUL(J,IT),ZP(J,IT),CUL(J,IT),W(K)
0176 GO TO 78
0177 PRINT 85,J,CUL(J,IT),ZP(J,IT),CUL(J,IT),ZN(J)
0178 PRINT 85,J,CUL(J,IT),ZP(J,IT),CUL(J,IT),ZN(J)
0179 CONTINUE
0180 IF(NLOG.EQ.0) GO TO 89
0181 PRINT 81
0182 DO 82 J=1,NF
0183 K=J+NT(IT)
0184 A1=EXP(CUL(J,IT))
0185 A3=EXP(ZP(J,IT))
0186 IF(K.LE.NOB) GO TO 84

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00046970
00046980
00046990
00047000

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FORTRAN IV G LEVEL 21          UTCFCST          DATE = 77065          14/15/06
0187 IF(IT.EQ.NTO.AND.J.LE.NU) GO TO 87
0188 PRINT 85,J,A1,A2,A3
0189 GO TO EXP(82)
0190 A4=EXP(83)
0191 GO TO EXP(83)
0192 A4=EXP(ZR(J))
0193 PRINT 85,J,A1,A2,A3,A4
0194 CONTINUE
0195 IF(EFFNO(LE,NOB) GO TO 91
0196 DO 90 J=FF,LF
0197 A(J)=E(J)
0198 IF(IT*IFF.EQ.0) GO TO 95
0200 IGHIT(6)=CH(IT)
0201 CALL PLOT(SERIES,ZP(1,IT),NF,0,0,0,RMIN,RMAX,RMID,.50,GTIT)
0202 CONTINUE
0203 PRINT 99
0204 DO 99 J=1,NF,PS(J)
0205 PRINT 85,J,0) GO TO 140
0206 IF(NU.EQ.0) GO TO 140
0207 U(1)=ZP(1,NTO)
0208 PRN(1)=ZN(1)-U(1)
0209 DO 111 I=1,NU
0210 PRN(I)=ZP(I,NTO)
0211 DO 130 I=1,NU
0212 PRN(I)=I
0213 MIN=I+1
0214 M=MIN,NF
0215 TOT=0
0216 DO 117 N=1,I
0217 MN=N-M
0218 TOT=TOT+PS(MN)*ZN(M)
0219 U(M)=TOT+ZP(M,NTO)
0220 IF(M.LE.NU) GO TO 123
0221 PRN(M)=ZP(M,NTO),U(M)
0222 GO TO 126
0223 PRINT 121,M,ZP(M,NTO),U(M),ZN(M)
0224 CONTINUE
0225 IF(IWTFP.EQ.0) GO TO 129
0226 NPP=INF-I
0227 CALL PLOT(SERIES,U(MIN),NPP,0,0,0,RMIN,RMAX,RMID,.50,24HABOVE UPDA
+
0228 TED FORECASTS)
0229 IF(I.EQ.NU) GO TO 130
0230 ZN(MIN)=ZN(MIN)-U(MIN)
0231 CONTINUE
0232 DO 134 J=1,NU
0233 ZN(J)=ZN(J)+B(J)
0234 DO 144 J=1,MAX
0235
0236
0237
0238
0239
0240
0241
0242
0243
0244
0245
0246
0247
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0250
0251
0252
0253
0254
0255
0256
0257
0258
0259
0260
0261
0262
0263
0264
0265
0266
0267
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0269
0270
0271
0272
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0274
0275
0276
0277
0278
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0280
0281
0282
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0288
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0290
0291
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0299
0300
0301
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0332
0333

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FORTRAN IV G LEVEL 21          UHHAUS          DATE = 77065          12/59/42
0001      SUBROUTINE UHHAUS(NPROB,NOB,Y,NP,TH,DIFF,SIGNS,EPS1,EPS2,MIT,
          +PLAN,END,SCRAT)
          C UNIVERSITY OF WISCONSIN COMPUTING CENTER BOX AND JENKINS ARIMA MODELLING
          C SUBROUTINE ADAPTED TO FORTRAN IV G LEVEL 21, IBM 360/365 COMPUTER.
          C
          DIMENSION SCRAT(1),Y(1),TH(1),DIFF(1),SIGNS(1)
          C
          NPSO=NP*NF
          NPNOR=NP*NOB
          I=1
          IB=IA+NP
          IC=IB+NP
          ID=IC+NP
          IE=ID+NP
          IF=IE+NP
          IG=IF+NOB
          IH=IG+NP
          IJ=IH
          CALL HAUS59(NPROB,NOB,Y,NP,TH,DIFF,SIGNS,EPS1,EPS2,MIT,
          +PLAN,END,FRU,SCRAT(IA),SCRAT(IB),SCRAT(IC),SCRAT(ID),
          +SCRAT(IE),SCRAT(IF),SCRAT(IG),SCRAT(IH),SCRAT(IJ),
          +SCRAT(IJ))
          RETURN
          END
0002
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0010
0011
0012
0013
0014
0015
0016
0017
00026000
00026030
00026040
00026050
00026060
00026070
00026080
00026090
00026100
00026110
00026120
00026130
00026140
00026150
00026160
00026170
00026180
00026190
00026200
00026210
00026220

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