R82-42 OSP 89965

MIT

IDENTIFICATION AND ESTIMATION OF A MONTHLY MULTIVARIATE STOCHASTIC STREAMFLOW MODEL FOR THE NILE RIVER BASIN

by
MARIO A. DIAZ-GRANADOS
and
RAFAEL L. BRAS

DEPARTMENT
OF
CIVIL
ENGINEERING

RALPH M. PARSONS LABORATORY
HYDROLOGY AND WATER RESOURCE SYSTEMS

SCHOOL OF ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts 02139

Report No. 283

Prepared under the support of
Technology Adaptation Program

July 1982

R82-42 OSP 89965

IDENTIFICATION AND ESTIMATION OF A MONTHLY MULTIVARIATE STOCHASTIC STREAMFLOW MODEL FOR THE NILE RIVER BASIN

by

Mario A. Diaz-Granados

and

Rafael L. Bras

RALPH M. PARSONS LABORATORY

HYDROLOGY AND WATER RESOURCE SYSTEMS

Report No. 283

Prepared under the support of
Technology Adaptation Program

July 1982

ABSTRACT

A technique for identification and estimation of a monthly multivariate stochastic model, appropriate for forecasting purposes, is presented. The model uses a black-box approach, where its basic structure is determined by casuality principles, and the parameter estimation is performed by regression procedures, such as Ordinary and Iternative Generalized Least Squared methods. Nile River Basin data are used in a general computer program for parameter estimation and residual analysis.

ACKNOWLEDGEMENTS

This work was sponsored by the M.I.T. Technology Adaptation Program which is funded through a grant from the Agency for International Development, United States Department of State. The ideas and opinions are those of the authors and do not necessarily reflect those of the sponsors.

Acknowledgements must be given to the staff of the Technology Planning Program which includes personnel at M.I.T. and Cairo University. Their administrative support and cooperation has been very helpful.

Particular thanks are due to Ms. Elaine C. Healy who typed this report.

PREFACE

This report is one of a series of publications which describe various studies undertaken under the sponsorship of the Technology Adaptation Program at the Massachusetts Institute of Technology.

The United States Department of State, through the Agency for International Development, awarded the Massachusetts Institute of Technology a contract to provide support at M.I.T. for the development, in conjunction with institutions in selected developing countries, of capabilities useful in the adaptation of technologies and problem-solving techniques to the needs of those countries. This particular study describes research conducted in conjunction with Cairo University, Cairo, Egypt.

In the process of making this TAP supported study some insight has been gained into how appropriate technologies can be identified and adapted to the needs of developing countries per se, and it is expected that the recommendations developed will serve as a guide to other developing countries for the solution of similar problems which may be encountered there.

Fred Moavenzadeh

Program Director

TABLE OF CONTENTS

Chapter 1

INTRODUCTION

Stochastic mathematical programming models are commonly used to derive optimal release policies for multiple purpose reservoirs. Most of them determine a closed-loop reservoir control law by maximizing the expected utility of the system operation, where the release depends on the present reservoir storage and the previous or present inflow, i.e., the states of the system. However, closed-loop controls can be derived only for stationary systems and thus, real-time forecast information cannot be included.

In 1980, Curry and Bras (1) developed a new algorithm, denominated Adaptive Control, which bypasses the drawback pointed out in closed loop control. It uses a dynamic programming formulation of the value iteration type, with state variables defined as previous inflow and present storage. The inflow is represented by a first order periodic Markov chain, with real time information introduced by updating conditional Markovian transition matrices.

The purpose of this report is to present the technique for the identification of a monthly multivariate stochastic streamflow model, appropriate for deriving the conditional Markovian transition matrices needed in the algorithm described by Curry and Bras (1), and to implement a general computer program for its estimation and residual analysis.

Chapter 2

MONTHLY MULTIVARIATE STREAMFLOW FORECAST MODEL

2.1 Forecasting Approach

The basin of a river can be considered as a physical system which transforms a spatially and temporally varying precipitation process into a temporally varying flow at a specific observation station. There are two extreme approaches to forecast the inflow. The conceptual one attempts to reproduce the response of the basin by means of a detailed moisture balance accounting model which routes the precipitation through the catchment; however, it requires a large amount of physical data to calibrate a reliable model. The black-box approach uses statistical techniques with no physical considerations to derive a mathematical relation between precipitation (or some surrogate measure), and streamflows; it has the advantage of requiring only historical data of precipitation (or its surrogate) and streamflow for calibration.

The model considered in this report uses a black-box approach, where its basic structure is determined by using physical principles, while the coefficients are obtained by statistical techniques. The following presentation follows the work of Curry and Bras, 1980.

2.2 The Proposed General Model

Several factors affect the choice of a model, and they depend on the purpose at hand. In the present case, the desired model must be able to:

1. Account for seasonal variation of mean and variance observed in monthly riverflows.
2. Use observations of upstream gaging stations.
3. Give multi-lead forecasts.

These basic factors lead to the following general model, whose structural form is:

$$B_i \underline{Y}(k,i) = A_i \begin{bmatrix} \underline{Y}(k,i-1) \\ \underline{Y}(k,i-2) \\ \vdots \\ \underline{Y}(k,i-n_1(i)) \end{bmatrix} + \underline{U}(i) + \underline{V}(k,i) + G_i \begin{bmatrix} \underline{V}(k,i-1) \\ \underline{V}(k,i-2) \\ \vdots \\ \underline{V}(k,i-n_2(i)) \end{bmatrix} \qquad (2.1)$$

$$i = 1, \ldots, 12$$

where B_i is a $n_o x n_o$ matrix of coefficients for month i, n_o is the number of stations,

$$\underline{Y}(k,i) = \begin{bmatrix} y_1(k,i) \\ y_2(k,i) \\ \vdots \\ y_{n_o}(k,i) \end{bmatrix} \qquad (2.2)$$

in which $y_j(k,i)$ identifies the flow at station j in the year k, month i. In Equation 2.1, A_i is a $n_o \times n_o n_1(i)$ matrix of coefficients for the month i; $n_1(i)$ is the maximum lag of the flow forecast in month i; $\underline{U}(i)$ is the deterministic component of the model,

$$\underline{U}(i) = \begin{bmatrix} u_1(i) \\ u_2(i) \\ \vdots \\ u_{n_o}(i) \end{bmatrix} \qquad (2.3)$$

where $u_j(i)$ is the deterministic term of station j, month i; and $\underline{V}(k,i)$ represents the disturbance component, which is a vector of individual random variables $v_j(k,i)$ for each of the stations considered in the analysis, i.e.,

$$\underline{V}(k,i) = \begin{bmatrix} v_1(k,i) \\ v_2(k,i) \\ \vdots \\ v_{n_o}(k,i) \end{bmatrix} \qquad (2.4)$$

The variables $v_j(k,i)$ can be expressed as linear combinations of white noise:

$$v_j(k,i) = \sum_{m=1}^{n_o} C_i(j,m) w_m(k,i) \qquad (2.5)$$

where C_i is a n_o x n_o matrix of coefficients and $w_j(k,i)$, $j=1,\ldots,n_o$ is a random sequence that satisfies the following conditions:

$$\text{i} - E[w_j(k,i)] = 0 \quad \forall \; i,j,k$$

$$\text{ii} - E[w_j(k,i)w_{j'}(k',i')] = \delta(i-i')\delta(j-j')\delta(k-k')\sigma_w^2$$

where $\delta(\cdot)$ is the Kronecker delta (2.5a)

$$\text{iii} - E[w_j(k,i)y_{j'}(k,i-\ell)] = 0 \quad \forall \; i,j,j'; \quad \ell>0$$

where $E(\cdot)$ is the expected value of the argument

The last term of Equation 2.1 takes in account the fact that the random component may be serially correlated for finite lag, i.e., the value of $n_2(i)$, which is the maximum lag in the disturbance structure in month i. G_i is a n_o x $n_on_2(i)$ matrix of coefficients.

In the general formulation, the discharge $y_j(k,i)$ is dependent on current discharges at other stations as well as previous flows at any other station. Since, in general, the matrices C_i and G_i do not have a particular form, the random disturbance of each station is related to the random disturbance at all other stations.

The general model is not parsimonious in its use of parameters. Given the length of most simultaneous multivariate riverflow records, it is difficult to obtain reliable parameter estimates. However, using physical considerations, more parsimonious models can be identified. Basically, these considerations deal with the hierarchical causality structure between the gaging stations of the basin.

2.3 Use of Causality

According to Granger and Newbold (2), causality can be defined as follows:

Let $P(a_t|B_t)$ the conditional distribution function at time t of a specific event "a" given some information, B; define R_t as all the information in the universe at time t, besides the event a, and s_t a single element of R_t. If the equation

$$P(a_t|R_t) \neq P(a_t|R_t - s_t) \tag{2.6}$$

holds, then the element s_t is causal to a_t. This definition is too general to be practical. However, instead of dealing with all the information in the universe and with conditional distribution functions, a limited set of information and the conditional mean can be used. The results of the causality analysis allow to conclude that, in general, variables causal to a discharge at a given station are previous flows at the site and past and present flows at upstream points. Thus, in Equation 2.1, elements of $\underline{Y}(k,i)$ may depend on other elements of the vector. This implies that a one step ahead forecast for a particular station requires forecasts of discharge at other upstream stations. This difficulty can be avoided by expressing Equation 2.1 in its reduced form:

$$\underline{Y}(k,i) = D_i \begin{bmatrix} \underline{Y}(k,i-1) \\ \underline{Y}(k,i-2) \\ \vdots \\ \underline{Y}(k,i-n_1(i)) \end{bmatrix} + \underline{U}'(i) + \underline{V}'(k,i) + E_i \begin{bmatrix} \underline{V}(k,i-1) \\ \underline{V}(k,i-2) \\ \vdots \\ \underline{V}(k,i-n_2(i)) \end{bmatrix} \qquad (2.7)$$

$$i = 1, \ldots, 12$$

where

$$D_i = B_i^{-1} A_i$$

$$\underline{U}'(i) = B_i^{-1} \underline{U}(i)$$

$$\underline{V}'(k,i) = B_i^{-1} \underline{V}(k,i)$$

$$E_i = B_i^{-1} G_i$$

In the reduced form, all discharges depend only on past values at the various stations, and the one step forecast requires only currently known discharges. By causality then, it may be possible to set some of the coefficients of D_i to zero a priori.

To complete the identification of the model, it is necessary to specify the value of the maximum lag of any flow variable, i.e., $n_1(i)$; the disturbance structure, i.e., the value of $n_2(i)$ and the characteristics of matrix E_i. The value of $n_1(i)$ can be determined by use of information obtained during the estimation and adequacy checks of the model. Using the Nile River Basin data, Curry and Bras (1) found, for that specific case, a value of $n_1(i)$ of 12 for all i. This value is taken here. From now on, it is assumed that the error term of the model is non-autocorrelated, which means that $n_2(i)$ and E_i are zero.

The model then reduces to:

$$\underline{Y}(k,i) = D_i \begin{bmatrix} \underline{Y}(k,i-1) \\ \underline{Y}(k,i-2) \\ \vdots \\ \underline{Y}(k,i-12) \end{bmatrix} + \underline{U}'(i) + \underline{V}'(k,i) \tag{2.8}$$

$$i = 1, \ldots, 12$$

2.4 Model Estimation

Equation 2.8, for any particular station j and month i is

$$y_j(k,i) = \sum_{\ell=1}^{12} \sum_{m=1}^{n_o} \{D_i(j,12(m-1)+\ell)y_m(k,i-\ell)\} + u_j'(i) + v_j'(k,i) \tag{2.9}$$

Given n years of observations this equation can be written for the station j as

$$\underline{Z}_j = X_j \, \underline{B}_j + \underline{e}_j \tag{2.10}$$

where

$$\underline{Z}_j = \begin{bmatrix} y_j(1,i) \\ y_j(2,i) \\ \vdots \\ y_j(n,i) \end{bmatrix} \tag{2.11}$$

$$X_j = \begin{bmatrix} 1 & y_1(1,i-1) & \cdots & y_{n_o}(1,i-1) & \cdots & y_1(1,i-12) & \cdots & y_{n_o}(1,i-12) \\ 1 & y_1(2,i-1) & \cdots & y_{n_o}(2,i-1) & \cdots & y_1(2,i-12) & \cdots & y_{n_o}(2,i-12) \\ \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ 1 & y_1(n,i-1) & \cdots & y_{n_o}(n,i-1) & \cdots & y_1(n,i-12) & \cdots & y_{n_o}(n,i-12) \end{bmatrix} \tag{2.12}$$

$$\underline{B}_j = \begin{bmatrix} u_j'(i) \\ D_i(j,1) \\ \vdots \\ D_i(j,12(n_o-1)+1) \\ \vdots \\ D_i(j,12) \\ \vdots \\ D_i(j,12n_o) \end{bmatrix} \tag{2.13}$$

$$\underline{e}_j = \begin{bmatrix} v'_j(1,i) \\ v'_j(2,i) \\ \vdots \\ v'_j(n,i) \end{bmatrix} \qquad (2.14)$$

In concept, the parameters of Equation 2.10 may be identified using Ordinary Least Squares (OLS) procedures. The implied assumptions are:

1. X_j is non-stochastic, which implies that the source of variation in the vector $\underline{Z}_j$ is variation in the $\underline{e}_j$ vector, and the properties of the estimators are conditional upon X_j.
2. The expected value of each element of $\underline{e}_j$ is zero.
3. $\underline{e}_j$ terms have constant variance σ_e^2 and are pairwise uncorrelated.
4. X_j has rank $K < n$ (i.e., the number of observations exceeds the number of parameters to be estimated.)

The OLS estimates of the coefficients $\hat{\underline{B}}_j$, the variance of the error term, $s^2_{e_j}$ and the covariance matrix of the coefficients $S_{\hat{B}_j\hat{B}_j}$ are:

$$\hat{\underline{B}}_j = [X_j^T X_j]^{-1} X_j^T \underline{Z}_j \qquad (2.15)$$

$$s^2_{e_j} = [\underline{e}_j^T \underline{e}_j]/(n-K) \qquad (2.16)$$

$$S_{\hat{B}_j\hat{B}_j} = s^2_{e_j} [X_j^T X_j]^{-1} \qquad (2.17)$$

where the superscript T means transposition and K is the number of predictors in the regression equation, which are determined from the set of potential explanatory variables (causality considerations) by using the standard stepwise OLS regression procedure. The above estimates are consistent and the best linear unbiased estimates if all necessary assumptions are fulfilled. However, since the elements of the matrix X_j are in fact lagged streamflows at the various stations, it is expected that the disturbance vector of Equation 2.8 is cross correlated, i.e., $E[v_j(k,i)v_\ell(k,i)] \neq 0 \;\; \forall\, j, \ell$. Under this condition, estimators $\hat{\underline{B}}_j$, $s^2_{e_j}$, and $S_{\hat{B}_j\hat{B}_j}$, although consistent, are not asymptotically efficient. To explicitly acknowledge cross correlation, it is reasonable to simultaneously estimate the coefficients of Equation 2.10 for all the stations, i.e., $j=1,\ldots n_o$. Then, the n observations of the n_o equations of the multivariate model can be expressed as

$$\underline{Z}' = X' \, \underline{B}' + \underline{e}' \tag{2.18}$$

where

$$\underline{Z}' = \begin{bmatrix} \underline{Z}_1 \\ \underline{Z}_2 \\ \vdots \\ \underline{Z}_{n_o} \end{bmatrix}, \quad \underline{B}' = \begin{bmatrix} \underline{B}_1 \\ \underline{B}_2 \\ \vdots \\ \underline{B}_{n_o} \end{bmatrix}, \quad \underline{e}' = \begin{bmatrix} \underline{e}_1 \\ \underline{e}_2 \\ \vdots \\ \underline{e}_{n_o} \end{bmatrix} \tag{2.19a,b,c}$$

and

$$X' = \begin{bmatrix} X_1 & & 0 \\ & X_2 \ddots & \\ 0 & & X_{n_o} \end{bmatrix} \qquad (2.20)$$

The residuals $\underline{e}'$ will have the following generalized covariance structure:

$$\Omega \equiv E[\underline{e}'\underline{e}'^T] = \begin{bmatrix} E[\underline{e}_1\underline{e}_1^T] & E[\underline{e}_1\underline{e}_2^T] & \cdots & E[\underline{e}_1\underline{e}_{n_o}^T] \\ E[\underline{e}_2\underline{e}_1^T] & E[\underline{e}_2\underline{e}_2^T] & \cdots & E[\underline{e}_2\underline{e}_{n_o}^T] \\ \vdots & \vdots & & \vdots \\ E[\underline{e}_{n_o}\underline{e}_1^T] & E[\underline{e}_{n_o}\underline{e}_2^T] & \cdots & E[\underline{e}_{n_o}\underline{e}_{n_o}^T] \end{bmatrix}$$

$$= \begin{bmatrix} \sigma_{e_1}\sigma_{e_1} & \sigma_{e_1}\sigma_{e_2} & \cdots & \sigma_{e_1}\sigma_{e_{n_o}} \\ \sigma_{e_2}\sigma_{e_1} & \sigma_{e_2}\sigma_{e_2} & \cdots & \sigma_{e_2}\sigma_{e_{n_o}} \\ \vdots & \vdots & & \vdots \\ \sigma_{e_{n_o}}\sigma_{e_1} & \sigma_{e_{n_o}}\sigma_{e_2} & \cdots & \sigma_{e_{n_o}}\sigma_{e_{n_o}} \end{bmatrix} I_{nn}$$

$$\equiv \Sigma_C \otimes I_{nn} \qquad (2.21)$$

where $\sigma_{e_i}\sigma_{e_i}$ denotes the variance of an element of $\underline{e}_i$ (they all have the same variance) and $\sigma_{e_i}\sigma_{e_j}$ the covariance of elements of $\underline{e}_i$ and $\underline{e}_j$. I_{nn} is the identity matrix of order n and the symbol $\otimes$ denotes Kronecker multiplication of matrices.*

The above is not amenable to OLS estimation. However, the use of Generalized Least Squares (GLS) estimation can yield consistent and efficient estimators:

By definition, Ω is a positive definite matrix. Therefore, it can be decomposed as

$$\Omega = PP^T \tag{2.22}$$

Premultiplying Equation 2.18 by P^{-1} gives another similar linear equation,

$$\underline{Z}'' = X''\underline{B}' + \underline{e}'' \tag{2.23}$$

where

---

*If A and B are matrices of order mxn and pxq respectively, the Kronecker product $A \otimes B$ is a matrix of order mpxnq, defined as

$$A \otimes B = \begin{bmatrix} a_{11}B & a_{12}B & \cdots & a_{1n}B \\ a_{21}B & a_{22}B & \cdots & a_{2n}B \\ \vdots & \vdots & & \vdots \\ a_{m1}B & a_{m2}B & \cdots & a_{mn}B \end{bmatrix}$$

$$\underline{Z}'' = P^{-1}\underline{Z}'$$

$$X'' = P^{-1}X'$$

$$\underline{e}'' = P^{-1}\underline{e}'$$

In this case, the covariance of $\underline{e}''$ is given by,

$$\begin{aligned} E[\underline{e}''\underline{e}''^{T}] &= P^{-1}E[\underline{e}'\ \underline{e}'^{T}]\ P^{-1T} \\ &= P^{-1}\ \Omega\ P^{-1T} \\ &= I \end{aligned} \tag{2.24}$$

which satisfies the assumptions required for OLS estimation. The Generalized Least Squares Estimator is:

$$\underline{\hat{B}}' = [X'^{T}\ \Omega^{-1}X']^{-1}\ X'^{T}\ \Omega^{-1}\underline{Z}' \tag{2.25}$$

$$S_{\hat{B}'\hat{B}'} = [X'^{T}\ \Omega^{-1}\ X']^{-1} \tag{2.26}$$

In the above two expressions, matrix Ω is unknown a priori. To estimate it, Zellner (3) proposed to use the OLS estimator on each individual equation (i.e., Equation 2.18) for all the stations. Once the set of regression equations is obtained, they can be used to calculate the elements of the matrix $\sum_C$ by using:

$$s_c(i,j) = \frac{(\underline{Z}_i - X_i\hat{\underline{B}}_i)^T(\underline{Z}_j - X_j\hat{\underline{B}}_j)}{(n-K_i)^{1/2}(n-K_j)^{1/2}} \tag{2.27}$$

where K_i, K_j are the number of predictors in the respective regression equations.

The necessity of estimate matrix Ω suggests that the GLS estimation must be used iteratively in order to assure that Equation 2.24 is satisfied. Equations 2.25 and 2.27 are used in sequence repeatedly. Convergence is achieved when the estimate of Ω in the last iteration Ω_{i-1} and the value of P_i of the present iteration satisfy Equation 2.24. Considering the large order of the matrices in 2.24, ($nn_o \times nn_o$), the above can be an expensive exercise. Nevertheless a more efficient criterion can be obtained.

From Equation 2.21, Ω is defined as

$$\Omega = \sum_C \otimes I_{nn} \tag{2.21}$$

But, $\sum_C$ (an $n_o \times n_o$ matrix) can be decomposed,

$$\sum_C = QQ^T \quad \text{and}$$

$$P = Q \otimes I_{nn} \tag{2.28}$$

$$P^{-1} = Q^{-1} \otimes I_{nn}$$

Replacing 2.28 in Equation 2.24 during a typical iteration,

$$[Q_i^{-1} \otimes I_{nn}][\sum C_{i-1} \otimes I_{nn}][Q_i^{-1^T} \otimes I_{nn}]$$

$$= [Q_i^{-1} \otimes I_{nn}][(Q_{i-1}Q_{i-1}^T) \otimes I_{nn}][Q_i^{-1} \otimes I_{nn}]$$

$$= [Q_i^{-1} \otimes I_{nn}][(Q_{i-1} \otimes I)(Q_{i-1}^T \otimes I_{nn})][Q_i^{-1} \otimes I_{nn}]$$

$$= [(Q_i^{-1}\ Q_{i-1}) \otimes I_{nn}]\ [(Q_{i-1}^T\ Q_i^{-1^T}) \otimes I_{nn}]$$

$$= [(Q_i^{-1}\ Q_{i-1})(Q_{i-1}^T\ Q_i^{-1^T})] \otimes I_{nn} \qquad (2.29)$$

Therefore, to achieve convergence, the first term of the right hand in Equation 2.29 has to tend to the identity matrix $I_{n_o n_o}$. The fact that the dimensions of that term are only $n_o \times n_o$ reduces computations considerably.

2.5 Residual Analysis

A basic assumption of the general model (Equation 2.1) and consequently of the model with non-autocorrelated noise (Equation 2.8) is that each element of the noise vector $\underline{V}(k,i)$ is a linear combination of the white noise vector $\underline{W}(k,i)$, whose characteristics lead to the properties of $\underline{V}(k,i)$ of zero mean and zero autocorrelations and cross-correlations of lag greater or equal to one. Therefore, the appropriateness of the OLS and GLS estimators depend on the statistical behavior of the residuals, i.e., the whiteness characteristics. There are several tests for whiteness. The first three moments of the residuals and the correlations at several lags can be easily calculated. The Durbin-Watson test is appropriate to verify autocorrelation of residuals, although in some cases its results are inconclusive. To test normality of the residuals, the estimated histogram can be plotted in standard normal probability paper and compared to expected straight line behavior. The following paragraph describes the Durbin-Watson test.

The Durbin-Watson test checks the null hypothesis of white noise error structure against the hypothesis of a first order autoregressive error structure. The statistic used is known as the Durbin-Watson "d" statistic, which can be expressed, for each station j in month i, as

$$d_{ij} = [\sum_{k=2}^{n} (\hat{v}_j(k,i) - \hat{v}_j(k-1,i))^2] / \sum_{k=1}^{n} \hat{v}_j^2(k,i) \tag{2.30}$$

where $\hat{v}_j(k,i)$ is an element of the vector $\hat{\underline{e}}_j$, estimated from the regression Equation 2.10 by

$$\hat{\underline{e}}_j = \underline{Z}_j - X_j \hat{\underline{B}}_j \tag{2.31}$$

If n is large, Equation 2.30 can be approximated to

$$d_{ij} \simeq 2(1 - \hat{\rho}_1) \tag{2.32}$$

where $\hat{\rho}_1$ is the first order sample autocorrelation of $\hat{\underline{e}}_j$. Thus, no sample autocorrelations beyond the first order are considered in assessing the time series structure of the residuals. From Equation 2.32, it follows that if $\hat{\rho}_1$ is zero, then d_{ij} is equal to 2; positive values of $\hat{\rho}_1$ imply $0 < d_{ij} < 2$ and negative values $2 < d_{ij} < 4$. The larger the absolute value of $\hat{\rho}_1$ is, the further from 2 is d. The problem with determining the sampling distribution of d_{ij} is that it depends on the X_j values; however, Durbin and Watson established upper, d_u, and lower, d_ℓ, limits for the significance levels of d_{ij}. These limits are function of the number of regressors and the number of observations. Appendix E gives the tabulated values of d_ℓ and d_u for the 5 per cent and 1 per cent levels of significance. The results of the test are:

1. If $d_{ij} < d_\ell$, reject the hypothesis of non-autocorrelated $\underline{e}_j$ in favor of the hypothesis of positive autocorrelation.
2. If $d_{ij} > d_u$, do not reject the null hypothesis.
3. If $(4 - d_{ij}) < d_\ell$, reject the null hypothesis in favor of the hypothesis of negative autocorrelation.
4. If $d_\ell < d_{ij} < d_u$, the test is inconclusive.

It is important to note that this test is not applicable when lagged values of the dependent variable (i.e., same station, same month but previous years) appear among the explanatory variables. However, if that is the case and the number of observations is large (n > 30), Durbin (4) suggests a modification of the d statistic, i.e.,

$$h_{ij} = (1 - 0.5\, d_{ij})(n/(1 - n\mathrm{Var}(b_j(\ell))))^{1/2} \qquad (2.33)$$

to test for autocorrelated residuals. In the above equation, $b_j(\ell)$ is the coefficient of the first autoregressive term (as previously defined). Under the hypothesis of non-autocorrelated noise, h_{ij} is distributed as a standard normal deviate. The result of the test is that if $|h_{ij}|$ is greater than 1.645, the null hypothesis of zero autocorrelation is rejected at the 5% significance level. This value changes to 2.327 if 1% significance level is used.

Chapter 3

INTRODUCTION TO AUMESP

AUMESP (an acronym for An AUtoregressive Multivariate Model EStimation Program) is a library of computer programs consisting of a main program and 11 subroutines. The main program (also called AUMESP) enables the user to perform parameter estimation and residual analysis of an autoregressive multivariate monthly (seasonal) streamflow model using regression techniques such as Ordinary Least Squares (OLS) and Iterative Generalized Least Squares (GLS). The theoretical bases of the above methods were discussed in Chapter 2 of this report.

This Chapter presents the general information about AUMESP and the main features of each subroutine.

Chapter 4 describes how the program, which is listed in Appendix A, is used. An example, using data from the Nile River Basin, is presented. The data used is given in Appendix B. The results of OLS and iterative GLS estimation procedures are compared. The output of the program appears in Appendix C.

3.1 Basic Characteristics of AUMESP

This program was developed in a Honeywell Level 68/DPS computer operated under the Multics system. However, it can be used on an IBM CMS system without any change. In its present form, the program can handle up to 10 stations with a maximum of 70 years of monthly (seasonal) data. The compiled program required a memory of 50949 words. Appendix D contains all the information the user will need for changing the capacity of the program.

Figure 3.1 illustrates the general flow of information among subroutines, which are described in the next section.

3.2 Description of AUMESP Subroutines

SUBROUTINE RDTA

This subroutine reads the input data. Chapter 4 contains the User's Manual, with all necessary input instructions.

SUBROUTINE ARRE

This subroutine determines the set of possible predictors of the independent variable on which stepwise regression will be performed. It is based on the definition of matrices ICAUS and ILAG, read before, and basically conforms the vector X, which contains the data for all the years of record of the possible explanatory variables (it is equivalent to matrix X_j in Equation 2.10). The program considers a maximum lag of twelve months, beginning from the initial lag specified in matrix ILAG.

SUBROUTINE STWR (IJKR)

This subroutine calls subroutines CORRE and STPR. The parameter IJKR corresponds to the number of the station for which calculations are actually in progress.

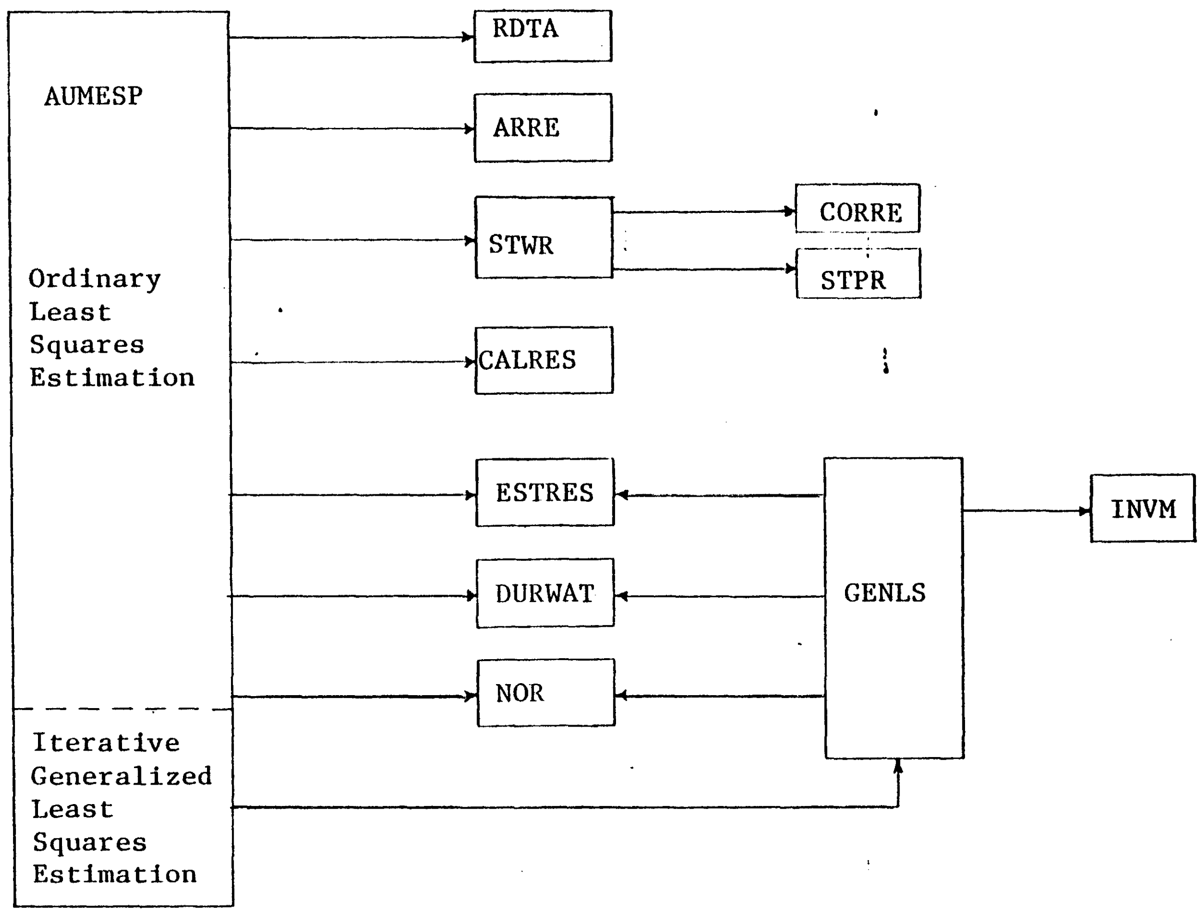


Figure 3.1: AUMESP Subroutine Network

SUBROUTINE CORRE

This subroutine computes the monthly means, standard deviations and sums of cross-products for the possible predictors.

SUBROUTINE STPR

This is one of the main subroutines of the program. It performs stepwise regression to estimate the parameters of Equation 2.10. The computational procedure is based on the stepwise version presented by Jenrich (5). It uses a forward selection procedure in which, at every stage, the variables already in the regression are re-examined. A variable which may have been the best single variable to enter at an early stage may, at a later stage, be superfluous due to relationships between it and other variables now in the regression. The forward selection uses the partial F criterion to enter the next variable into the regression. The F statistic is evaluated for all the variables not included yet in the regression; the variable which has the largest value is entered if it is greater than the value given by the F distribution at the significance level for entry, chosen by the user. The re-examination also uses the partial F criterion to delete variables of the regression. It is evaluated for all the variables included now in the regression; the variable which has the smallest value is removed if it is less than the value given by the F distribution at the significance level for deletion, also chosen by the user. The procedure is completed when no variable can be entered or removed. The significance level for entry has to be less or equal to the significance level for deletion. The user can choose values of significance levels of 1, 5, 10, and 25 percent.

SUBROUTINE CALRES (I)

This subroutine calculates estimated values of the dependent variable using the regression equation given by subroutine STPR. The residuals are computed subtracting the computed values from the true ones. The parameter I is the number of the station whose calculations are actually in progress.

SUBROUTINE ESTRES (I)

The purpose of this subroutine is to calculate statistics of the residuals, basically the mean, standard deviation, mean square error, and correlation coefficients at lags 1, 2, and 3. When the option NSPLIT ≠ 0, these statistics are computed for both halves of the data. As in subroutine CALRES, the parameter I identifies the number of the station whose calculations are actually in progress.

SUBROUTINE NOR (I,J)

This subroutine plots the estimated cumulative distribution function of the residuals, which allows for visual inspection of their normality. Besides, it fits a straight line to the estimated distribution (linear regression with normal probability scale in the abscissa), and calculates the R^2 of the regression. The parameters I, J correspond to the station and month numbers of the calculations in progress. If NSPLIT is different from zero, this subroutine plots only the estimated cumulative distribution function of the residuals of the first half of the data. If IGRAPH is equal to zero, this subroutine is not executed.

SUBROUTINE DURWAT (I,J)

This subroutine examines the residuals according to the Durbin-Watson test (see Section 2.5) at significance levels of 1 and 5 percent, and basically, determines if the residuals are autocorrelated or not. The parameters I, J are as in subroutine NOR.

SUBROUTINE GENLS (J)

This is the subroutine that performs the iterative Generalized Least Squares estimation (see Section 2.4). It uses Equation 2.25 to calculate, simultaneously for all the stations, the coefficients of the regression equations initially obtained by the OLS procedure. The standard deviations of the coefficients are calculated by Equation 2.26 and the estimate of Ω by Equation 2.27.

To check convergence of the iterative procedure described in Section 2.4, the elements out of the principal diagonal of two consecutive estimates of the residual correlation matrix are compared. Convergence is reached if the difference is less than 5 percent.

The Residual analyses are also performed using subroutines ESTRES, DURWAT and NOR described above.

SUBROUTINE MINV

This subroutine performs the inversion of a matrix. If the original matrix is singular, it gives a warning message to subroutine GENLS. The inversion computations are performed in DOUBLE PRECISION.

Chapter 4

USER'S MANUAL AND EXAMPLE

4.1 Read Statements

Subroutine RDTA is the subroutine that reads the input data from disk on two different units. Almost all READ statements are unformatted (except the statement for reading the names of the stations) and thus each variable needs only be separated by one or more spaces. The READ statement flow follows.

First Unit: File 04

The following is the data set read from File 04:

Record 1: NE, NY, NM.

NE: number of stations considered in the regression analysis.

NY: number of years of simultaneous seasonal streamflow data.

NM: number of seasons per year.

Record 2: JJ1, JJ2.

JJ1: number of the season from which the regression analysis starts.

JJ2: number of the season in which the regression analysis ends.

This read statement allows the user to restrict the number of seasons analyzed. For example, if NM is 12, and JJ1 and JJ2 are 4 and 7 respectively, the program performs parameter estimation and residual analysis for April to July at all the stations.

Record 3: IGEN, MQ, IGRAPH, ITAB, NSPLIT

IGEN: Option to perform the iterative Generalized Least Squares Estimation:

= 0 only Ordinary Least Squares

≠ OLS and GLS.

MQ: Number of the file in the disk where the results will be stored.

IGRAPH: Option to plot the cumulative distribution function of the residuals:

= 0 no graph

≠ graph

ITAB: Option to print out the results.

= 0 short output

≠ 0 complete output.

NSPLIT: Option to split the data set in two halves in order to calculate the parameters of the regression equation using only the first half. The second half is used in a verification step.

= 0 no split

≠ split.

Record 4: NAME (K)

NAME (K): name of the K-th station. This record is read with 8A1 format. There must be NE records.

Record 5: ICAUS (I,J)

ICAUS(I,J): causality matrix which allows setting some of the possible predictors equal to zero a priori. If ICAUS(I,J) = 0, station I is not causal to flows at station J. There are NE records with NE data points each.

Record 6: ILAG(I,J)

ILAG(I,J): minimum lag (in seasons) considered in the regression analysis if flows at station I are causal of flows at station J. For example, if ILAG(I,J) is 2, the variable corresponding to lag 1 does not belong to the set of possible explanatory variables. There are NE records with NE data points each.

Record 7: IFIN, IFOUT

IFIN: significance level for the entry of variables into the regression equation.

IFOUT: significance level for the deletion of variables from the regression equation.

The user can choose the following values of IFIN and IFOUT: 1, 5, 10, and 25 percent. Note: IFIN has to be less or equal to IFOUT.

<u>Second Unit</u>: File 15

(NExNY) records: DATO (I,K,J)

DATO (I,K,J): streamflow value for station I, season K and year J. For each station, a group of NY records with NM values each is read.

4.2 Example: Nile River Basin

Data from the Nile River Basin were used to run the program. Five stations were chosen, whose locations are shown in Figure 4.1. These stations are:

1. Wadi Halfa, Main Nile
2. Atbara, River Atbara
3. Khartoum, Blue Nile
4. Malakal, White Nile
5. Mongalla, Albert Nile.

The historical monthly flows for the period 1905-1967 were used. They are listed in Appendix B, together with the rest of the input data. According to causality considerations (see Section 2.3), the causality matrix for this specific case is:

I ↓ \ J →	1	2	3	4	5
1	1	0	0	0	0
2	1	1	0	0	0
3	1	0	1	0	0
4	1	0	0	1	0
5	1	0	0	1	1

In this table, flows at Atbara can be causal of flows at Wadi Halfa and Atbara itself; on the other hand, flows at Wadi Halfa can be explained by flows at all five stations.

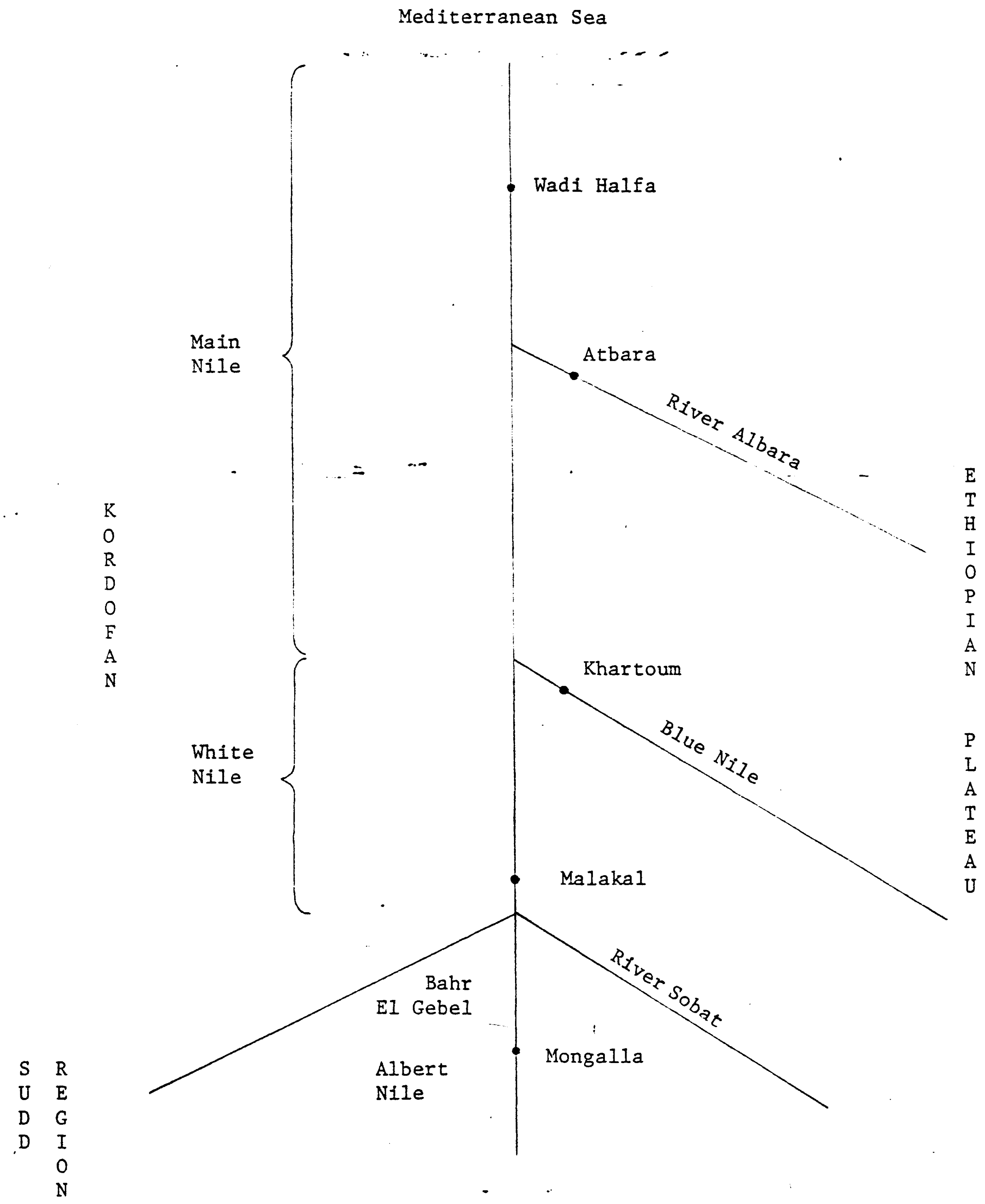


Figure 4.1: Schematic Diagram of Nile River Basin

Appendix C presents the results for the month of August with the options ITAB $\neq 0$ (i.e., complete output), IGRAPH $\neq 0$ (i.e., the cumulative distribution function of the residuals is plotted) and NSPLIT $\neq 0$ (i.e., the streamflow data is divided in two halves; the coefficients are calculated using the first half and the second half is used in a verification step).

Following the printout, the analysis begins with the OLS estimation for Wadi Halfa in the month of August. The first table shows the set of possible predictors, each one of them associated to a variable number which is maintained throughout the example. For the set of possible predictors, the means and standard deviations are printed. Following, the stepwise regression results are presented. The regression equation has a constant term and four predictors which correspond to Atbara in the previous month, Karthoum also in the previous month, Malakal in May and Wadi Halfa at lag 12. After this, the table of the residuals on the first half of the data is shown. The statistics of the residuals, for both halves, are printed and also the result of the Durbin-Watson test, which concludes that the hypothesis of zero autocorrelation cannot be rejected at confidence levels of 1 and 5 percent. Finally, the cumulative histogram of the residuals of the first half is plotted in normal probability paper, which fits adequately to a straight line ($R^2 = 0.93$). Similar tables follow for the rest of the stations, showing good results in the behavior of the residuals. Thereafter, the iterative Generalized Least Squares estimation begins, with similar tables and figures. The residual correlation matrix of the iterations are printed. They constitute the basis for the test of convergence of the iterative procedure. Of interest is the improvement obtained by the GLS relative to the OLS results. Table 4.1 shows a summary of the residual statistics such as the mean, standard deviation and mean square error for both halves of the streamflow data, calculated with the regression equation whose coefficients were estimated using only the first half. The mean square error of GLS in the second half always decreases or remains constant with respect to the OLS results, which implies that the iterative GLS is better than the OLS estimation when forecasting is the purpose of the model.

		FIRST HALF 1905-1936			SECOND HALF 1937-1967		
		Mean	Std.Dev.	MSE	Mean	Std.Dev.	MSE
WADI HALFA	OLS	0	1590	$0.245x10^7$	1005	2954	$0.942x10^7$
	GLS1	0	1644	$0.262x10^7$	912	2645	$0.757x10^7$
	GLS2	0	1672	$0.271x10^7$	893	2602	$0.732x10^7$
	GLS3	0	1681	$0.274x10^7$	888	2593	$0.727x10^7$
	GLS4	0	1685	$0.275x10^7$	886	2590	$0.725x10^7$
ATBARA	OLS	0	1296	$0.163x10^7$	167	1509	$0.223x10^7$
	GLS1	0	1297	$0.163x10^7$	158	1494	$0.218x10^7$
	GLS2	0	1299	$0.163x10^7$	155	1488	$0.217x10^7$
	GLS3	0	1299	$0.163x10^7$	153	1486	$0.216x10^7$
	GLS4	0	1299	$0.163x10^7$	153	1485	$0.216x10^7$
KARTHOUM	OLS	0	1988	$0.383x10^7$	1479	2079	$0.630x10^7$
	GLS1	0	2049	$0.407x10^7$	1069	1931	$0.471x10^7$
	GLS2	0	2076	$0.418x10^7$	1011	1902	$0.449x10^7$
	GLS3	0	2084	$0.421x10^7$	999	1896	$0.444x10^7$
	GLS4	0	2087	$0.422x10^7$	997	1894	$0.443x10^7$
MALAKAL	OLS	0	115	$0.128x10^5$	-12	160	$0.249x10^5$
	GLS1	0	115	$0.128x10^5$	-12	157	$0.241x10^5$
	GLS2	0	115	$0.129x10^5$	-12	156	$0.237x10^5$
	GLS3	0	115	$0.129x10^5$	-12	156	$0.236x10^5$
	GLS4	0	115	$0.129x10^5$	-12	155	$0.236x10^5$
MONGALLA	OLS	0	261	$0.662x10^5$	164	348	$0.143x10^6$
	GLS1	0	265	$0.680x10^5$	163	349	$0.143x10^6$
	GLS2	0	267	$0.693x10^5$	162	349	$0.143x10^6$
	GLS3	0	269	$0.699x10^5$	161	350	$0.143x10^6$
	GLS4	0	269	$0.702x10^5$	161	350	$0.143x10^6$

Table 4.1: OLS and GLS Results

References

(1) Curry, K., and R. Bras, Multivariate Seasonal Time Series Forecast with Application to Adaptive Control, Report No. 253, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, M.I.T., 1980.

(2) Granger, C. and P. Newbold, Forecasting Economic Time Series, Academic Press, New York, 1977.

(3) Johnston, J., Econometric Methods, McGraw-Hill, New York, 1972.

(4) Durbin, J., Testing for Serial Correlation in Least-Squares Regression when Some of the Regressors are Lagged Dependent Variables, Econometrica, Vol. 38, 1970.

(5) Jenrich, R., Stepwise Regression, Statistical Methods for Digital Computers, Ch. 4, ed. Ralston A. and H. Wilf, John Wiley & Sons, 1973.

Appendix A

COMPUTER PROGRAM LISTING

```
c
c
c
c     ***********************************************************
c     *                                                         *
c     *  this program performs the estimation of the general   *
c     *  model in reduced form and with non-autocorrelated     *
c     *  noise proposed by k. curry & r. bras. ("multivariate  *
c     *  seasonal time series forecast with application to     *
c     *  adaptive control," technical report no. 253,          *
c     *  department of civil engineering, mit, ralph m.        *
c     *  parsons laboratory for water resources and hydro-     *
c     *  dynamics, cambridge, mass., 1980).                    *
c     *                                                         *
c     ***********************************************************
c
c
c
c     main program
c
c
      common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab
     &,nsplit,nyi
      common/a4/name
      common/d5/month
      common/pi/jj1,jj2
      dimension name(10,8),month(12)
      call rdta
      igan=igen
      do 200 j=jj1,jj2
      igen=igan
      do 100 i=1,ne
      write(mq,300)(name(i,k),k=1,8),month(j)
      call arre(i,j)
      call stwr(i)
      call calres(i)
      call estres(i)
      call durwat(i,j)
      if(igraph.eq.0)go to 100
      call nor(i,j)
100   continue
      if(igen.eq.0)go to 200
      write(6,400)j
400   format(3x,'the value of j is ',i3)
      call genls(j)
200   continue
300   format('1',////,43x,47('-'),/,44x,'ols analysis',
     &' for station',1x,8a1,1x,', month',1x,a3,/,
     &43x,47('-'),////)
      stop
      end
c
c        -------------------------
c         subroutine rdta
c        -------------------------
c
```

```
      common/a3/icaus,ilag
      common/a4/name
      common/d5/month
      common/a5/ksum
      common/p1/jj1,jj2
      common/m14/ifin,ifout,ig,ih
      dimension dato(10,12,70),icaus(10,10),ilag(10,10),
     &    name(10,8),ksum(10),month(12)
      read(4,*)ne,ny,nm
      read(4,*)jj1,jj2
      read(4,*)igen,mq,igraph,itab,nsplit
      do 10 i=1,ne
10    read(4,15)(name(i,j),j=1,8)
15    format(8a1)
      do 20 i=1,ne
      read(4,*)(icaus(i,j),j=1,ne)
20    continue
      do 30 i=1,ne
      read(4,*)(ilag(i,j),j=1,ne)
30    continue
      read(4,*)ifin,ifout
      do 50 i=1,ne
      do 40 j=1,ny
40    read(15,*)(dato(i,k,j),k=1,nm)
50    continue
      if(ifin.eq.25)go to 70
      if(ifin.eq.10)go to 71
      if(ifin.eq.5)go to 72
      ig=4
      go to 80
70    ig=1
      go to 80
71    ig=2
      go to 80
72    ig=3
80    if(ifout.eq.25)go to 85
      if(ifout.eq.10)go to 86
      if(ifout.eq.5)go to 87
      ih=4
      go to 90
85    ih=1
      go to 90
86    ih=2
      go to 90
87    ih=3
90    continue
      if(nsplit.eq.0)go to 150
      ny1=ny
      nyy=ny/2
      nyyy=2*nyy
      if(nyyy.eq.ny)go to 160
      ny=nyy+1
      go to 150
160   ny=nyy
150   n=ny-1
      ng=nm*ne+1
      do 5 i=1,ne
5     ksum(i)=0
      do 7 i=1,ne
      do 6 j=1 ne
```

```
6     ksum(i)=ksum(i)+icaus(j,i)
7     continue
      return
      end
c
c
c          ---------------------
c           subroutine arre
c          ---------------------
c
c
           subroutine arre(i,j)
           common/a1/dato
           common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
           common/a3/icaus,ilag
           common/a4/name
           common/d5/month
           common/a5/ksum
           common/b2/idex
           common/a6/x
           dimension dato(10,12,70),icaus(10,10),ilag(10,10),
     &     name(10,8),ksum(10),idex(121),x(10000),month(12),mes(3),
     &     kkz(3),nam(3)
           ki=ksum(i)
           do 10 ik=2,ng
10         idex(ik)=0
           idex(1)=3
           write(mq,15)
15         format(10x,'** set of possible predictors',
     &     ///,3x,3(10x,'variable',4x,'station',4x,'month'),/)
17         kp=0
           do 60 iy=2,ny
           x(iy-1)=dato(i,j,iy)
           kk=1
           do 50 is=1,ne
           if(icaus(is,i).eq.0)go to 50
           kk=kk+1
           do 40 il=1,nm
           k=(il-1)*ki+kk
           lag=il+ilag(is,i)-1
           jj=j-lag
           ii=iy
           if(jj)20,20,30
20         ii=iy-1
           jj=nm+jj
30         im=iy-1+(k-1)*(ny-1)
           x(im)=dato(is,jj,ii)
           if(iy.gt.2)go to 40
           kp=kp+1
           nam(kp)=is
           mes(kp)=jj
           kkz(kp)=k
           if(kp.lt.3)go to 40
           m1=nam(1)
           m2=nam(2)
           m3=nam(3)
           j1=mes(1)
           j2=mes(2)
           j3=mes(3)
```

```
          k2=kkz(2)
          k3=kkz(3)
          write(mq,70)k1,(name(m1,jz1),jz1=1,8),month(j1),k2,
     &    (name(m2,jz2),jz2=1,8),month(j2),k3,(name(m3,jz3),jz3
     &    =1,8),month(j3)
          kp=0
 40       continue
 50       continue
 60       continue
          if(nsplit.eq.0)go to 80
          ny2=ny+2
          do 160 iy=ny2,ny1
          iy2=iy+5000
          x(iy2-1)=dato(i,j,iy)
          kk=1
          do 150 is=1,ne
          if(icaus(is,i).eq.0)go to 150
          kk=kk+1
          do 140 il=1,nm
          k=(il-1)*ki+kk
          lag=il+ilag(is,i)-1
          jj=j-lag
          ii=iy
          if(jj)120,120,130
 120      ii=iy-1
          jj=nm+jj
 130      im=iy-1+(k-1)*(ny1-ny-1)+5000
          x(im)=dato(is,jj,ii)
 140      continue
 150      continue
 160      continue
 70       format(15x,i3,7x,8a1,4x,a3,2(13x,i3,7x,8a1,4x,a3))
 80       return
          end
c
c
c         ----------------
c          subroutine stwr
c         ----------------
c
c
          subroutine stwr(ijkr)
          common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
          common/a9/xbar,std
          dimension xbar(121),std(121)
          m=nm*ki+1
          call corre
          if(itab.eq.0)go to 127
          write(mq,50)
 50       format(////,10x,'** mean and standard deviation values ',
     &    'of the set of possible predictors',///,
     &    3x,3(10x,'variable',4x,'mean',6x,'std dev'),//)
          write(mq,107)(i,xbar(i),std(i),i=1,m)
 107      format(15x,i3,2x,f10.2,2x,f9.2,13x,i3,2x,f10.2,2x
     &    ,f9.2,13x,i3,2x,f10.2,2x,f9.2,13x)
  127     call stpr(ier,ijkr)
          if(ier)158,159,158
```

```
     & /,42x,'negative implying extreme ill condition')
 159      return
          end
c
c
c         ------------------
c          subroutine corre
c         ------------------
c
c
          subroutine corre
          common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
          common/a6/x
          common/a8/b,d,t,s,l
          common/a9/xbar,std
          common/a7/rx,r
          dimension x(10000).b(150),d(121),t(121),s(121),l(121),
     &    xbar(121),std(121),r(7381)
          double precision rx(121,121)
          do 100 j=1,m
          b(j)=0.
 100      t(j)=0.
          k=(m*m+m)/2
          do 102 i=1,k
 102      r(i)=0.
          fn=n
          lp=0
          do 108 j=1,m
          do 107 i=1,n
          lp=lp+1
 107      t(j)=t(j)+x(lp)
          xbar(j)=t(j)
 108      t(j)=t(j)/fn
          do 115 i=1,n
          jk=0
          lp=i-n
          do 110 j=1,m
          lp=lp+n
          d(j)=x(lp)-t(j)
 110      b(j)=b(j)+d(j)
          do 115 j=1,m
          do 115 k=1,j
          jk=jk+1
 115      r(jk)=r(jk)+d(j)*d(k)
          jk=0
          do 210 j=1,m
          xbar(j)=xbar(j)/fn
          do 210 k=1,j
          jk=jk+1
 210      r(jk)=r(jk)-b(j)*b(k)/fn
          jk=0
          do 220 j=1,m
          jk=jk+j
 220      std(j)=sqrt(abs(r(jk)))
          jk=0
          do 230 i=1,m
```

```
      fn=sqrt(fn-1.)
      do 240 j=1,m
240   std(j)=std(j)/fn
      do 250 i=1,m
250   d(i)=rx(i,i)
      return
      end
c
c
c     -----------------
c      subroutine stpr
c     -----------------
c
c
c
      subroutine stpr(ier,ijkr)
      common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
      common/a9/xbar,std
      common/a7/rx,r
      common/b2/idex
      common/a8/b,d,t,s,l
      common/b1/nstep,ans
      common/g3/jcoef
      common/m14/ifin,ifout,ig,ih
      dimension xbar(121),std(121),r(7381),
     & idex(121),b(150),d(121),t(121),s(121),l(121),
     & nstep(5),ans(11),ll(121),jcoef(10,15),
     & u(121),jv2(34),f(34,4)
      double precision rx(121,121)
      data f/5.83,2.57,2.02,1.81,1.69,1.62,1.57,1.54,1.51,1.49
     & ,1.47,1.46,1.45,1.44,1.43,1.42,1.42,1.41,1.41,1.4,1.4,
     & 1.4,1.39,1.39,1.39,1.38,1.38,1.38,1.38,1.38,1.36,1.35,
     & 1.34,1.32,39.86,8.53,5.54,4.54,4.06,3.78,3.59,3.46,
     & 3.36,3.29,3.23,3.18,3.4,3.1,3.07,3.05,3.03,3.01,2.99,
     & 2.97,2.96,2.95,2.94,2.93,2.92,2.91,2.9,2.89,2.89,2.88,
     & 2.84,2.79,2.75,2.71,161.4,18.51,10.13,7.71,6.61,5.99,
     & 5.59,5.32,5.12,4.96,4.84,4.75,4.67,4.6,4.54,4.49,4.45,
     & 4.41,4.38,4.35,4.32,4.3,4.28,4.26,4.24,4.23,4.21,
     & 4.2,4.18,4.17,4.08,4.0,3.92,3.84,4052.0,98.5,34.12,
     & 21.2,16.26,13.75,12.25,11.26,10.56,10.04,9.65,9.33,
     & 9.07,8.86,8.68,8.53,8.4,8.29,8.18,8.1,8.02,7.95,7.88,
     & 7.82,7.77,7.72,7.68,7.64,7.6,7.56,7.31,7.08,6.85,6.63/
      data jv2 /1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,
     & 19,20,21,22,23,24,25,26,27,28,29,30,40,60,120,10000/
      ier=0
      tol=0.001
      sh=rx(1,1)
      sa=rx(1,1)
      np=0
      nt=0
5     nt=nt+1
      if(np.eq.0)go to 15
      vn=-fout*sh
      vcom=vn
      jcont=-1
      do 10 i=2,m
      if(rx(i,i).ge.0.)go to 10
      jcont=jcont+1
      vk=rx(1,i)*rx(i,1)/rx(i,i)
      if(jcont.eq.0)vcom=vk
      if(vk.lt.vcom)go to 10
```

```
          vcom=vk
          k=i
10        continue
          mj=n-np-1
          do 11 j=2,34
          if(jv2(j-1).le.mj.and.jv2(j).gt.mj)go to 12
11        continue
12        fout=(mj-jv2(j-1))*(f(j,ih)-f(j-1,ih))/(jv2(j)-jv2(j-1))
     &    +f(j-1,ih)
          if(vcom.eq.vn)write(mq,14)
14        format(//,10x,'** warning: possible problems with the '
     &    'stepwise regression',/)
          if((1+np-n)*vcom/rx(1,1).lt.fout)go to 30
15        icon=-1
          inum=-1
          do 20 i=2,m
          ralv=rx(i,i)/d(i)
          if(ralv.lt.tol)go to 20
          icon=0
          inum=inum+1
          vk=rx(1,i)**2/rx(i,i)
          if(inum.eq.0)vcan=vk
          if(vk.lt.vcan)go to 20
          vcan=vk
          k=i
20        continue
          if(icon.eq.-1)go to 75
          mj=n-np-1
          do 24 j=2,34
          if(jv2(j-1).le.mj.and.jv2(j).gt.mj)go to 25
24        continue
25        fin=(mj-jv2(j-1))*(f(j,ig)-f(j-1,ig))/(jv2(j)-jv2(j-1))
     &    +f(j-1,ig)
          if((n-np-2)*vcan/(rx(1,1)-vk).lt.fin)go to 75
          flag=-1.
          np=np+1
          go to 40
30        flag=1.
          np=np-1
40        c=rx(k,k)
          do 50 i=1,k
          u(i)=rx(i,k)
50        rx(i,k)=0.
          do 60 i=k,m
          u(i)=rx(k,i)
60        rx(k,i)=0.
          u(k)=flag
          do 70 i=1,m
          do 70 j=i,m
70        rx(i,j)=rx(i,j)-u(i)*u(j)/c
          if(np.eq.0)go to 5
          ntmp=np/5
          ntmp=ntmp*5
          if(np.ne.ntmp)go to 5
          write(mq,72)nt
72        format(////,10x,'** partial stepwise regression results ',
     &    'after',i3,1x,'steps',//)
          nstop=0
          go to 80
75        write(mq,77)
```

```
      nstop=1
77    format(////,10x,'** final stepwise regression results',//)
80    ndf=n-np-1
      write(mq,205)ifin,ifout
205   format(13x,'significance levels for f test: entry',i3,
     &'%',/,45x,'deletion',i3,'%',//)
      ss=rx(1,1)
      sd=sa-ss
      sa=ss
      zms=ss/ndf
      nrdf=np
      rss=d(1)-ss
      cpr=rss/sh
      rms=rss/np
      ff=rms/zms
      sss=sqrt(zms)
      rg=sqrt(rss/d(1))
      ans(9)=xbar(1)
      write(mq,200)nt,k
200   format(13x,'step number',i3,//,13x,'variable entered',
     &' or deleted',i4)
      write(mq,210)rss
210   format(13x,'cumulative sum of squares reduced ',
     &'......',2x,e13.7,//)
      write(mq,220)sh,cpr
220   format(13x,'total sum of squares ',19('.'),2x,e13.7,/,
     &13x,'cumulative proportion reduced ',10('.'),2x,e13.7,//)
      write(mq,230)nrdf,ndf
230   format(13x,'degree of freedom: regression',i3,/,32x,
     &'residual',2x,i3,//)
      write(mq,240)ff,rg,sss
240   format(13x,'f-value for analysis of variance .......',
     &2x,e13.7,/,13x,'multiple correlation coefficient ',
     &'.......',2x,e13.7,/,13x,'standard error of estimate ',
     &'.............',2x,e13.7,//)
      write(mq,250)
250   format(13x,'variables in equation:',//,35x,'variable',
     &5x,'regression',6x,'std. error of',4x,'f-value',/,36x,
     &'number',6x,'coefficient',6x,'reg. coeff.',//)
      je=0
      do 90 i=2,m
      if(rx(i,i).ge.0.)go to 90
      je=je+1
      b(je)=rx(1,i)
      s(je)=(-zms*rx(i,i))**0.5
      t(je)=(b(je)/s(je))**2
      ans(9)=ans(9)-b(je)*xbar(i)
      write(mq,260)i,b(je),s(je),t(je)
      l(je)=i
      jcoef(ijkr,je)=i
260   format(37x,i3,7x,f12.5,5x,f12.6,3x,f9.3)
90    continue
      write(mq,270)ans(9)
      if(nstop.eq.0)go to 5
270   format(35x,'constant',4x,f12.5)
```

```
c         ------------------
c          subroutine calres
c         ------------------
c
c
          subroutine calres(i)
          common/b6/nki
          common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
          common/a8/b,d,t,s,l
          common/b1/nstep,ans
          common/b3/xx,yy
          common/a6/x
          common/b5/ry
          dimension b(150),d(121),t(121),s(121),l(121),nstep(5),
     &    ans(11),xx(70,15,10),yy(70,10),ry(70,10),x(10000),nki(10)
          dimension bi(3),bj(3),bk(3)
          ka=0
          if(itab.eq.0)go to 54
          write(mq,50)
 50       format(///,10x,'** table of residuals',//,2x,3(11x,
     &    'y value',5x,'y est.',3x,'residual'),/)
 54       nz=nstep(4)
          nki(i)=nz
          do 200 ib=1,n
          yest=ans(9)
          xx(ib,1,i)=1.
          yy(ib,i)=x(ib)
          do 100 jb=1,nz
          nk=n*(l(jb)-1)+ib
          yest=yest+b(jb)*x(nk)
          jc=jb+1
          xx(ib,jc,i)=x(nk)
 100      continue
          ka=ka+1
          bi(ka)=x(ib)
          bj(ka)=yest
          ry(ib,i)=x(ib)-yest
          bk(ka)=ry(ib,i)
          if(ka.lt.3)go to 200
          if(itab.eq.0)go to 143
          write(mq,300)(bi(kp),bj(kp),bk(kp),kp=1,3)
 143      ka=0
 200      continue
          if(nsplit.eq.0)go to 600
          ny2=ny+1
          ny3=ny1-1
          do 400 ib=ny2,ny3
          yest=ans(9)
          xx(ib,1,i)=1.
          ib1=ib+5000
          yy(ib,i)=x(ib1)
          do 500 jb=1,nz
          nk=(ny1-ny-1)*(l(jb)-1)+ib+5000
          yest=yest+b(jb)*x(nk)
          jc=jb+1
          xx(ib,jc,i)=x(nk)
 500      continue
          ry(ib,i)=x(ib1)-yest
```

```
     &    1x,f10.2,1x,f8.2))
600       nzz=nz+1
          return
          end
c
c
c         -------------------
c          subroutine estres
c         -------------------
c
c
          subroutine estres(i)
          common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
          common/b2/sl
          common/b5/ry
          dimension sl(121),ry(70,10)
          xn=n
          sum1=0.
          sum2=0.
          do 100 ky=1,3
100       sl(ky)=0.
          do 300 ky=1,n
          sum1=sum1+ry(ky,i)
          sum2=sum2+ry(ky,i)**2
          do 200 ja=1,3
          if(ky.lt.(xn-ja+1))sl(ja)=sl(ja)+ry(ky,i)*ry(ky+ja,i)
200       continue
300       continue
          sum1=sum1/xn
          xmse=sum2/(xn+1.)
          sum2=sqrt(abs(sum2/xn-sum1**2))
          do 400 ky=1,3
          sl(ky)=sl(ky)/(xn-ky)
          if(sum2.ne.0.)sl(ky)=sl(ky)/sum2**2-sum1**2/sum2**2
400       continue
          write(mq,500)sum1,sum2,xmse,(sl(ky),ky=1,3)
500       format(///,10x,'** residual statistics:',//,34x,
     &    'mean ',19('.'),f12.4,/,34x,'std dev ',16('.')
     &    ,f12.4,/,34x,'mean square error ......',1x,e11.5,
     &    /,34x,'correlation at lag 1 ...',
     &   f12.4,/,46x,'at lag 2 ...',f12.4,/,46x,'at lag 3 ...',f12.4)
          if(nsplit.eq.0)go to 1000
          xn=ny1-ny-1
          sum1=0.
          sum2=0.
          do 600 ky=1,3
600       sl(ky)=0.
          ny2=ny+1
          ny3=ny1-1
          do 700 ky=ny2,ny3
          sum1=sum1+ry(ky,i)
          sum2=sum2+ry(ky,i)**2
          do 800 ja=1,3
          if(ky.lt.(ny1-ja))sl(ja)=sl(ja)+ry(ky,i)*ry(ky+ja,i)
800       continue
700       continue
          sum1=sum1/xn
          sum3=sum2
          sum2=sqrt(abs(sum2/xn-sum1**2))
          xmse=sum3/(xn+1.)
```

```
      do 900 ky=1,3
      sl(ky)=sl(ky)/(xn-ky)
      if(sum2.ne.0.)sl(ky)=sl(ky)/sum2**2-sum1**2/sum2**2
900   continue
      write(mq,950)sum1,sum2,xmse,(sl(ky),ky=1,3)
950   format(///,10x,'** residual statistics for the second ',
     &'half of the data:',//,34x,'mean ',19('.'),f12.4,/,34x,
     &'std dev ',16('.'),f12.4,/,34x,'mean square error ',
     &6('.'),1x,e11.5,/,34x,'correlation at lag 1 ...',
     &f12.4,/,46x,'at lag 2 ...',f12.4,/,46x,'at lag 3 ...',f12.4)
1000  return
      end
c
c
c     ----------------
c      subroutine nor
c     ----------------
c
c
      subroutine nor(i,j)
      common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
      common/b5/ry
      common/a8/b,a,pro,s,l
      common/a4/name
      common/d5/month
      common/d7/itx,ity
      dimension ry(70,10),b(150),a(121),pro(121),s(121),l(121),
     &name(10,8),month(12),bx(15),by(15),itx(75),ity(40)
      dimension prob(51)
      logical c(45,105)
      logical punto/'*'/,blanco/' '/
      data prob/0.00621,0.0082,0.01072,0.0139,
     &0.01786,0.02275,0.02872,0.0359,
     &0.04457,0.0548,0.06681,0.08076,0.0968,0.1151,0.1357,0.1587,0.1841,
     &0.2119,0.242,0.2743,0.3085,0.3446,0.3821,0.4207,0.4602,0.5,0.5398,
     &0.5793,0.6179,0.6554,0.6915,0.7257,
     &0.758,0.7881,0.8159,0.8413,0.8643,
     &0.8849,0.9032,0.91924,0.93319,0.9452,0.95543,0.96407,0.97128,
     &0.97725,0.98214,0.98610,0.98928,0.9918,0.99379/
       do 50 lw=1,45
       do 50 lz=1,105
50    c(lw,lz)=blanco
      do 100 ik=1,n
      a(ik)=ry(ik,i)
100   continue
      do 300 ij=1,n
      do 200 jl=ij,n
      if(a(ij).le.a(jl))go to 200
      bk=a(jl)
      a(jl)=a(ij)
      a(ij)=bk
200   continue
300   continue
      do 400 ik=1,n
      bk=ik
      pro(ik)=bk/(n+1)
400   continue
      write(mq,500)
500   format('1',///,10x,'** normal probability plot',//)
```

```
      sum2=0.
      sum3=0.
      sum4=0.
      sum5=0.
      nh=101
      nv=40
      xmax=0.994
      xmin=0.006
      ymax=a(n)+1.
      ymin=a(1)-1.
      y2=ymin-ymax
      do 600 k=1,n
      kk=n-k+1
      y1=a(kk)-ymax
      t=(nv-1)*y1/y2+1.
      ii=int(t)
      if(t-ii.gt.0.5)ii=ii+1
      do 650 ke=2,51
      if(prob(ke-1).le.pro(kk).and.pro(kk).lt.prob(ke))go to 630
      go to 650
630   em=(prob(ke)+prob(ke-1))/2.
      sum1=sum1+a(k)
      sum2=sum2+em
      sum3=sum3+a(k)*em
      sum4=sum4+a(k)*a(k)
      sum5=sum5+em*em
      jj=(ke-1)*2-1
      if(pro(kk).ge.em)jj=jj+1
      go to 660
650   continue
660   c(ii,jj)=punto
600   continue
      kla=5
      klb=1
      do 700 k=1,11
      bx(k)=prob(klb)
      klb=klb+kla
700   continue
      aa=(ymax-ymin)/5.
      do 800 k=1,6
      by(k)=ymax-(k-1)*aa
800   continue
      k=1
      lg=1
      do 950 ii=1,nv
      if(k.eq.ii)go to 920
      write(mq,910)ity(ii),(c(ii,jj),jj=1,nh)
910   format(7x,a1,t20,'I',101a1)
      go to 950
920   write(mq,930)ity(ii),by(lg),(c(ii,jj),jj=1,nh)
930   format(7x,a1,2x,f8.2,t20,'+',101a1)
      k=k+8
      lg=lg+1
950   continue
      write(mq,960)ymin,(bx(ii),ii=1,11)
960   format(10x,f8.2,t20,10('+',9('-')),'+',/,t14,11(f10.4))
      write(mq,970)(itx(ii),ii=1,75)
970   format(/,40x,75a1)
      z1=sum3-sum1*sum2/n
      z2=sum4-sum1*sum1/n
```

```
      z3=sum5-sum2*sum2/n
      a1=z1/z2
      a0=sum2/n-a1*sum1/n
      r2=z1*z1/(z2*z3)
      write(mq,990)a0,a1,r2
990   format(///,10x,'** linear regression: cdf =',2x,f10.5,1x,
     & '+',1x,f10.5,1x,'* residual',5x,'; r2 = ',f10.5)
      return
      end
c
c
c     -------------------
c      subroutine genls
c     -------------------
c
c
      subroutine genls(j)
      common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
      common/a8/b,daf,tsr,sla,ljm
      common/b5/ry
      common/b6/nki
      common/b4/sig
      common/b3/xx,yy
      common/a6/cf
      common/a4/name
      common/d5/month
      common/a7/a,yz
      common/g3/jcoef
      common/j9/dd1
      dimension bi(3),bj(3),bk(3),name(10,8),sig1(10,10),
     & month(12),bt(10,10),ry(70,10),nki(10),sig(10,10),
     & xx(70,15,10),yy(70,10),cf(100,100),yz(7381)
      dimension b(150),daf(121),tsr(121),sla(121),ljm(121),
     & jcoef(10,15)
      double precision a(14641),dd1
      nzy=-1
      write(mq,5)month(j)
5     format('1',////,50x,25('*'),/,51x,'gls analysis, month ',
     & a3,/,50x,25('*'),//)
5316  nzy=nzy+1
      nkm=0
      do 10 ks=1,ne
      nkm=nkm+nki(ks)
      do 10 kt=1,ne
10    sig(ks,kt)=0.
      nkm=nkm+ne
      do 40 ks=1,ne
      do 30 kt=ks,ne
      su1=0.
      su2=0.
      su3=0.
      su4=0.
      su5=0.
      do 20 kr=1,n
      su1=su1+ry(kr,ks)
      su2=su2+ry(kr,kt)
      su3=su3+ry(kr,ks)*ry(kr,kt)
      su4=su4+ry(kr,ks)*ry(kr,ks)
      su5=su5+ry(kr,kt)*ry(kr,kt)
      sig(ks,kt)=sig(ks,kt)+ry(kr,ks)*ry(kr,kt)
```

```
20         continue
           sig(ks,kt)=sig(ks,kt)/(sqrt(n-nki(ks))*sqrt(n-nki(kt)))
           sig(kt,ks)=sig(ks,kt)
           su6=su3-su1*su2/n
           su7=sqrt(su4-su1*su1/n)
           su8=sqrt(su5-su2*su2/n)
           sig1(ks,kt)=su6/(su7*su8)
           sig1(kt,ks)=sig1(ks,kt)
30         continue
40         continue
           if(nzy.gt.0)go to 2019
           write(mq,2007)
           go to 2086
2019       write(mq,2008)nzy
2008       format(///,10x,'** residual correlation matrix of gls ',
     &     'estimation, (iteration',i3,' ):',//)
2007       format(///,10x,'** residual correlation matrix of ols ',
     &     'estimation: ',//)
2086       write(mq,2050)((name(ks,kt),kt=1,8),ks=1,ne)
2050       format(23x,10(8a1,2x),/)
           write(mq,2059)
2059       format(/,'  ')
           do 2000 kjf=1,ne
2000       write(mq,1000)(name(kjf,ks),ks=1,8),(sig1(kjf,kfg),kfg=1,ne)
1000       format(13x,8a1,3x,10(f6.3,4x),/)
           if(nzy.gt.0)go to 1234
           do 772 ks=1,ne
           do 772 kr=1,ne
           bt(ks,kr)=sig1(ks,kr)
772        continue
           go to 109
1234       calcom=0.
           do 775 ks=1,ne
           do 776 kr=1,ne
           if(ks.eq.kr)go to 776
           rat=(bt(ks,kr)-sig1(ks,kr))/bt(ks,kr)
           rat=abs(rat)
           if(rat.gt.calcom)calcom=rat
776        continue
775        continue
           valc=100.*calcom
           if(calcom.le.0.05)go to 5308
           do 595 ks=1,ne
           do 595 kr=1,ne
595        bt(ks,kr)=sig1(ks,kr)
           write(mq,748)valc,nzy
748        format(///,10x,'** ',f6.2,' maximum percentaje of ',
     &     'crosscorrelation difference between two consecutive ',
     &     'iterations, at iteration',i3)
           if(nzy.gt.20)go to 832
           go to 109
5308       write(mq,748)valc,nzy
           write(mq,749)
749        format(13x,'less than the tolerance limit;therefore gls ends')
832        go to 340
109        continue
           kminv=0
           do 381 jp=1,ne
           do 381 jq=1,ne
           kminv=kminv+1
```

```
381     a(kminv)=sig(jq,jp)
        call invm(ne)
        if(dd1.eq.0)go to 46
        kminv=0.
        do 382 jp=1,ne
        do 382 jq=1,ne
        kminv=kminv+1
382     sig(jq,jp)=a(kminv)
        go to 47
46      write(mq,48)
48      format(10x,'** matrix sig is singular',//)
        go to 340
47      do 110 im=1,ne
        kc=im-1
        nna=nki(im)+1
        do 50 km=1,im
50      kc=kc+nki(km)
        kc=kc-nki(im)
        do 100 in=1,ne
        nnb=nki(in)+1
        kd=in-1
        do 60 kn=1,in
60      kd=kd+nki(kn)
        kd=kd-nki(in)
        do 90 jm=1,nna
        do 80 jn=1,nnb
        c=0.
        do 70 ib=1,n
        c=c+xx(ib,jm,im)*xx(ib,jn,in)
70      continue
        ie=kc+jm
        if=kd+jn
        cf(ie,if)=c*sig(im,in)
80      continue
90      continue
100     continue
110     continue
        kminv=0
        do 383 jp=1,nkm
        do 383 jq=1,nkm
        kminv=kminv+1
383     a(kminv)=cf(jq,jp)
        call invm(nkm)
        if(dd1.eq.0.)go to 121
        kminv=0
        do 384 jp=1,nkm
        do 384 jq=1,nkm
        kminv=kminv+1
384     cf(jq,jp)=a(kminv)
        go to 122
121     write(mq,4023)
4023    format(//,10x,'** the variance-covariance matrix of ',
     &  'the regression',/,13x,'coefficients is algorithmically'
     &  ,' singular; the gls analysis is ended')
        go to 340
122     do 240 im=1,ne
        nna=nki(im)+1
        kc=im-1
        do 200 km=1,im
200     kc=kc+nki(km)
```

```
      kc=kc-nki(im)
      do 230 jm=1,nna
      cc=0.
      do 220 in=1,ne
      c=0.
      do 210 ib=1,n
      c=c+xx(ib,jm,im)*yy(ib,in)
210   continue
      c=sig(im,in)*c
      cc=cc+c
220   continue
      ie=kc+jm
      yz(ie)=cc
230   continue
240   continue
      do 270 ip=1,nkm
      c=0.
      do 260 iq=1,nkm
      c=c+cf(ip,iq)*yz(iq)
260   continue
      b(ip)=c
270   continue
      ixio=0
      nazb=nzy+1
      do 330 im=1,ne
      write(mq,8072)(name(im,iq),iq=1,8),nazb
8072  format(////,47x,32('-'),/,48x,'station',1x,8a1,' iteration '
     & ,i2,/,47x,32('-'),///,10x,'** gls regression results:',/)
      write(mq,8076)
8076  format(/,42x,'variable',5x,'regression',6x,'std. error of'
     & ,/,43x,'number',6x,'coefficient',6x,'reg. coeff.',/)
      nna=nki(im)+1
      kc=im-1
      do 300 km=1,im
300   kc=kc+nki(km)
      kc=kc-nki(im)
      kq=kc+1
      ixio=ixio+1
      scov=sqrt(cf(ixio,ixic))
      write(mq,8039)b(kq),scov
8039  format(42x,'constant',4x,f12.5,5x,f12.6)
      nmb=nna-1
      do 305 kp=1,nmb
      kq=kp+kc+1
      ixio=ixio+1
      scov=sqrt(cf(ixio,ixio))
305   write(mq,8003)jcoef(im,kp),b(kq),scov
8003  format(44x,i3,7x,f12.5,5x,f12.6)
      if(itab.eq.0)go to 4391
      write(mq,5437)
5437  format(///,10x,'** table of residuals',//,2x,3(11x,
     & 'y value',5x,'y est.',3x,'residual'),/)
4391  ia=0
      do 320 ib=1,n
      c=0.
      do 310 kp=1,nna
      kq=kp+kc
      c=c+xx(ib,kp,im)*b(kq)
310   continue
      ry(ib,im)=yy(ib,im)-c
```

```
      ia=ia+1
      bi(ia)=yy(ib,im)
      bj(ia)=c
      bk(ia)=ry(ib,im)
      if(ia.lt.3)go to 320
      if(itab.eq.0)go to 6329
      write(mq,315)(bi(ia),bj(ia),bk(ia),ia=1,3)
6329  ia=0
315   format(10x,f10.2,1x,f10.2,1x,f8.2,2(10x,
     & f10.2,1x,f10.2,1x,f8.2))
320   continue
      if(nsplit.eq.0)go to 325
      ny2=ny+1
      ny3=ny1-1
      do 321 ib=ny2,ny3
      c=0.
      do 311 kp=1,nna
      kq=kp+kc
      c=c+xx(ib,kp,im)*b(kq)
311   continue
      ry(ib,im)=yy(ib,im)-c
321   continue
 325  call estres(im)
      call durwat(im,j)
      if(igraph.eq.0)go to 330
      call nor(im,j)
      write(mq,4444)
4444  format('1')
330   continue
      go to 5316
340   return
      end
c
c
c     --------------------
c      subroutine durwat
c     --------------------
c
c
      subroutine durwat(i,j)
      common/a2/ne,ny,nm,ng,n,m,ki,igen,mq,igraph,itab,nsplit,ny1
      common/a3/icaus,ilag
      common/b1/nstep,ans
      common/b5/ry
      common/a8/b,d,t,s,l
      common/g3/jcoef
      common/b6/nki
      common/f9/dwl,dwu,dwl1,dwu1
      dimension ndw(38),dwl(38,5),dwu(38,5),dwl1(38,5),dwu1(38,5)
      dimension icaus(10,10),ilag(10,10),nstep(5),ans(11),ry(70,10)
     & ,b(150),d(121),t(121),s(121),l(121),jcoef(10,15),nki(10)
      data ndw/15,16,17,18,19,20,21,22,23,24,25,26,27,
     & 28,29,30,31,32,33,34,35,36,37,38,39,40,45,50,55,
     & 60,65,70,75,80,85,90,95,100/
      mig1=5
      mig2=1
      write(mq,30)
30    format(///,10x,'** durbin-watson test:',/)
      aa=0.
      bb=ry(1,i)**2
```

```
        do 50 ib=2,n
        aa=aa+(ry(ib,i)-ry(ib-1,i))**2
        bb=bb+ry(ib,i)**2
50      continue
        dd=aa/bb
        lw=0
        do 100 jb=1,i
        lw=lw+icaus(jb,i)
100     continue
        lww=0
        do 120 jb=1,ne
        lww=lww+icaus(jb,i)
120     continue
        nz=nki(i)
        lwa=il*lww+lw+1
        do 150 jb=1,nz
        if(jcoef(i,jb).eq.lwa)go to 800
150     continue
        write(mq,7327)
7327    format(13x,'there is not a lagged autoregressive term')
200     if(nz.eq.0)go to 750
        if(n.lt.15)go to 700
        if(nz.gt.5)go to 500
        if(dd.gt.2.)go to 350
        do 250 ie=2,38
        if(ndw(ie-1).le.n.and.ndw(ie).gt.n)go to 300
250     continue
300     dl=dwl(ie-1,nz)+(dwl(ie,nz)-dwl(ie-1,nz))*
     &  (n-ndw(ie-1))/(ndw(ie)-ndw(ie-1))
        du=dwu(ie-1,nz)+(dwu(ie,nz)-dwu(ie-1,nz))*
     &  (n-ndw(ie-1))/(ndw(ie)-ndw(ie-1))
        dl1=dwl1(ie-1,nz)+(dwl1(ie,nz)-dwl1(ie-1,
     &  nz))*(n-ndw(ie-1))/(ndw(ie)-ndw(ie-1))
        du1=dwu1(ie-1,nz)+(dwu1(ie,nz)-dwu1(ie-1,
     &  nz))*(n-ndw(ie-1))/(ndw(ie)-ndw(ie-1))
        if(dd.lt.dl)go to 305
        if(dd.gt.du)go to 315
        write(mq,304)mig1
        go to 340
304     format(13x,'the test is inconclusive; significance ',
     &  'level',i2,'%')
305     write(mq,310)mig1
310     format(13x,'positive first order autocorrelation'
     &  ,'; significance level',i2,'%')
        go to 340
315     write(mq,320)mig1
320     format(13x,'non autocorrelated; significance level',
     &  i2,'%')
340     if(dd.lt.dl1)go to 341
        if(dd.gt.du1)go to 342
        write(mq,304)mig2
        go to 850
341     write(mq,310)mig2
        go to 850
342     write(mq,320)mig2
        go to 850
350     de=4.-dd
        do 400 ie=2,38
        if(ndw(ie-1).le.n.and.ndw(ie).gt.n)go to 450
400     continue
```

```
450     dl=dwl(ie-1,nz)+(dwl(ie,nz)-dwl(ie-1,nz))*
     &  (n-ndw(ie-1))/(ndw(ie)-ndw(ie-1))
        du=dwu(ie-1,nz)+(dwu(ie,nz)-dwu(ie-1,nz))*
     &  (n-ndw(ie-1))/(ndw(ie)-ndw(ie-1))
        dl1=dwl1(ie-1,nz)+(dwl1(ie,nz)-dwl1(ie-1,
     &  nz))*(n-ndw(ie-1))/(ndw(ie)-ndw(ie-1))
        du1=dwu1(ie-1,nz)+(dwu1(ie,nz)-dwu1(ie-1,
     &  nz))*(n-ndw(ie-1))/(ndw(ie)-ndw(ie-1))
        if(de.lt.dl)go to 455
        if(de.gt.du)go to 465
        write(mq,475)mig1
475     format(13x,'the test is inconclusive; ',
     &  'significance level',i2,'%')
        go to 480
455     write(mq,460)mig1
460     format(13x,'negative first order autocorrelation; ',
     &  'significance level',i2,'%')
        go to 480
465     write(mq,470)mig1
470     format(13x,'non autocorrelated; significance ',
     &  'level',i2,'%')
480     if(de.lt.dl1)go to 485
        if(de.gt.du1)go to 486
        write(mq,475)mig2
        go to 850
485     write(mq,460)mig2
        go to 850
486     write(mq,470)mig2
        go to 850
500     write(mq,610)
610     format(13x,'the number of variables is greater than ',
     &  '5; the test cannot be performed')
        go to 850
700     write(mq,720)
720     format(13x,'the number of observations is less than ',
     &  '15; the test cannot be performed')
        go to 850
750     write(mq,760)
760     format(13x,'there is not any explanatory variable')
        go to 850
800     write(mq,1027)
1027    format(13x,'there is a lagged autoregressive term')
        if(n.ge.30)go to 807
        write(mq,1055)
1055    format(13x,'the number of observations is less ',
     &  'than 30. the test cannot be performed')
        go to 850
807     r=1-0.5*dd
        rs=n*s(jb)**2
        if(rs.ge.1.)go to 845
        h=r*sqrt(n/(1-rs))
        if(h.gt.1.645)go to 830
        write(mq,820)mig1
820     format(13x,'not reject the hypothesis of zero ',
     &  'autocorrelation; significance level',i2,'%')
        go to 842
830     write(mq,840)mig1
840     format(13x,'reject the hypothesis of zero ',
     &  'autocorrelation; significance level',i2,'%')
842     if(h.gt.2.327)go to 843
```

```
      write(mq,820)mig2
      go to 850
843   write(mq,840)mig2
      go to 850
845   write(mq,846)
846   format(13x,'the durbin-watson test for lagged ',
     &'variables cannot be used')
850   return
      end
c
c
c     -----------------
c      subroutine invm
c     -----------------
c
c
      subroutine invm(n)
      common/a8/zz,za,zb,zc,l
      common/a7/a,r
      common/b2/m
      common/j9/d
      dimension r(7381),zz(150),za(121),zb(121),
     &zc(121),l(121),m(121)
      double precision d,biga,hold,a(14641)
      d=1.
      nk=-n
      do 80 k=1,n
      nk=nk+n
      l(k)=k
      m(k)=k
      kk=nk+k
      biga=a(kk)
      do 20 j=k,n
      iz=n*(j-1)
      do 20 i=k,n
      ij=iz+i
10    if(dabs(biga)-dabs(a(ij)))15,20,20
15    biga=a(ij)
      l(k)=i
      m(k)=j
20    continue
      j=l(k)
      if(j-k)35,35,25
25    ki=k-n
      do 30 i=1,n
      ki=ki+n
      hold=-a(ki)
      ji=ki-k+j
      a(ki)=a(ji)
30    a(ji)=hold
35    i=m(k)
      if(i-k)45,45,38
38    jp=n*(i-1)
      do 40 j=1,n
      jk=nk+j
      ji=jp+j
      hold=-a(jk)
      a(jk)=a(ji)
40    a(ji)=hold
45    if(biga)48,46,48
```

```
46        d=0.0
          return
48        do 55 i=1,n
          if(i-k)50,55,50
50        ik=nk+i
          a(ik)=a(ik)/(-biga)
55        continue
          do 65 i=1,n
          ik=nk+i
          hold=a(ik)
          ij=i-n
          do 65 j=1,n
          ij=ij+n
          if(i-k)60,65,60
60        if(j-k)62,65,62
62        kj=ij-i+k
          a(ij)=hold*a(kj)+a(ij)
65        continue
          kj=k-n
          do 75 j=1,n
          kj=kj+n
          if(j-k)70,75,70
70        a(kj)=a(kj)/biga
75        continue
          a(kk)=1./biga
80        continue
          k=n
100       k=k-1
          if (k)150,150,105
105       i=l(k)
          if(i-k)120,120,108
108       jq=n*(k-1)
          jr=n*(i-1)
          do 110 j=1,n
          jk=jq+j
          hold=a(jk)
          ji=jr+j
          a(jk)=-a(ji)
110       a(ji)=hold
120       j=m(k)
          if(j-k)100,100,125
125       ki=k-n
          do 130 i=1,n
          ki=ki+n
          hold=a(ki)
          ji=ki-k+j
          a(ki)=-a(ji)
130       a(ji)=hold
          go to 100
150       return
          end
c
c
c         -----------
c          block data
c         -----------
c
c         the block data contains the tables required
c         in the durbin-watson test, the names of
c         the months and the titles of the axes for
```

```
c          the normal probability plots
c
c
           block data
           common/d5/month
           common/f9/dwl,dwu,dwl1,dwu1
           common/d7/itx,ity
           dimension month(12),dwl(38,5),dwu(38,5),itx(75),ity(40)
           dimension dwl1(38,5),dwu1(38,5)
           data dwl/1.08,1.1,1.13,1.16,1.18,1.2,1.22,1.24,1.26,1.27,
     &1.29,1.3,1.32,1.33,1.34,1.35,1.36,1.37,1.38,1.39,1.4,1.41,1.42,
     &1.43,1.43,1.44,1.48,1.50,1.53,1.55,1.57,1.58,1.60,1.61,1.62,1.63
     &,1.64,1.65,0.95,0.98,1.02,1.05,1.08,1.1,1.13,1.15,1.17,1.19,
     &1.21,1.22,1.24,1.26,1.29,1.29,1.30,1.31,1.32,1.33,1.34,1.35,1.36
     &,1.37,1.38,1.39,1.43,1.46,1.49,1.51,1.54,1.55,1.57,1.59,1.60,
     &1.61,1.62,1.63,0.82,0.86,.9,.93,.97,1.,1.03,1.05,1.08,1.1,1.12,
     &1.14,1.16,1.18,1.2,1.21,1.23,1.24,1.26,1.27,1.28,1.29,1.31,1.32,
     &1.33,1.34,1.38,1.42,1.45,1.48,1.50,1.52,1.54,1.56,1.57,1.59,1.6,
     &1.61,0.69,.74,.78,.82,.86,.9,.93,.96,.99,1.01,1.04,1.06,1.08,1.1,
     &1.12,1.14,1.16,1.18,1.19,1.21,1.22,1.24,1.25,1.26,1.27,1.29,1.34,
     &1.38,1.41,1.44,1.47,1.49,1.51,1.53,1.55,1.57,1.58,1.59,.56,
     &.62,.67,.71,.75,.79,.83,.86,.9,.93,.95,.98,1.01,1.03,1.05,1.07
     &,1.09,1.11,1.13,1.15,1.16,1.18,1.19,1.21,1.22,1.23,1.29,1.34,
     &1.38,1.41,1.44,1.46,1.49,1.51,1.52,1.54,1.56,1.57/
           data dwu/1.36,1.37,1.38,1.39,1.4,1.41,1.42,1.43,1.44,1.45,
     &1.45,1.46,1.47,1.48,1.48,1.49,1.50,1.5,1.51,1.51,1.52,1.52,1.53,
     &1.54,1.54,1.54,1.57,1.59,1.6,1.62,1.63,1.64,1.65,1.66,1.67,1.68,
     &1.69,1.69,1.54,1.54,1.54,1.53,1.53,1.54,1.54,1.54,1.54,
     &1.55,1.55,1.55,1.56,1.56,1.56,1.57,1.57,1.57,1.58,1.58,1.58,
     &1.59,1.59,1.59,1.6,1.6,1.62,1.63,1.64,1.65,1.66,
     &     1.67,1.68,1.69,1.7,1.7,
     &1.71,1.72,1.75,1.73,1.71,1.69,1.68,1.68,1.67,1.66,1.66,1.66,
     &1.66,1.65,1.65,1.65,1.65,1.65,1.65,1.65,1.65,1.65,1.65,1.65,
     &1.66,1.66,1.66,1.66,1.67,1.67,1.68,1.69,1.7,1.7,1.71,
     &     1.72,1.72,1.73,1.73,1.64,
     &1.97,1.93,1.9,1.87,1.85,1.83,1.81,1.8,1.79,1.78,1.77,1.76,1.76,
     &1.75,1.74,1.74,1.74,1.73,1.73,1.73,1.73,1.73,1.72,1.72,1.72,
     &1.72,1.72,1.72,1.72,1.73,1.73,1.74,1.74,1.74,1.75,1.75,1.75,
     &1.76,2.21,2.15,2.1,2.06,2.02,1.99,1.96,1.94,1.92,1.9,1.89,
     &1.88,1.86,1.85,1.84,1.83,1.83,1.82,1.81,1.81,1.8,1.8,1.8,
     &1.79,1.79,1.79,1.78,1.77,1.77,1.77,1.77,1.77,1.77,1.77,1.77,
     &1.78,1.78,1.78/
            integer itx/' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     &      ' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     &      ' ',' ',' ',' ',' ','n','o','r','m','a','l',' ','p','r',
     &      'o','b','a','b','i','l','i','t','y',' ','s','c','a','l',
     &      'e',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     &      ' ',' ',' ',' ',' ',' ',' ',' ',' ',' '/
            integer ity/' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     &      ' ',' ',' ',' ','r','e','s','i','d','u','a','l',' ',' ',
     &      ' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',
     &      ' ',' ',' '/
            integer month/'jan','feb','mar','apr','may','jun',
     &      'jul','aug','sep','oct','nov','dec'/
           data dwl1/0.81,0.84,.87,.9,.93,.95,.97,1.,1.02,1.04,1.05,
     &1.07,1.09,1.1,1.12,1.13,1.15,1.16,1.17,1.18,1.19,1.21,1.22,
     &1.23,1.24,1.25,1.29,1.32,1.36,1.38,1.41,1.43,1.45,1.47,1.48,
     &1.5,1.51,1.52,.7,.74,.77,.8,.83,.84,.89,.91,.94,.96,.98,1.,
     &1.02,1.04,1.05,1.07,1.08,1.1,1.11,1.13,1.14,1.15,1.16,1.18,
     &1.19,1.2,1.24,1.28,1.32,1.35,1.38,1.40,1.42,1.44,1.46,1.47,
```

```
&1.49,1.50,.59,.63,.67,.71,.74,.77,.8,.83,.86,.88,.9,.93,.95,
&.97,.99,1.01,1.02,1.04,1.05,1.07,1.08,1.1,1.11,1.12,1.14,1.15
&,1.2,1.24,1.28,1.32,1.35,1.37,1.39,1.42,1.43,1.45,1.47,1.48,
&.49,.53,.57,.61,.65,.68,.72,.75,.77,.8,.83,.85,.88,.9,.92,.94
&,.96,.98,1.,1.01,1.03,1.04,1.06,1.07,1.09,1.1,1.16,1.2,1.25,
&1.28,1.31,1.34,1.37,1.39,1.41,1.43,1.45,1.46,
&.39,.44,.48,.52,.56,.6,.63,.66,.7,.72,.75,.78,.81,.83,.85,
&.88,.9,.92,.94,.95,.97,.99,1.0,1.02,1.03,1.05,1.11,1.16,1.21
&,1.25,1.28,1.31,1.34,1.36,1.39,1.41,1.42,1.44/
      data dwu1/1.07,1.09,1.1,1.12,1.13,1.15,1.16,1.17,
&1.19,1.2,1.21,1.22,1.23,1.24,1.25,1.26,1.27,1.28,1.29,1.30,
&1.31,1.32,1.32,1.33,1.34,1.34,1.38,1.4,1.43,1.45,1.47,1.49,
&1.5,1.52,1.53,1.54,1.55,1.56,1.25,1.25,1.25,1.26,1.26,1.27,
&1.27,1.28,1.29,1.3,1.3,1.31,1.32,1.32,1.33,1.34,1.34,1.35,
&1.36,1.36,1.37,1.38,1.38,1.39,1.39,1.4,1.42,1.45,1.47,1.48
&,1.5,1.52,1.53,1.54,1.55,1.56,1.57,1.58,1.46,1.44,1.43,1.42,
&1.41,1.41,1.41,1.4,1.4,1.41,1.41,1.41,1.41,1.41,1.42,1.42,
&1.42,1.43,1.43,1.43,1.44,1.44,1.45,1.45,1.45,1.46,1.48,1.49,
&1.51,1.52,1.53,1.55,1.56,1.57,1.58,1.59,1.6,1.6,1.7,1.66,
&1.63,1.6,1.58,1.57,1.55,1.54,1.53,1.53,1.52,1.52,1.51,1.51,
&1.51,1.51,1.51,1.51,1.51,1.51,1.51,1.51,1.51,1.52,1.52,1.52,
&1.53,1.54,1.55,1.56,1.57,1.58,1.59,1.60,1.6,1.61,1.62,1.63,
&1.96,1.9,1.85,1.8,1.77,1.74,1.71,1.69,1.67,1.66,1.65,1.64,
&1.63,1.62,1.61,1.61,1.6,1.6,1.59,1.59,1.59,1.59,1.59,1.58,
&1.58,1.58,1.58,1.59,1.59,1.6,1.61,1.61,1.62,1.62,1.63,1.63,
&1.64,1.65/
      end
```

Appendix B

INPUT DATA

File 04

```
5 63 12
8 8
1 25 1 1 1
wadi hal
atbara
karthum
malakal
mongalla
1 0 0 0 0
1 1 0 0 0
1 0 1 0 0
1 0 0 1 0
1 0 0 1 1
1 0 0 0 0
1 1 0 0 0
1 0 1 0 0
1 0 0 1 0
1 0 0 1 1
5 5
```

File 15

Historical Monthly Streamflows at Wadi Hal; 1905-1967; 10**G Cubic Meters

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1905	3730.	2330.	1850.	1410.	1270.	1300.	3070.	13600.	20400.	12700.	5790.	4680.
1906	3520.	2410.	1920.	1720.	1510.	1530.	4200.	19400.	25600.	16200.	6400.	4960.
1907	3970.	2710.	2050.	1770.	1840.	1750.	3900.	12800.	17800.	10900.	6250.	4410.
1908	3370.	2170.	1810.	1420.	1350.	1490.	3940.	21700.	27800.	19700.	8710.	5790.
1909	4620.	3500.	2850.	2040.	2320.	3240.	6899.	22100.	27000.	19300.	9540.	6730.
1910	5570.	4410.	3530.	2280.	1820.	2210.	4200.	17700.	25500.	19600.	10500.	6420.
1911	5000.	3630.	2780.	2000.	1820.	2250.	4280.	16500.	23900.	15000.	8050.	5760.
1912	3880.	2540.	1920.	1450.	1230.	1080.	3700.	20800.	19600.	11100.	6100.	4580.
1913	3650.	2310.	1870.	1480.	1360.	1800.	2230.	7680.	13400.	7860.	4139.	3020.
1914	2100.	1420.	1290.	1100.	1180.	1140.	2900.	22900.	22300.	18000.	10500.	6260.
1915	4190.	2930.	2050.	1380.	1290.	1600.	3080.	12300.	16400.	15000.	7840.	4920.
1916	3510.	2170.	1500.	1180.	1130.	1320.	6100.	27100.	31700.	23200.	12200.	7060.
1917	5340.	4130.	3790.	2410.	1760.	2080.	5830.	19600.	31500.	24200.	11600.	6880.
1918	5350.	4350.	4810.	4540.	4340.	3460.	6300.	15600.	18800.	11900.	6670.	5010.
1919	3700.	2390.	2070.	1620.	1470.	1680.	5070.	19200.	22400.	13000.	6260.	4500.
1920	3430.	2050.	1590.	1310.	1220.	1970.	6230.	20700.	19100.	15800.	8710.	5180.
1921	3800.	2180.	1680.	1300.	1120.	1380.	3300.	17900.	21500.	15200.	7140.	4580.
1922	3420.	1960.	1380.	1060.	880.	1000.	3820.	19300.	25500.	17000.	8130.	5060.
1923	3650.	1970.	1260.	1130.	1520.	2370.	5000.	22500.	23100.	16700.	6970.	4790.
1924	3730.	2400.	1650.	1240.	1400.	1550.	5730.	19600.	23300.	14500.	7900.	5290.
1925	3760.	2470.	1820.	1370.	1290.	1630.	4440.	15700.	17900.	12800.	5940.	4090.
1926	3390.	2230.	1820.	1690.	1760.	2700.	4960.	21600.	23100.	14900.	7500.	4810.
1927	3850.	2740.	1960.	1590.	1570.	1500.	4750.	18300.	20300.	13700.	5510.	3670.
1928	2590.	1690.	1460.	1330.	1720.	2710.	7520.	19900.	21000.	12200.	6610.	4350.
1929	3480.	2230.	1810.	1480.	1790.	3770.	10000.	25400.	25800.	18700.	9320.	5210.
1930	4210.	2870.	2210.	1730.	1740.	1910.	5590.	19700.	18500.	11500.	5230.	3660.
1931	2720.	1640.	1470.	1260.	1340.	1200.	3370.	16900.	21600.	14800.	7920.	4420.
1932	3440.	2010.	1670.	1340.	1390.	1980.	5070.	20200.	23400.	15900.	7300.	4680.
1933	4200.	3380.	2730.	1670.	1760.	1930.	3810.	14400.	22800.	15100.	8690.	5660.
1934	4190.	2710.	2010.	1670.	1660.	1820.	7600.	22100.	24400.	16500.	7400.	5020.
1935	4200.	2850.	2140.	1700.	1840.	2680.	8000.	22900.	24200.	17200.	7520.	4950.
1936	3950.	2640.	2230.	1770.	1730.	1800.	6230.	20000.	25600.	15600.	6890.	4200.
1937	3170.	1900.	1650.	1450.	1400.	1800.	4840.	21600.	23800.	13499.	5790.	4310.
1938	3350.	2090.	2210.	1670.	1470.	1600.	4520.	23800.	27000.	19800.	8850.	5260.
1939	4120.	3160.	2340.	2140.	2220.	2170.	4230.	14000.	18400.	12400.	7580.	4360.
1940	3160.	2080.	2500.	1830.	1350.	1550.	3430.	16200.	18200.	9780.	4280.	2990.
1941	2040.	1820.	2150.	1670.	1150.	1930.	4430.	13300.	15100.	11100.	7430.	3990.
1942	2990.	2080.	2540.	2520.	1810.	1920.	5450.	22400.	21000.	14500.	5520.	3810.
1943	3030.	1850.	2500.	2220.	1610.	1560.	3280.	17000.	24300.	12900.	6090.	3530.
1944	2670.	1700.	2570.	2450.	1800.	2130.	5190.	18300.	18500.	12100.	5040.	3640.

Continuation

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1945	2610.	1880.	2750.	2280.	1500.	2010.	3890.	16000.	19600.	15900.	8000.	4890.
1946	3700.	2290.	2510.	2470.	2130.	1610.	7370.	26900.	27700.	14600.	8230.	5200.
1947	3990.	3080.	3060.	2600.	2860.	2920.	3480.	16400.	22900.	13900.	5760.	4060.
1948	3410.	2680.	2500.	2560.	2200.	1830.	5860.	17500.	19200.	15500.	8690.	4560.
1949	3490.	2590.	2410.	2520.	2550.	2010.	4630.	18500.	20200.	13200.	6960.	4380.
1950	3750.	2720.	2540.	2510.	2720.	2270.	5430.	22400.	23300.	14100.	5910.	3780.
1951	3110.	1890.	2320.	2420.	1990.	1300.	3400.	16500.	18200.	11900.	7610.	4420.
1952	3040.	2320.	2760.	2250.	1590.	1490.	3930.	15790.	20450.	11400.	5300.	3280.
1953	2490.	1830.	2320.	2420.	1510.	1740.	5200.	23000.	20400.	12700.	5430.	3620.
1954	2560.	1790.	2550.	2350.	1650.	1440.	6870.	25200.	27600.	19000.	7370.	4490.
1955	3520.	2580.	2150.	2480.	2530.	2390.	5030.	19900.	22900.	17200.	6400.	4090.
1956	3410.	2730.	2470.	2590.	2720.	2630.	6660.	20100.	20800.	17900.	11100.	5260.
1957	3750.	3020.	2480.	2920.	3070.	3390.	4770.	18600.	19500.	8530.	4360.	3020.
1958	2320.	1880.	2170.	2400.	1770.	1610.	5920.	25200.	22700.	15200.	7150.	4540.
1959	3220.	2310.	2280.	2540.	2270.	1860.	3970.	19500.	27800.	14800.	8470.	4350.
1960	3120.	2220.	2230.	2500.	2500.	1800.	4480.	17400.	20400.	13500.	5370.	3140.
1961	2550.	1780.	2310.	2600.	2030.	1510.	6550.	23200.	26800.	17400.	7560.	4920.
1962	3670.	2760.	2590.	2990.	2980.	3220.	5000.	17400.	22600.	15500.	5830.	4020.
1963	3350.	2820.	2560.	2820.	3250.	3590.	6990.	22100.	19700.	10600.	4880.	4560.
1964	4300.	3240.	2860.	2700.	3630.	4100.	7920.	24900.	25700.	16400.	9450.	5850.
1965	5750.	5080.	4390.	3580.	4170.	4520.	5820.	14800.	15600.	11000.	6600.	4910.
1966	3930.	3020.	2540.	3210.	3550.	3110.	5570.	12800.	17500.	7290.	4470.	4530.
1967	4650.	3306.	2108.	2985.	3317.	3030.	5890.	19902.	22050.	13919.	6240.	5270.

Historical Monthly Streamflows at Atbara ; 1905-1967; 10**6 Cubic Meters

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1905	0.	0.	0.	0.	0.	143.	1610.	4280.	4090.	724.	212.	66.
1906	0.	0.	0.	0.	0.	20.	1560.	5700.	4320.	897.	268.	106.
1907	0.	0.	0.	0.	0.	106.	1850.	4710.	3530.	607.	207.	85.
1908	38.	9.	0.	0.	0.	916.	2130.	8160.	5790.	1350.	327.	121.
1909	48.	17.	0.	3.	16.	513.	1570.	7650.	4990.	997.	244.	91.
1910	36.	5.	0.	0.	0.	62.	1160.	8130.	5730.	1880.	371.	115.
1911	48.	10.	0.	0.	0.	115.	923.	5300.	4920.	711.	308.	88.
1912	30.	5.	0.	0.	0.	126.	1990.	6990.	3330.	407.	136.	46.
1913	34.	3.	0.	0.	0.	0.	593.	2350.	1690.	210.	32.	5.
1914	0.	0.	0.	0.	0.	10.	1570.	7180.	3280.	1030.	331.	82.
1915	25.	3.	0.	0.	0.	136.	858.	3060.	2750.	684.	146.	35.
1916	5.	0.	0.	0.	0.	79.	5160.	13200.	6440.	1540.	454.	173.
1917	68.	10.	0.	0.	0.	221.	1240.	4430.	7410.	1210.	270.	95.
1918	35.	9.	0.	0.	3.	22.	1050.	3620.	1200.	390.	67.	8.
1919	0.	0.	0.	0.	0.	100.	1790.	4650.	2910.	457.	79.	2.
1920	0.	0.	0.	0.	0.	219.	1860.	6040.	2600.	922.	200.	43.
1921	0.	0.	0.	0.	0.	50.	1150.	5520.	3430.	776.	147.	12.
1922	0.	0.	0.	0.	0.	43.	1990.	7900.	6470.	1000.	169.	17.
1923	0.	0.	0.	0.	0.	72.	1280.	6100.	3680.	725.	139.	45.
1924	12.	0.	0.	0.	0.	64.	2480.	6080.	4460.	774.	259.	58.
1925	0.	0.	0.	0.	0.	48.	1120.	3950.	2020.	466.	74.	0.
1926	0.	0.	0.	0.	0.	0.	2020.	4580.	3340.	624.	142.	0.
1927	0.	0.	0.	0.	0.	55.	1610.	4350.	2750.	615.	75.	0.
1928	0.	0.	0.	0.	0.	173.	1300.	4670.	2350.	476.	105.	0.
1929	0.	0.	0.	0.	0.	236.	2580.	7240.	3760.	974.	165.	36.
1930	0.	0.	0.	0.	0.	41.	2370.	4170.	2510.	449.	110.	19.
1931	0.	0.	9.	0.	0.	22.	1060.	5520.	3550.	931.	186.	54.
1932	0.	0.	0.	0.	0.	7.	1930.	6330.	4360.	813.	145.	49.
1933	0.	0.	0.	0.	0.	0.	874.	3640.	4190.	994.	290.	119.
1934	8.	0.	0.	0.	0.	333.	2830.	7420.	3300.	1040.	171.	66.
1935	0.	0.	0.	0.	6.	232.	1460.	5040.	4850.	1130.	192.	66.
1936	0.	0.	0.	0.	0.	0.	1740.	5580.	4750.	810.	176.	64.
1937	0.	0.	0.	0.	0.	9.	1560.	6400.	3780.	780.	154.	47.
1938	0.	0.	0.	0.	0.	0.	1590.	7360.	4820.	1380.	260.	93.
1939	0.	0.	0.	0.	0.	13.	1270.	3970.	2580.	820.	190.	39.
1940	0.	0.	0.	0.	0.	0.	1070.	4700.	2230.	390.	78.	28.
1941	0.	0.	0.	0.	0.	37.	789.	3090.	1710.	562.	274.	60.
1942	0.	0.	0.	0.	0.	0.	1600.	5420.	3220.	807.	150.	59.
1943	0.	0.	0.	0.	0.	0.	1270.	6010.	5640.	998.	234.	69.
1944	25.	8.	0.	0.	0.	0.	2360.	5390.	2720.	593.	125.	50.

Continuation

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1945	17.	0.	0.	0.	123.	295.	1210.	4510.	3810.	1390.	290.	82.
1946	16.	0.	0.	0.	0.	316.	2440.	10680.	3750.	901.	294.	102.
1947	37.	17.	1.	0.	0.	34.	893.	4940.	3350.	826.	145.	70.
1948	39.	13.	0.	0.	0.	231.	1650.	4580.	2990.	990.	191.	89.
1949	50.	13.	0.	0.	0.	92.	1090.	4110.	3180.	834.	183.	81.
1950	59.	0.	0.	0.	0.	0.	2180.	6550.	4930.	832.	182.	92.
1951	54.	2.	0.	0.	0.	31.	1680.	4570.	2860.	856.	314.	115.
1952	46.	0.	0.	0.	0.	0.	1120.	4950.	3260.	637.	137.	44.
1953	18.	1.	0.	0.	0.	212.	2060.	7350.	3710.	950.	216.	112.
1954	62.	19.	2.	0.	0.	171.	2310.	9020.	6880.	2140.	384.	163.
1955	0.	0.	0.	0.	0.	0.	1030.	5250.	5010.	1860.	298.	76.
1956	0.	0.	0.	0.	0.	0.	1940.	6020.	3790.	1940.	607.	158.
1957	112.	61.	29.	16.	9.	72.	774.	5270.	3140.	410.	108.	71.
1958	57.	37.	5.	0.	0.	97.	1540.	7360.	4020.	1110.	207.	81.
1959	44.	14.	2.	0.	0.	0.	1740.	8240.	5550.	1100.	337.	129.
1960	59.	24.	5.	0.	0.	8.	1510.	4200.	3330.	805.	170.	55.
1961	22.	4.	0.	0.	0.	47.	4440.	6130.	4830.	1200.	253.	155.
1962	67.	25.	6.	0.	0.	0.	1180.	6050.	4490.	1000.	230.	158.
1963	44.	18.	0.	0.	15.	17.	1450.	5050.	3350.	812.	149.	103.
1964	37.	23.	7.	0.	0.	0.	2040.	7230.	4760.	917.	191.	18.
1965	165.	135.	0.	0.	15.	40.	1120.	3960.	2260.	324.	35.	0.
1966	6.	0.	0.	128.	117.	415.	692.	3490.	1820.	217.	42.	31.
1967	8.	3.	3.	78.	190.	111.	1580.	5960.	4000.	934.	90.	14.

Historical Monthly Streamflows at Karthoum; 1905-1967; 10**6 Cubic Meters

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1905	1210.	644.	483.	351.	334.	802.	2850.	11000.	13600.	6180.	2980.	2010.
1906	1220.	644.	638.	540.	400.	852.	4740.	16300.	20300.	9780.	4030.	2400.
1907	1420.	668.	556.	477.	501.	795.	3380.	9490.	11300.	5540.	2700.	1620.
1908	730.	381.	285.	233.	292.	575.	3460.	17400.	19500.	12900.	5150.	3160.
1909	1700.	904.	417.	527.	1050.	3460.	8400.	25600.	17900.	11500.	4850.	2850.
1910	1950.	1350.	915.	441.	459.	1100.	4420.	15300.	18700.	13500.	4540.	2190.
1911	1320.	766.	543.	419.	556.	873.	5080.	17500.	18600.	8320.	4170.	2370.
1912	1340.	824.	576.	324.	207.	848.	5910.	15900.	11400.	4390.	2210.	1230.
1913	870.	473.	351.	217.	566.	466.	1880.	7520.	8620.	3000.	1140.	590.
1914	340.	203.	166.	158.	246.	734.	5250.	19000.	14300.	11300.	5720.	2260.
1915	1250.	680.	478.	318.	461.	971.	3320.	8060.	11300.	8430.	3510.	1840.
1916	942.	537.	358.	250.	368.	828.	6760.	20200.	21500.	16100.	6050.	2960.
1917	1730.	1020.	835.	551.	645.	1410.	7300.	17700.	22900.	15800.	4820.	2500.
1918	1290.	780.	625.	337.	400.	1170.	5370.	12900.	11300.	5000.	2000.	1150.
1919	726.	438.	321.	175.	241.	1120.	6200.	16800.	17300.	5180.	2220.	1230.
1920	646.	368.	358.	308.	313.	1650.	6170.	13200.	11400.	8750.	3170.	1870.
1921	888.	433.	347.	202.	259.	865.	3410.	14600.	14500.	7350.	2310.	1180.
1922	727.	388.	297.	171.	175.	801.	4570.	16000.	16100.	8990.	2560.	1350.
1923	782.	507.	375.	454.	569.	2000.	5890.	16500.	13900.	7290.	2850.	1700.
1924	848.	572.	420.	414.	497.	1000.	5890.	15000.	15600.	7200.	3800.	1830.
1925	860.	493.	436.	304.	417.	1260.	3840.	13300.	10700.	6010.	2070.	1110.
1926	644.	454.	507.	535.	1090.	1710.	5590.	18900.	15100.	7950.	2440.	1480.
1927	813.	456.	464.	416.	391.	1290.	5450.	16200.	12900.	6900.	1660.	860.
1928	500.	299.	301.	420.	1110.	1720.	8100.	17100.	12800.	6080.	2170.	1180.
1929	632.	386.	348.	355.	1380.	3610.	10300.	18600.	18400.	11300.	3240.	1700.
1930	1020.	622.	535.	374.	578.	1370.	6330.	14700.	12200.	4750.	1680.	859.
1931	460.	273.	282.	350.	215.	868.	3570.	14800.	15100.	8630.	2440.	1100.
1932	577.	345.	316.	235.	516.	1240.	4890.	15600.	15900.	8070.	2090.	1040.
1933	649.	349.	384.	251.	495.	1030.	3220.	13200.	15100.	8400.	2940.	1470.
1934	721.	361.	395.	351.	442.	1260.	7020.	18200.	14900.	8530.	2620.	1470.
1935	891.	483.	440.	464.	756.	2190.	9450.	20300.	18400.	9140.	2760.	1540.
1936	914.	621.	583.	513.	547.	913.	7170.	17400.	16700.	7580.	2200.	1050.
1937	611.	387.	464.	365.	433.	1050.	6470.	17500.	14800.	5600.	1950.	1100.
1938	588.	397.	426.	316.	373.	995.	7380.	18800.	18200.	11700.	3290.	1460.
1939	771.	494.	489.	397.	550.	1170.	4680.	12100.	11800.	7160.	2920.	1280.
1940	655.	393.	401.	302.	353.	851.	2940.	16000.	12700.	4070.	1120.	697.
1941	383.	261.	302.	163.	359.	1940.	4830.	11400.	10900.	7110.	2900.	1100.
1942	557.	330.	537.	409.	511.	1010.	6560.	18000.	14200.	8210.	1860.	912.
1943	477.	352.	327.	257.	422.	439.	4050.	15800.	15200.	6750.	2290.	974.
1944	509.	377.	280.	239.	542.	778.	4880.	13800.	11400.	4910.	1310.	634.

Continuation

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1945	398.	266.	276.	210.	392.	841.	3810.	13400.	14800.	9600.	3490.	1380.
1946	656.	387.	329.	338.	380.	1250.	7750.	23000.	18000.	7970.	2950.	1500.
1947	788.	507.	533.	747.	570.	799.	3630.	16400.	16300.	7280.	1990.	1270.
1948	597.	424.	591.	343.	332.	1760.	7320.	14600.	14400.	10800.	3670.	1440.
1949	777.	483.	453.	438.	268.	1750.	6190.	15900.	15200.	7910.	2310.	1430.
1950	824.	446.	368.	436.	781.	1330.	5390.	16500.	16300.	8270.	1880.	916.
1951	518.	348.	394.	356.	289.	889.	3570.	14400.	11000.	8180.	3170.	1450.
1952	738.	461.	428.	293.	410.	770.	4860.	15400.	13500.	7050.	1810.	860.
1953	533.	321.	338.	233.	486.	1100.	6230.	18000.	12600.	6260.	1930.	1070.
1954	710.	440.	389.	310.	278.	1090.	7800.	20000.	18200.	10500.	2600.	1300.
1955	925.	635.	425.	457.	613.	1160.	5980.	17600.	16200.	10200.	2570.	1450.
1956	896.	467.	401.	365.	541.	1230.	6500.	15700.	13100.	14500.	4490.	1690.
1957	997.	587.	797.	1140.	759.	1500.	4270.	16400.	11800.	3570.	1270.	758.
1958	450.	389.	215.	275.	344.	1330.	6600.	19000.	14400.	9370.	2960.	1410.
1959	887.	482.	475.	297.	540.	810.	3970.	14200.	17800.	9210.	3890.	1740.
1960	950.	563.	462.	438.	498.	807.	5190.	17000.	14300.	7930.	1940.	966.
1961	450.	324.	354.	402.	460.	850.	7340.	17400.	18300.	11000.	2920.	1990.
1962	883.	480.	392.	383.	427.	1280.	3870.	15300.	14500.	8830.	1830.	978.
1963	450.	280.	168.	300.	870.	1120.	5180.	16700.	12900.	4780.	1320.	1040.
1964	658.	284.	136.	168.	453.	984.	7460.	19300.	17300.	11200.	3380.	1340.
1965	748.	433.	205.	204.	466.	637.	3120.	12400.	9690.	6980.	2020.	1100.
1966	486.	285.	207.	272.	265.	1400.	3580.	12300.	12200.	2050.	1070.	1410.
1967	1110.	384.	170.	443.	472.	825.	4320.	15000.	14500.	8210.	2270.	1500.

Historical Monthly Streamflows at Malakal ; 1905-1967; 10**6 Cubic Meters

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1905	2380.	1670.	1520.	1240.	1370.	1660.	2200.	2530.	2760.	3040.	2960.	2830.
1906	2140.	1440.	1580.	1400.	1550.	2050.	2530.	2860.	3130.	3470.	3430.	3250.
1907	2310.	1590.	1660.	1580.	1550.	1920.	2380.	2810.	3030.	3280.	3150.	2690.
1908	2050.	1570.	1440.	1300.	1490.	1720.	2380.	2850.	3070.	3440.	3470.	3580.
1909	3110.	1820.	1570.	1710.	1990.	2400.	2950.	3500.	4060.	4610.	4170.	4190.
1910	3960.	2230.	1800.	1450.	1690.	2130.	2580.	2910.	3120.	3440.	3420.	3540.
1911	2830.	1660.	1570.	1370.	1570.	2020.	2540.	2790.	2900.	3090.	3000.	2660.
1912	1880.	1460.	1370.	1220.	1190.	1580.	2310.	2920.	3160.	3310.	3070.	2710.
1913	1810.	1390.	1460.	1330.	1710.	1720.	2250.	2620.	2730.	2950.	2220.	1630.
1914	1450.	1230.	1310.	1260.	1310.	1630.	2170.	2730.	3230.	3590.	3380.	3340.
1915	2600.	1460.	1390.	1300.	1510.	1850.	2440.	2820.	2980.	3270.	3270.	3050.
1916	1950.	1410.	1360.	1300.	1460.	1840.	2500.	2910.	3400.	3990.	4080.	4280.
1917	4280.	3240.	2220.	1860.	2010.	2390.	2880.	3230.	3520.	4140.	4400.	4810.
1918	4970.	4620.	4840.	2880.	2450.	2910.	3330.	3800.	4010.	4000.	3610.	2930.
1919	2190.	1810.	1800.	1580.	1760.	2260.	2810.	3160.	3220.	3500.	3460.	2880.
1920	1870.	1490.	1420.	1240.	1450.	1990.	2380.	2630.	2740.	3040.	2960.	2760.
1921	1750.	1240.	1230.	1130.	1430.	1720.	2210.	2500.	2580.	2870.	2710.	2600.
1922	1500.	1040.	963.	860.	1040.	1560.	2110.	2440.	2540.	2860.	2860.	2820.
1923	1710.	1040.	1060.	1300.	1410.	2010.	2460.	2940.	3160.	3360.	3070.	2960.
1924	1830.	1320.	1270.	1310.	1540.	1680.	2180.	2490.	2620.	2940.	2840.	2810.
1925	1860.	1270.	1290.	1210.	1470.	1830.	2360.	2660.	2750.	2990.	2880.	2590.
1926	1650.	1180.	1340.	1240.	1590.	1970.	2310.	2680.	2880.	3330.	3150.	3090.
1927	2500.	1400.	1390.	1310.	1340.	1700.	2250.	2560.	2650.	2850.	2710.	1810.
1928	1400.	1170.	1200.	1320.	1820.	2070.	2490.	2850.	2980.	3300.	3240.	3080.
1929	1920.	1410.	1410.	1360.	1960.	2300.	2680.	2870.	2990.	3310.	3150.	3080.
1930	2180.	1430.	1400.	1340.	1530.	1830.	2340.	2630.	2670.	2830.	2670.	2040.
1931	1550.	1190.	1250.	1200.	1270.	1690.	2310.	2640.	2870.	3180.	3160.	2810.
1932	1680.	1360.	1360.	1310.	1510.	2000.	2470.	2840.	3120.	3690.	3720.	3870.
1933	3420.	1820.	1670.	1600.	1670.	1960.	2420.	3130.	3450.	3730.	3660.	3420.
1934	2300.	1510.	1540.	1460.	1680.	1970.	2590.	2940.	3150.	3420.	3380.	3410.
1935	2420.	1520.	1520.	1510.	1710.	2230.	2700.	2930.	2970.	3180.	3120.	3070.
1936	1980.	1570.	1470.	1310.	1570.	2030.	2390.	2620.	2750.	2980.	2880.	2400.
1937	1640.	1320.	1340.	1240.	1540.	1980.	2320.	2820.	2960.	3320.	3080.	2750.
1938	1800.	1350.	1430.	1380.	1530.	1900.	2430.	2710.	2860.	3300.	3290.	3400.
1939	3170.	1780.	1600.	1480.	1750.	2160.	2540.	2710.	2790.	3030.	3000.	2530.
1940	1650.	1350.	1370.	1280.	1370.	1730.	2190.	2490.	2590.	2790.	2630.	1900.
1941	1460.	1190.	1240.	1160.	1340.	1940.	2360.	2620.	2710.	2880.	2840.	2910.
1942	2050.	1330.	1440.	1210.	1480.	1940.	2380.	2690.	2960.	3140.	3000.	2730.
1943	1640.	1259.	1340.	1310.	1510.	1730.	2210.	2590.	2740.	2950.	2900.	2510.
1944	1600.	1320.	1320.	1320.	1600.	2040.	2420.	2670.	2810.	3080.	2860.	2400.

Continuation

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1945	1670.	1270.	1270.	1070.	1230.	1810.	2260.	2570.	2810.	3240.	3150.	3110.
1946	2290.	1310.	1220.	1060.	1220.	1700.	2260.	2950.	3510.	3780.	3740.	3880.
1947	3780.	2340.	1460.	1420.	1560.	1930.	2410.	2720.	2920.	3270.	3210.	3350.
1948	2700.	1510.	1440.	1320.	1480.	2000.	2450.	2720.	2890.	3140.	3150.	3340.
1949	2940.	1730.	1520.	1450.	1450.	1920.	2370.	2720.	3010.	3440.	3280.	3340.
1950	3080.	1710.	1480.	1420.	1710.	1960.	2430.	2820.	3090.	3420.	3300.	3180.
1951	2210.	1350.	1350.	1160.	1190.	1630.	2210.	2330.	2460.	2690.	2650.	2620.
1952	1780.	1270.	1220.	1180.	1420.	1740.	2190.	2470.	2570.	2780.	2750.	2560.
1953	1670.	1260.	1280.	1250.	1430.	1750.	2200.	2600.	2770.	3040.	2970.	2450.
1954	1710.	1250.	1290.	1290.	1360.	1780.	2320.	2770.	3130.	3490.	3360.	3220.
1955	2610.	1590.	1400.	1400.	1500.	1930.	2350.	2590.	2790.	3080.	3040.	3090.
1956	2840.	1970.	1580.	1540.	1820.	2080.	2480.	2750.	3000.	3320.	3180.	3240.
1957	3040.	1780.	1650.	1790.	1600.	2060.	2450.	2740.	2790.	2960.	2800.	2340.
1958	1600.	1280.	1290.	1180.	1380.	1750.	2340.	2670.	2840.	3110.	2960.	3010.
1959	2220.	1360.	1380.	1240.	1560.	1910.	2300.	2530.	2680.	2920.	2860.	2940.
1960	2320.	1430.	1400.	1320.	1610.	1950.	2390.	2640.	2680.	2840.	2780.	2730.
1961	1820.	1320.	1380.	1380.	1380.	1730.	2310.	2850.	3220.	3730.	3430.	3400.
1962	3300.	2700.	2420.	1810.	1900.	2260.	2720.	3060.	3240.	3530.	3500.	3730.
1963	3760.	2950.	2270.	1880.	2350.	2610.	3020.	3450.	3880.	4630.	4680.	4760.
1964	3930.	3100.	2890.	2480.	2440.	2560.	3170.	4150.	5200.	6090.	6210.	6420.
1965	6060.	4460.	3800.	3070.	2800.	2800.	3500.	4050.	4200.	4560.	4400.	4130.
1966	3200.	2320.	2190.	1990.	2320.	2780.	3250.	3610.	3930.	4410.	4520.	4400.
1967	3560.	2390.	2140.	1900.	1870.	2170.	2740.	3250.	3560.	4210.	4090.	4060.

Historical Monthly Streamflows at Mongalla; 1905-1967; 10**6 Cubic Meters

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1905	3060.	2570.	2640.	2590.	3110.	2670.	2840.	3040.	3500.	3200.	3450.	3500.
1906	2880.	2520.	2780.	2800.	2910.	3040.	3550.	3640.	4070.	3710.	3670.	3360.
1907	3160.	2660.	2750.	2710.	3000.	2990.	3020.	3350.	3390.	2930.	3180.	2770.
1908	2480.	2100.	2130.	1990.	2190.	2250.	2630.	3380.	2630.	2430.	3140.	2470.
1909	2270.	1910.	2020.	2480.	2760.	2680.	3000.	3060.	3780.	2920.	2460.	2560.
1910	2270.	1930.	1990.	2020.	2470.	2150.	2340.	2970.	3660.	3160.	3130.	2330.
1911	2000.	1630.	1720.	1720.	1980.	1910.	2210.	2270.	2520.	2540.	2490.	2200.
1912	1670.	1380.	1380.	1430.	1610.	1550.	2300.	2920.	3000.	2200.	2040.	1950.
1913	1480.	1370.	1470.	1660.	2340.	2320.	2480.	2440.	1880.	1810.	1930.	1820.
1914	1680.	1400.	1530.	1480.	1860.	1700.	2040.	2810.	2590.	2660.	3270.	2500.
1915	2010.	1710.	1870.	1900.	2330.	2340.	2260.	2620.	2820.	2970.	2790.	2270.
1916	1990.	1730.	1780.	1910.	2490.	2920.	3300.	4080.	5250.	4810.	4040.	3590.
1917	3200.	2850.	3060.	3060.	4380.	4910.	4990.	5420.	6430.	7350.	5300.	4850.
1918	4850.	4080.	4410.	4110.	4320.	3970.	3950.	4010.	3610.	3650.	3180.	2990.
1919	2770.	2330.	2390.	2360.	2660.	2380.	3010.	2780.	2860.	2700.	2570.	2380.
1920	2320.	1760.	1660.	1860.	2200.	2310.	2340.	2560.	2190.	2480.	2140.	1990.
1921	1530.	1220.	1200.	1120.	1190.	1200.	1630.	1830.	1580.	1650.	1290.	1180.
1922	1070.	891.	999.	1050.	1250.	1160.	1240.	1560.	1950.	1550.	1460.	1080.
1923	983.	801.	853.	913.	1430.	1330.	2090.	2850.	1930.	2200.	2170.	1780.
1924	1640.	1440.	1420.	1650.	1910.	1550.	1600.	1720.	1930.	2020.	1920.	1660.
1925	1540.	1300.	1430.	1450.	1670.	1520.	1560.	1860.	1610.	1520.	1750.	1650.
1926	1390.	1180.	1300.	1470.	1880.	1660.	2320.	3130.	2750.	3020.	2400.	2350.
1927	2230.	1940.	2090.	2150.	2240.	2230.	2260.	2340.	2220.	2260.	2090.	1990.
1928	1850.	1620.	1640.	1960.	3830.	2620.	2520.	2330.	2060.	2380.	2000.	1830.
1929	1700.	1440.	1480.	1510.	2240.	1760.	1780.	1950.	1930.	2000.	1880.	1660.
1930	1540.	1320.	1500.	1750.	1940.	1800.	1820.	2040.	2120.	2370.	2440.	2060.
1931	1960.	1680.	1880.	1940.	2300.	2180.	2760.	3300.	3130.	3020.	2470.	2410.
1932	2250.	1940.	2180.	2060.	2680.	2380.	2980.	3720.	3570.	3480.	2760.	2650.
1933	2480.	2180.	2350.	2260.	2500.	2280.	2570.	2680.	3410.	3040.	2470.	2350.
1934	2180.	1810.	1910.	1980.	2420.	2130.	2480.	3080.	2460.	1990.	1960.	1890.
1935	1760.	1500.	1590.	1670.	2340.	2170.	2280.	2130.	2260.	2240.	1820.	1720.
1936	1600.	1420.	1560.	1600.	1860.	2040.	2210.	2490.	2450.	2310.	1940.	1900.
1937	1810.	1630.	1730.	1890.	2500.	2250.	2910.	3170.	2350.	2650.	2730.	2510.
1938	2310.	2000.	2100.	2060.	2430.	2550.	2570.	3470.	3110.	2810.	2470.	2270.
1939	2140.	1830.	1940.	2120.	2190.	2020.	2220.	2300.	2140.	2010.	2120.	1900.
1940	1720.	1530.	1610.	1710.	2230.	1730.	2050.	2500.	2100.	1760.	1630.	1680.
1941	1580.	1320.	1560.	1520.	2150.	2760.	2100.	1980.	1970.	1970.	1920.	2040.
1942	1890.	1650.	1940.	1960.	2600.	2650.	3100.	3780.	3990.	3130.	2720.	2730.
1943	2610.	2210.	2270.	2170.	2460.	2530.	2760.	2750.	2640.	2270.	1950.	1840.
1944	1710.	1450.	1510.	1540.	2140.	1610.	1950.	1830.	1970.	1950.	1600.	1450.

Continuation

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1945	1320.	1070.	1070.	986.	1510.	1550.	1790.	2300.	2200.	1920.	1520.	1500.
1946	1280.	1100.	1120.	1190.	1600.	2100.	1870.	3260.	2890.	2280.	1900.	1620.
1947	1510.	1340.	1500.	1850.	2210.	2000.	2590.	3300.	3350.	3310.	2440.	2510.
1948	2340.	2090.	2150.	2060.	2350.	2440.	2770.	3130.	3430.	3620.	2940.	2480.
1949	2220.	1890.	1960.	1860.	2160.	2050.	2600.	2890.	2890.	2470.	1910.	1770.
1950	1630.	1350.	1410.	1530.	1660.	1560.	1880.	2720.	2580.	2880.	1710.	1450.
1951	1350.	1130.	1190.	1310.	1510.	1560.	1510.	1890.	1450.	1870.	2120.	2100.
1952	1870.	1640.	1680.	1910.	2400.	2180.	2420.	3530.	3180.	3150.	2400.	2250.
1953	1990.	1660.	1690.	1610.	1910.	1950.	2130.	2340.	1880.	1920.	1900.	1650.
1954	1510.	1280.	1380.	1520.	1910.	1800.	2020.	2690.	3010.	2230.	1870.	1700.
1955	1640.	1440.	1510.	1500.	1740.	1530.	1690.	2200.	2860.	3060.	2370.	1780.
1956	1620.	1430.	1490.	1640.	1950.	1850.	1940.	2500.	3060.	3010.	2100.	1860.
1957	1780.	1570.	1780.	1940.	2380.	2690.	2170.	2480.	2090.	2080.	1960.	1910.
1958	1810.	1570.	1700.	1730.	2080.	2100.	2770.	2870.	2520.	2470.	1940.	1880.
1959	1760.	1490.	1580.	1550.	2120.	1910.	1900.	2440.	2390.	2220.	2030.	1820.
1960	1630.	1490.	1680.	1830.	2090.	1860.	2210.	2500.	2640.	2780.	2350.	2040.
1961	1900.	1620.	1770.	1790.	2010.	2040.	2590.	3550.	3730.	4250.	4730.	4080.
1962	3450.	3040.	3560.	3660.	4330.	4090.	4700.	4890.	5000.	5040.	4520.	4370.
1963	4420.	3890.	4280.	4790.	6050.	5640.	5500.	5540.	5310.	4970.	5010.	5070.
1964	4890.	3740.	3860.	4510.	5290.	4940.	5720.	6320.	6860.	7340.	5760.	5270.
1965	5260.	4530.	4780.	4570.	4740.	4430.	4580.	4810.	4440.	5040.	4900.	4840.
1966	4290.	3780.	4130.	4130.	4360.	4060.	4250.	4510.	4680.	4730.	4730.	4310.
1967	3990.	3410.	3620.	3370.	3780.	3710.	4070.	5080.	4790.	5000.	5120.	4560.

Appendix C

OUTPUT EXAMPLE

ols analysis for station wadi hal , month aug

** set of possible predictors

variable	station	month	variable	station	month	variable	station	month
2	wadi hal	jul	7	wadi hal	jun	12	wadi hal	may
17	wadi hal	apr	22	wadi hal	mar	27	wadi hal	feb
32	wadi hal	jan	37	wadi hal	dec	42	wadi hal	nov
47	wadi hal	oct	52	wadi hal	sep	57	wadi hal	aug
3	atbara	jul	8	atbara	jun	13	atbara	may
18	atbara	apr	23	atbara	mar	28	atbara	feb
33	atbara	jan	38	atbara	dec	43	atbara	nov
48	atbara	oct	53	atbara	sep	58	atbara	aug
4	karthum	jul	9	karthum	jun	14	karthum	may
19	karthum	apr	24	karthum	mar	29	karthum	feb
34	karthum	jan	39	karthum	dec	44	karthum	nov
49	karthum	oct	54	karthum	sep	59	karthum	aug
5	malakal	jul	10	malakal	jun	15	malakal	may
20	malakal	apr	25	malakal	mar	30	malakal	feb
35	malakal	jan	40	malakal	dec	45	malakal	nov
50	malakal	oct	55	malakal	sep	60	malakal	aug
6	mongalla	jul	11	mongalla	jun	16	mongalla	may
21	mongalla	apr	26	mongalla	mar	31	mongalla	feb
36	mongalla	jan	41	mongalla	dec	46	mongalla	nov
51	mongalla	oct	56	mongalla	sep	61	mongalla	aug

** mean and standard deviation values of the set of possible predictors

variable	mean	std dev	variable	mean	std dev	variable	mean	std dev
1	19112.26	3924.84	2	5098.35	1715.10	3	1712.84	842.45
4	5559.03	1928.20	5	2474.19	257.85	6	2500.65	752.79
7	1952.58	683.95	8	129.71	185.19	9	1289.65	719.10
10	1966.45	287.98	11	2239.68	773.81	12	1617.74	586.50
13	0.81	3.06	14	520.71	288.36	15	1588.06	270.52
16	2360.65	753.80	17	1646.13	628.52	18	0.10	0.54
19	357.55	119.08	20	1404.84	329.34	21	1936.23	632.89
22	2100.97	775.55	23	0.29	1.62	24	446.84	160.66
25	1553.32	653.59	26	1881.35	690.10	27	2615.81	754.65
28	2.29	4.31	29	550.90	242.51	30	1609.35	690.29
31	1775.55	639.13	32	3863.87	760.62	33	12.48	19.39
34	948.39	390.60	35	2291.94	853.05	36	2088.16	747.21
37	5045.16	938.65	38	54.90	44.68	39	1680.61	650.81
40	3051.29	664.21	41	2315.81	759.31	42	7688.35	1850.67

43	194.23	98.88	44	3125.48	1246.13	45	3237.74	460.00
46	2569.68	828.78	47	15489.03	3533.82	48	832.35	357.04
49	8460.00	3165.74	50	3354.84	416.43	51	2782.58	1105.76
52	22567.74	4038.76	53	3870.97	1455.03	54	15210.32	3486.66
55	3046.45	365.32	56	2873.87	1063.94	57	18905.81	4043.13
58	5740.65	2077.46	59	15705.48	3676.98	60	2844.19	292.36
61	2834.52	815.57						

** final stepwise regression results

significance levels for f test: entry 5%
deletion 5%

step number 5

variable entered or deleted 58
cumulative sum of squares reduced ...... 0.3837539E+09

total sum of squares .... 0.4621317E+09
cumulative proportion reduced .... 0.8303994E+00

degree of freedom: regression 4
residual 26

f-value for analysis of variance .... 0.3182533E+02
multiple correlation coefficient .... 0.9112625E+00
standard error of estimate .... 0.1736241E+04

variables in equation:

variable number	regression coefficient	std. error of reg. coeff.	f-value
3	1.15987	0.472638	6.022
4	1.52568	0.207001	54.323
15	-3.27271	1.362173	5.772
57	-0.27481	0.089074	9.519
constant	19037.10669		

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
19400.00	19268.08	131.92	12800.00	15935.60	-3135.60	21700.00	18392.54	3307.46
22100.00	21197.70	902.30	17700.00	15521.83	2178.17	16500.00	17855.79	-1355.79
20800.00	21933.09	-1133.09	7680.00	11280.75	-3600.75	22900.00	22470.12	429.88
12300.00	13862.53	-1562.53	27100.00	27177.29	-77.29	19600.00	17587.25	2012.75
15600.00	15043.41	556.59	19200.00	20525.45	-1325.45	20700.00	20586.09	113.91

17900.00	15204.93	2695.07	19300.00	19994.85	-694.85	22500.00	19589.60	2910.40
19600.00	19676.59	-76.59	15700.00	15997.56	-297.56	21600.00	20390.43	1209.57
18300.00	18898.08	-598.08	19900.00	21917.55	-2017.55	25400.00	25860.80	-460.80
19700.00	19456.07	243.93	16900.00	16143.10	756.90	20200.00	19150.11	1049.89
14400.00	13946.88	453.12	22100.00	23574.36	-1474.36	22900.00	23478.51	-578.51

** residual statistics:

```
mean ..................      -0.0000
std dev ...............    1590.0684
mean square error ...... 0.24493E+07
correlation at lag 1 ...     -0.0801
            at lag 2 ...      0.0736
            at lag 3 ...     -0.2250
```

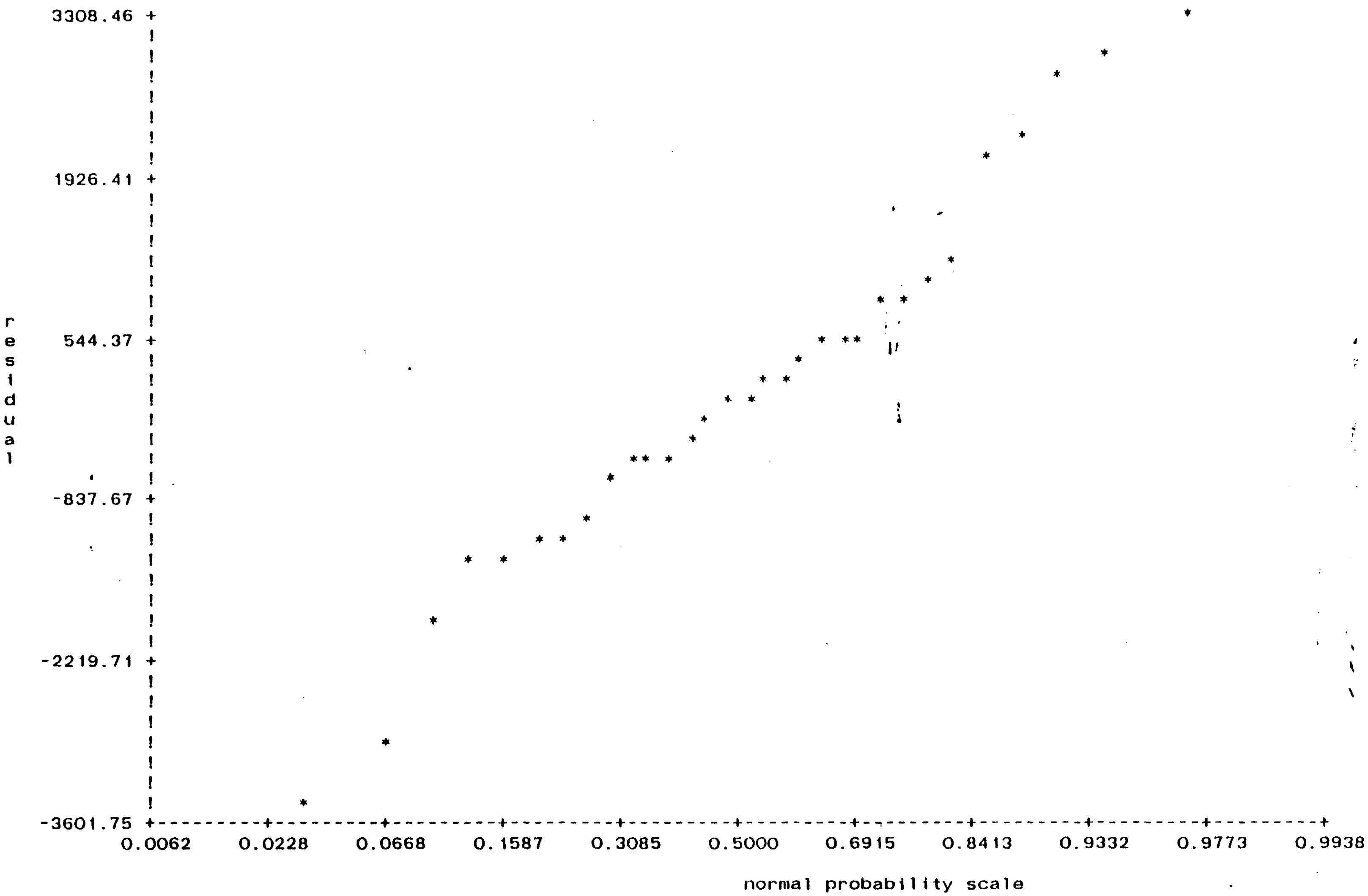
** residual statistics for the second half of the data:

```
mean ..................    1005.0260
std dev ...............    2954.0793
mean square error ...... 0.94226E+07
correlation at lag 1 ...      0.2735
            at lag 2 ...     -0.1255
            at lag 3 ...      0.0287
```

** durbin-watson test:

there is a lagged autoregressive term
not reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00017 * residual ; r2 = 0.93421

ols analysis for station atbara , month aug

** set of possible predictors

variable	station	month	variable	station	month	variable	station	month
2	atbara	jul	3	atbara	jun	4	atbara	may
5	atbara	apr	6	atbara	mar	7	atbara	feb
8	atbara	jan	9	atbara	dec	10	atbara	nov
11	atbara	oct	12	atbara	sep	13	atbara	aug

** mean and standard deviation values of the set of possible predictors

variable	mean	std dev	variable	mean	std dev	variable	mean	std dev
1	5782.58	2060.04	2	1712.84	842.45	3	129.71	185.19
4	0.81	3.06	5	0.10	0.54	6	0.29	1.62
7	2.29	4.31	8	12.48	19.39	9	54.90	44.68
10	194.23	98.88	11	832.35	357.04	12	3870.97	1455.03
13	5740.65	2077.46						

** final stepwise regression results

significance levels for f test: entry 5%
deletion 5%

step number 2

variable entered or deleted 7
cumulative sum of squares reduced ...... 0.7524211E+08

total sum of squares .... 0.1273126E+09
cumulative proportion reduced .... 0.5910029E+00

degree of freedom: regression 1
residual 29

f-value for analysis of variance .... 0.4190514E+02
multiple correlation coefficient .... 0.7687671E+00
standard error of estimate .... 0.1339975E+04

variables in equation:

variable number	regression coefficient	std. error of reg. coeff.	f-value
2	1.87987	0.290399	41.905
constant	2562.66309		

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
5700.00	5495.26	204.74	4710.00	6040.43	-1330.43	8160.00	6566.79	1593.21
7650.00	5514.06	2135.94	8130.00	4743.31	3386.69	5300.00	4297.78	1002.22
6990.00	6303.61	686.39	2350.00	3677.43	-1327.43	7180.00	5514.06	1665.94
3060.00	4175.59	-1115.59	13200.00	12262.80	937.20	4430.00	4893.70	-463.70
3620.00	4536.53	-916.53	4650.00	5927.63	-1277.63	6040.00	6059.22	-19.22
5520.00	4724.52	795.48	7900.00	6303.61	1596.39	6100.00	4968.90	1131.10
6080.00	7224.75	-1144.75	3950.00	4668.12	-718.12	4580.00	6360.00	-1780.00
4350.00	5589.26	-1239.26	4670.00	5006.50	-336.50	7240.00	7412.73	-172.73
4170.00	7017.96	-2847.96	5520.00	4555.33	964.67	6330.00	6190.82	139.18
3640.00	4205.67	-565.67	7420.00	7882.70	-462.70	5040.00	5307.28	-267.28

** residual statistics:

mean 0.0000
std dev 1296.0297
mean square error ...... 0.16272E+07
correlation at lag 1 ... 0.2438
at lag 2 ... 0.2356
at lag 3 ... -0.1535

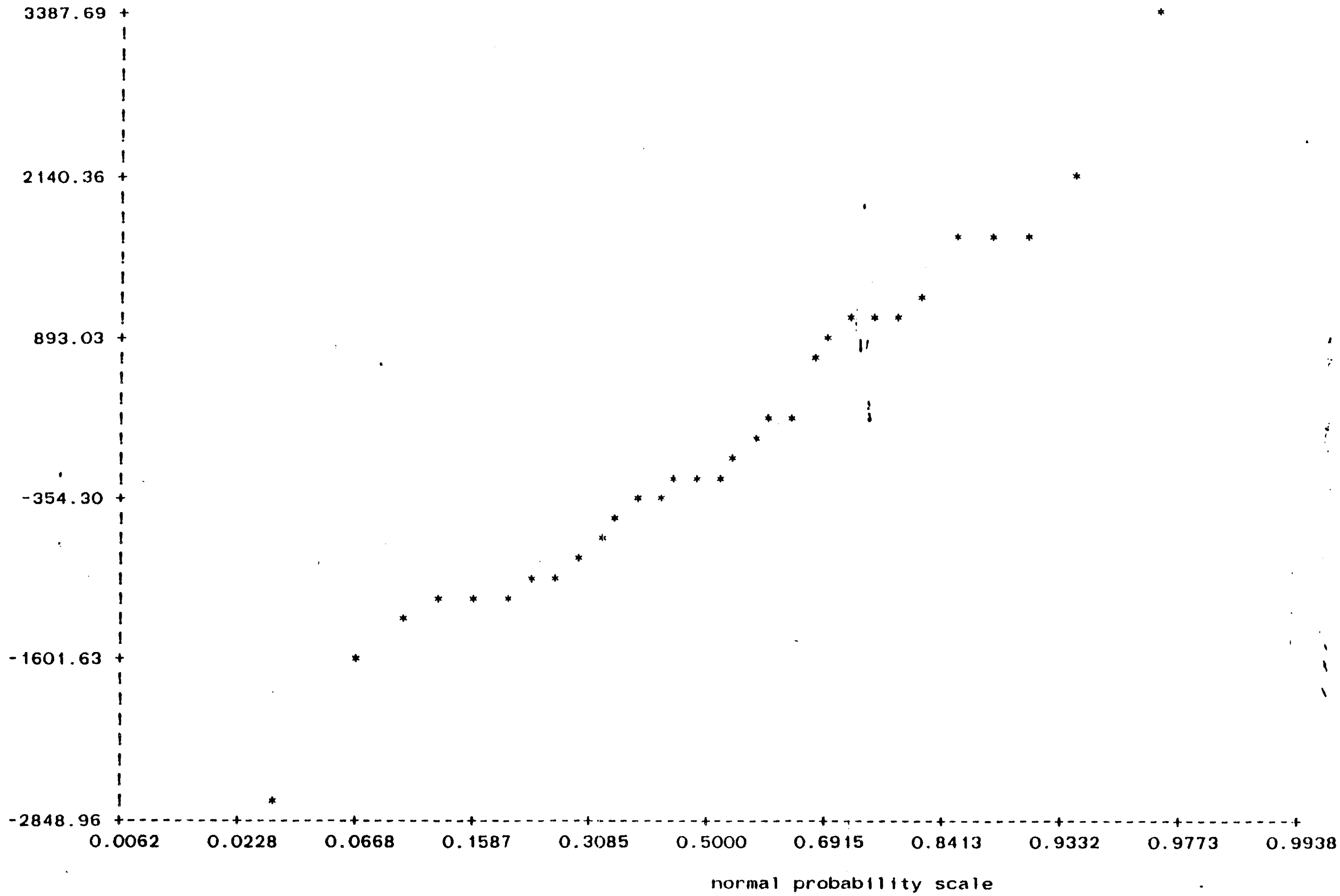
** residual statistics for the second half of the data:

mean 167.1454
std dev 1509.0436
mean square error ...... 0.22308E+07
correlation at lag 1 ... 0.0469
at lag 2 ... -0.3186
at lag 3 ... -0.1455

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00021 * residual ; r2 = 0.93286

ols analysis for station karthum , month aug

** set of possible predictors

variable	station	month	variable	station	month	variable	station	month
2	karthum	jul	3	karthum	jun	4	karthum	may
5	karthum	apr	6	karthum	mar	7	karthum	feb
8	karthum	jan	9	karthum	dec	10	karthum	nov
11	karthum	oct	12	karthum	sep	13	karthum	aug

** mean and standard deviation values of the set of possible predictors

variable	mean	std dev	variable	mean	std dev	variable	mean	std dev
1	15911.94	3582.43	2	5559.03	1928.20	3	1289.65	719.10
4	520.71	288.36	5	357.55	119.08	6	446.84	160.66
7	550.90	242.51	8	948.39	390.60	9	1680.61	650.81
10	3125.48	1246.13	11	8460.00	3165.74	12	15210.32	3486.66
13	15705.48	3676.98						

** final stepwise regression results

significance levels for f test: entry 5%
deletion 5%

step number 4

variable entered or deleted 10
cumulative sum of squares reduced ...... 0.2624572E+09

total sum of squares .... 0.3850137E+09
cumulative proportion reduced .... 0.6816828E+00

degree of freedom: regression 3
residual 27

```
f-value for analysis of variance .......  0.1927368E+02
multiple correlation coefficient .......  0.8256408E+00
standard error of estimate .............  0.2130523E+04
```

variables in equation:

variable number	regression coefficient	std. error of reg. coeff.	f-value
2	1.45935	0.205232	50.562
7	5.13545	2.088608	6.046
13	-0.54469	0.139558	15.233
constant	13524.83618		

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
16300.00	17757.80	-1457.80	9490.00	13009.48	-3519.48	17400.00	15361.69	2038.31
25600.00	20948.23	4651.77	15300.00	12963.96	2336.04	17500.00	16538.34	961.66
15900.00	16849.14	-949.14	7520.00	10036.91	-2516.91	19000.00	18132.86	867.14
8060.00	11512.88	-3452.88	20200.00	21757.59	-1557.59	17700.00	18413.53	-713.53
12900.00	15726.19	-2826.19	16800.00	17795.64	-995.64	13200.00	15268.09	-2068.09
14600.00	13534.97	1065.03	16000.00	14234.15	1765.85	16500.00	16009.05	490.95
15000.00	16070.51	-1070.51	13300.00	13490.17	-190.17	18900.00	16769.73	2130.27
16200.00	13525.43	2674.57	17100.00	18057.11	-957.11	18600.00	21224.24	-2624.24
14700.00	15825.55	-1125.55	14800.00	12129.76	2670.24	15600.00	14371.38	1228.62
13200.00	11519.06	1680.94	18200.00	18433.48	-233.48	20300.00	19882.77	417.23

** residual statistics:

```
mean ..................        0.0001
std dev ...............     1988.3246
mean square error ...... 0.38299E+07
correlation at lag 1 ...       0.3460
            at lag 2 ...      -0.1355
            at lag 3 ...      -0.2373
```

** residual statistics for the second half of the data:

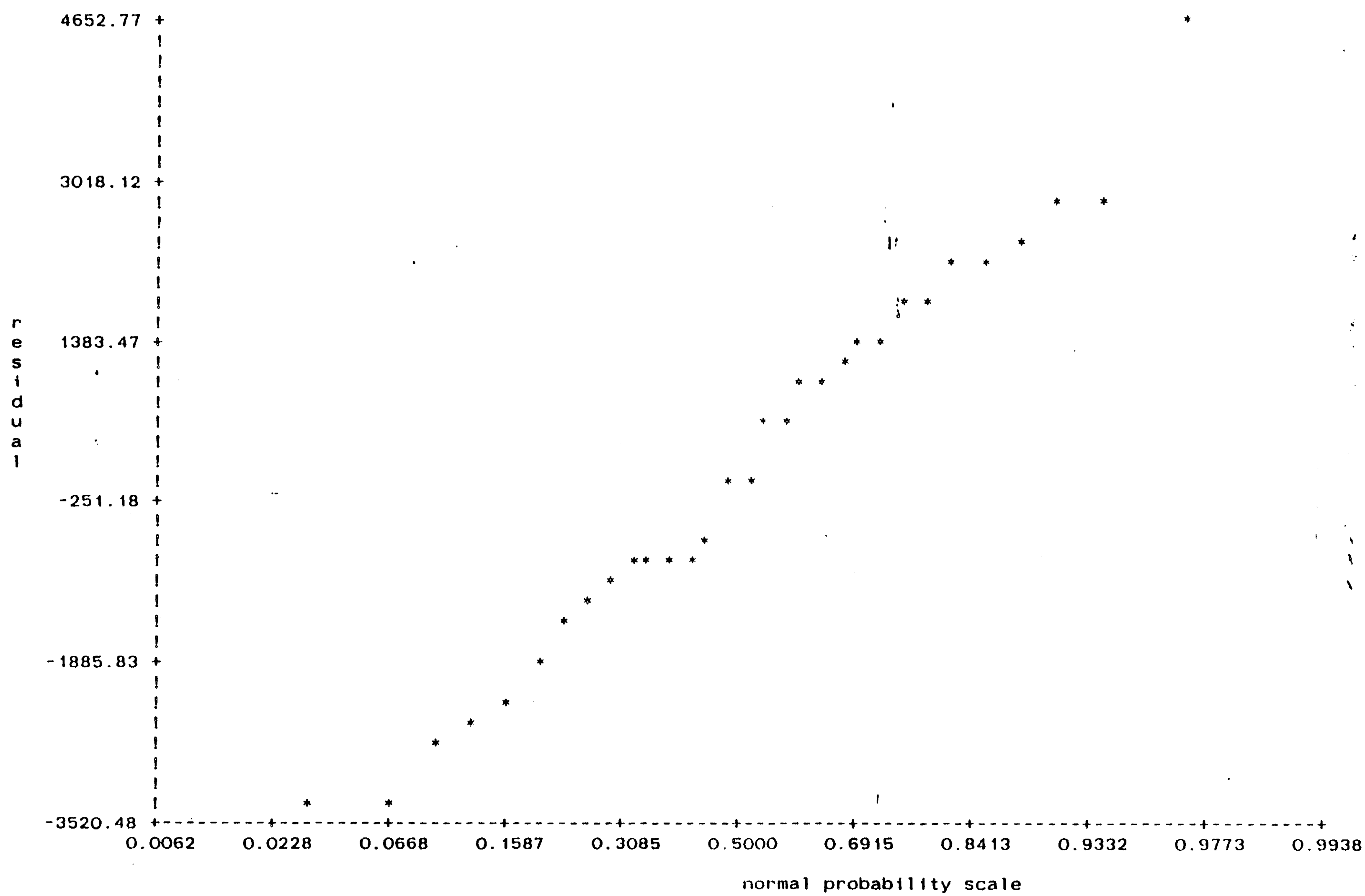
```
mean ..................     1479.4404
std dev ...............     2079.5810
mean square error ...... 0.63033E+07
correlation at lag 1 ...      -0.0835
            at lag 2 ...      -0.3355
            at lag 3 ...       0.0584
```

** durbin-watson test:

there is a lagged autoregressive term

reject the hypothesis of zero autocorrelation; significance level 5%
reject the hypothesis of zero autocorrelation; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00014 * residual ; r2 = 0.97365

ols analysis for station malakal , month aug

** set of possible predictors

variable	station	month	variable	station	month	variable	station	month
2	malakal	jul	4	malakal	jun	6	malakal	may
8	malakal	apr	10	malakal	mar	12	malakal	feb
14	malakal	jan	16	malakal	dec	18	malakal	nov
20	malakal	oct	22	malakal	sep	24	malakal	aug
3	mongalla	jul	5	mongalla	jun	7	mongalla	may
9	mongalla	apr	11	mongalla	mar	13	mongalla	feb
15	mongalla	jan	17	mongalla	dec	19	mongalla	nov
21	mongalla	oct	23	mongalla	sep	25	mongalla	aug

** mean and standard deviation values of the set of possible predictors

variable	mean	std dev	variable	mean	std dev	variable	mean	std dev
1	2847.10	289.57	2	2474.19	257.85	3	2500.65	752.79
4	1966.45	287.98	5	2239.68	773.81	6	1588.06	270.52
7	2360.65	753.80	8	1404.84	329.34	9	1936.23	632.89
10	1553.32	653.59	11	1881.35	690.10	12	1609.35	690.29
13	1775.55	639.13	14	2291.94	853.05	15	2088.16	747.21
16	3051.29	664.21	17	2315.81	759.31	18	3237.74	460.00
19	2569.68	828.78	20	3354.84	416.43	21	2782.58	1105.76
22	3046.45	365.32	23	2873.87	1063.94	24	2844.19	292.36
25	2834.52	815.57						

** final stepwise regression results

significance levels for f test: entry 5%
deletion 5%

step number 2

variable entered or deleted 8
cumulative sum of squares reduced ...... 0.2105090E+07

```
total sum of squares ....................  0.2515439E+07
cumulative proportion reduced ..........   0.8368681E+00


degree of freedom: regression   1
                   residual    29


f-value for analysis of variance .......  0.1487702E+03
multiple correlation coefficient .......  0.9148049E+00
standard error of estimate .............  0.1189535E+03
```

variables in equation:

variable number	regression coefficient	std. error of reg. coeff.	f-value
2	1.02734	0.084228	148.770
constant	305.26941		

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
2860.00	2904.43	-44.43	2810.00	2750.33	59.67	2850.00	2750.33	99.67
3500.00	3335.91	164.09	2910.00	2955.80	-45.80	2790.00	2914.70	-124.70
2920.00	2678.41	241.59	2620.00	2616.77	3.23	2730.00	2534.59	195.41
2820.00	2811.97	8.03	2910.00	2873.61	36.39	3230.00	3264.00	-34.00
3800.00	3726.30	73.70	3160.00	3192.08	-32.08	2630.00	2750.33	-120.33
2500.00	2575.68	-75.68	2440.00	2472.95	-32.95	2940.00	2832.52	107.48
2490.00	2544.86	-54.86	2660.00	2729.78	-69.78	2680.00	2678.41	1.59
2560.00	2616.77	-56.77	2850.00	2863.34	-13.34	2870.00	3058.53	-188.53
2630.00	2709.23	-79.23	2640.00	2678.41	-38.41	2840.00	2842.79	-2.79
3130.00	2791.42	338.58	2940.00	2966.07	-26.07	2930.00	3079.08	-149.08

** residual statistics:

```
mean ...................     -0.0000
std dev ................    115.0523
mean square error ......  0.12823E+05
correlation at lag 1 ...      0.0780
            at lag 2 ...     -0.0684
            at lag 3 ...     -0.2238
```

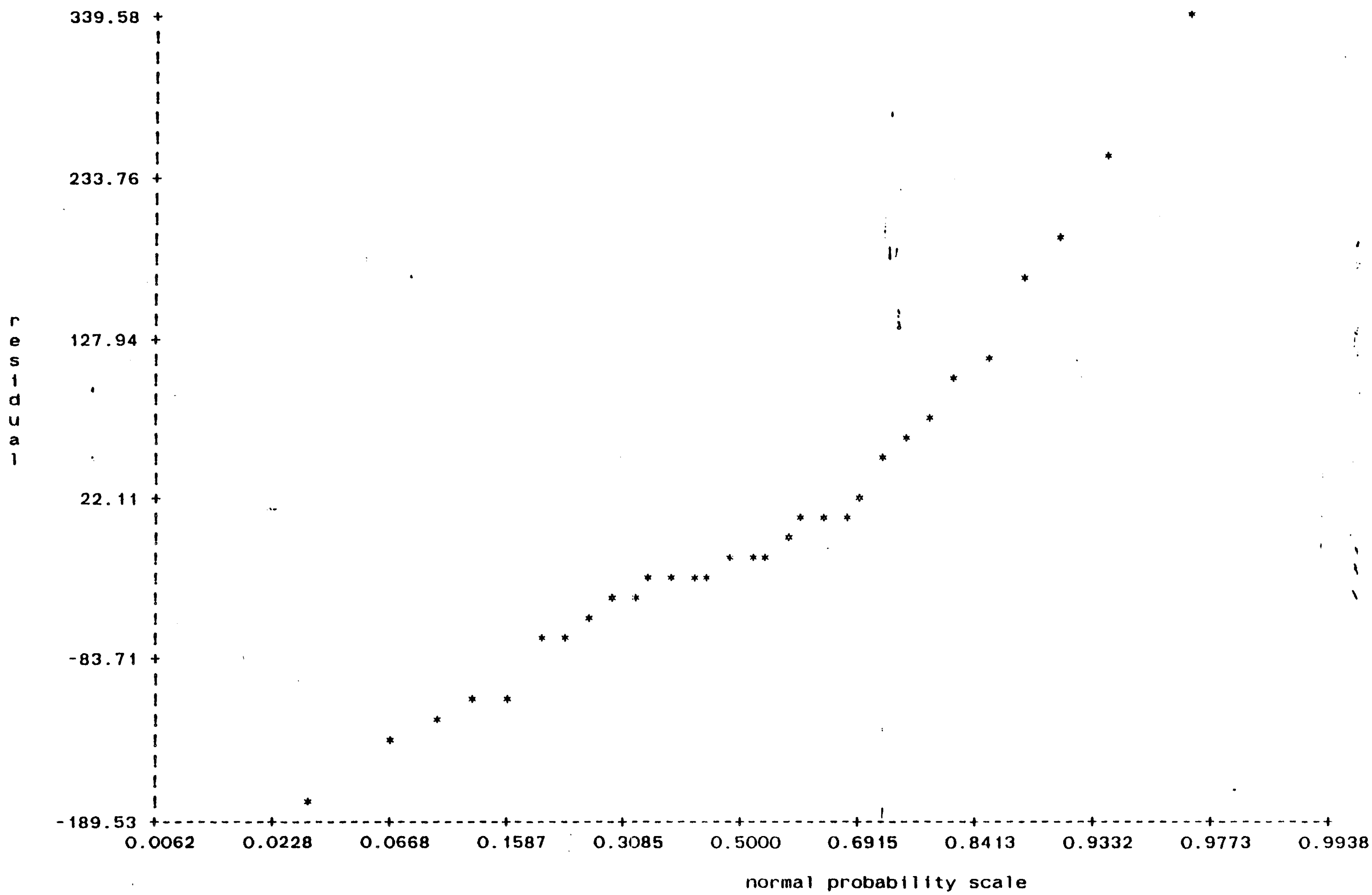
** residual statistics for the second half of the data:

```
mean ...................    -11.9564
std dev ................    159.8946
mean square error ......  0.24880E+05
correlation at lag 1 ...      0.1922
            at lag 2 ...     -0.0833
            at lag 3 ...      0.3560
```

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00225 * residual ; r2 = 0.85816

ols analysis for station mongalla , month aug

** set of possible predictors

variable	station	month	variable	station	month	variable	station	month
2	mongalla	jul	3	mongalla	jun	4	mongalla	may
5	mongalla	apr	6	mongalla	mar	7	mongalla	feb
8	mongalla	jan	9	mongalla	dec	10	mongalla	nov
11	mongalla	oct	12	mongalla	sep	13	mongalla	aug

** mean and standard deviation values of the set of possible predictors

variable	mean	std dev	variable	mean	std dev	variable	mean	std dev
1	2816.77	816.93	2	2500.65	752.79	3	2239.68	773.81
4	2360.65	753.80	5	1936.23	632.89	6	1881.35	690.10
7	1775.55	639.13	8	2088.16	747.21	9	2315.81	759.31
10	2569.68	828.78	11	2782.58	1105.76	12	2873.87	1063.94
13	2834.52	815.57						

** final stepwise regression results

significance levels for f test: entry 5%
deletion 5%

step number 3

variable entered or deleted 13
cumulative sum of squares reduced ...... 0.1790290E+08

total sum of squares .... 0.2002128E+08
cumulative proportion reduced .... 0.8941936E+00

degree of freedom: regression 2
residual 28

```
f-value for analysis of variance ....... 0.1183171E+03
multiple correlation coefficient ....... 0.9456181E+00
standard error of estimate ............. 0.2750571E+03
```

variables in equation:

variable number	regression coefficient	std. error of reg. coeff.	f-value
2	1.34337	0.124788	115.888
4	-0.40172	0.124621	10.391
constant	405.80841		

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
3640.00	4005.76	-365.76	3350.00	3257.62	92.38	3380.00	3059.10	320.90
3060.00	3327.16	-267.16	2970.00	2557.04	412.96	2270.00	2579.24	-309.24
2920.00	2848.78	71.22	2440.00	2797.33	-357.33	2810.00	2399.08	410.92
2620.00	2505.81	114.19	4080.00	3838.64	241.36	5420.00	5349.68	70.32
4010.00	3976.68	33.32	2780.00	3380.77	-600.77	2560.00	2665.50	-105.50
1830.00	2117.45	-287.45	1560.00	1569.43	-9.43	2850.00	2638.99	211.01
1720.00	1787.91	-67.91	1860.00	1830.59	29.41	3130.00	2767.19	362.81
2340.00	2541.97	-201.97	2330.00	2252.51	77.49	1950.00	1897.15	52.85
2040.00	2071.40	-31.40	3300.00	3189.54	110.46	3720.00	3332.43	387.57
2680.00	2853.96	-173.96	3080.00	2765.20	314.80	2130.00	2528.66	-398.66

** residual statistics:

```
mean ..................        0.0000
std dev ...............      261.4093
mean square error ...... 0.66199E+05
correlation at lag 1 ...      -0.2925
            at lag 2 ...       0.2512
            at lag 3 ...      -0.2117
```

** residual statistics for the second half of the data:

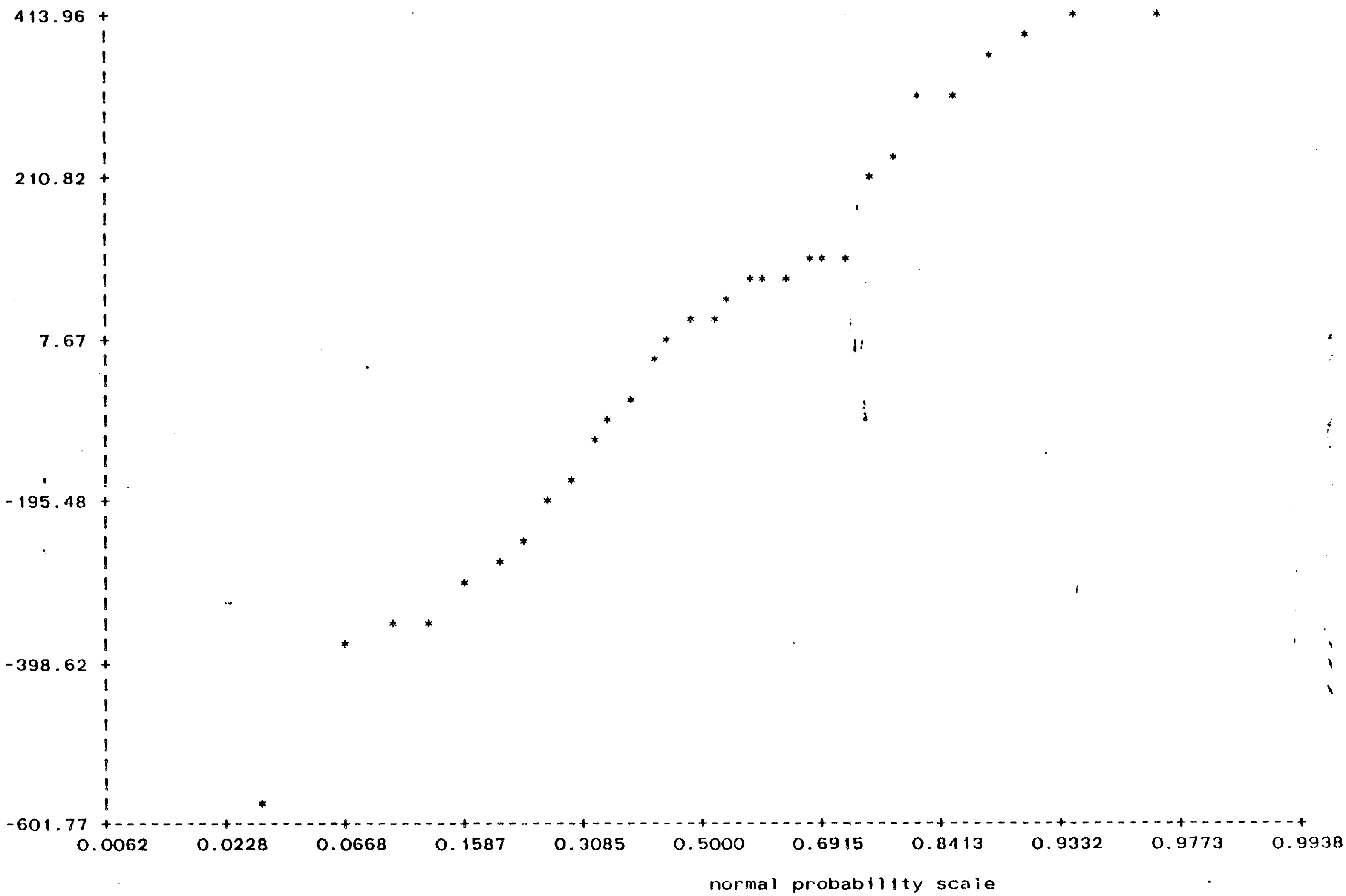
```
mean ..................      164.2062
std dev ...............      348.0010
mean square error ...... 0.14329E+06
correlation at lag 1 ...      -0.2256
            at lag 2 ...       0.0578
            at lag 3 ...      -0.3717
```

** durbin-watson test:

there is not a lagged autoregressive term
the test is inconclusive; significance level 5%

non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00105 * residual ; r2 = 0.96815

****

gls analysis, month aug

****

** residual correlation matrix of ols estimation:

	wadi hal	atbara	karthum	malakal	mongalla
wadi hal	1.000	0.453	0.512	0.132	0.341
atbara	0.453	1.000	0.515	0.207	0.267
karthum	0.512	0.515	1.000	0.169	0.083
malakal	0.132	0.207	0.169	1.000	0.240
mongalla	0.341	0.267	0.083	0.240	1.000

----

station wadi hal iteration 1

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	16190.47986	2094.881348
3	1.24318	0.375940
4	1.45804	0.170963
15	-2.24662	1.091525
57	-0.19809	0.072083

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
19400.00	18864.64	535.36	12800.00	16093.29	-3293.29	21700.00	18000.23	3699.77
22100.00	21620.43	479.57	17700.00	15902.47	1797.53	16500.00	17711.35	-1211.35
20800.00	21339.42	-539.42	7680.00	11706.75	-4026.75	22900.00	21332.57	1567.43
12300.00	14169.10	-1869.10	27100.00	26745.06	354.94	19600.00	18491.70	1108.30
15600.00	15938.67	-338.67	19200.00	20411.33	-1211.33	20700.00	20437.93	262.07
17900.00	15278.87	2621.13	19300.00	19445.31	-145.31	22500.00	19378.69	3121.31
19600.00	19944.55	-344.55	15700.00	15996.57	-296.57	21600.00	20169.98	1430.02
18300.00	18849.05	-549.05	19900.00	21902.80	-2002.80	25400.00	26070.29	-670.29
19700.00	19897.33	-197.33	16900.00	15957.82	942.18	20200.00	18979.48	1220.52
14400.00	14218.58	181.42	22100.00	23317.28	-1217.28	22900.00	23564.44	-664.44

** residual statistics:

```
mean ...................     -0.0072
std dev ................   1643.9939
mean square error ...... 0.26183E+07
correlation at lag 1 ...     -0.2213
            at lag 2 ...      0.1819
            at lag 3 ...     -0.2500
```

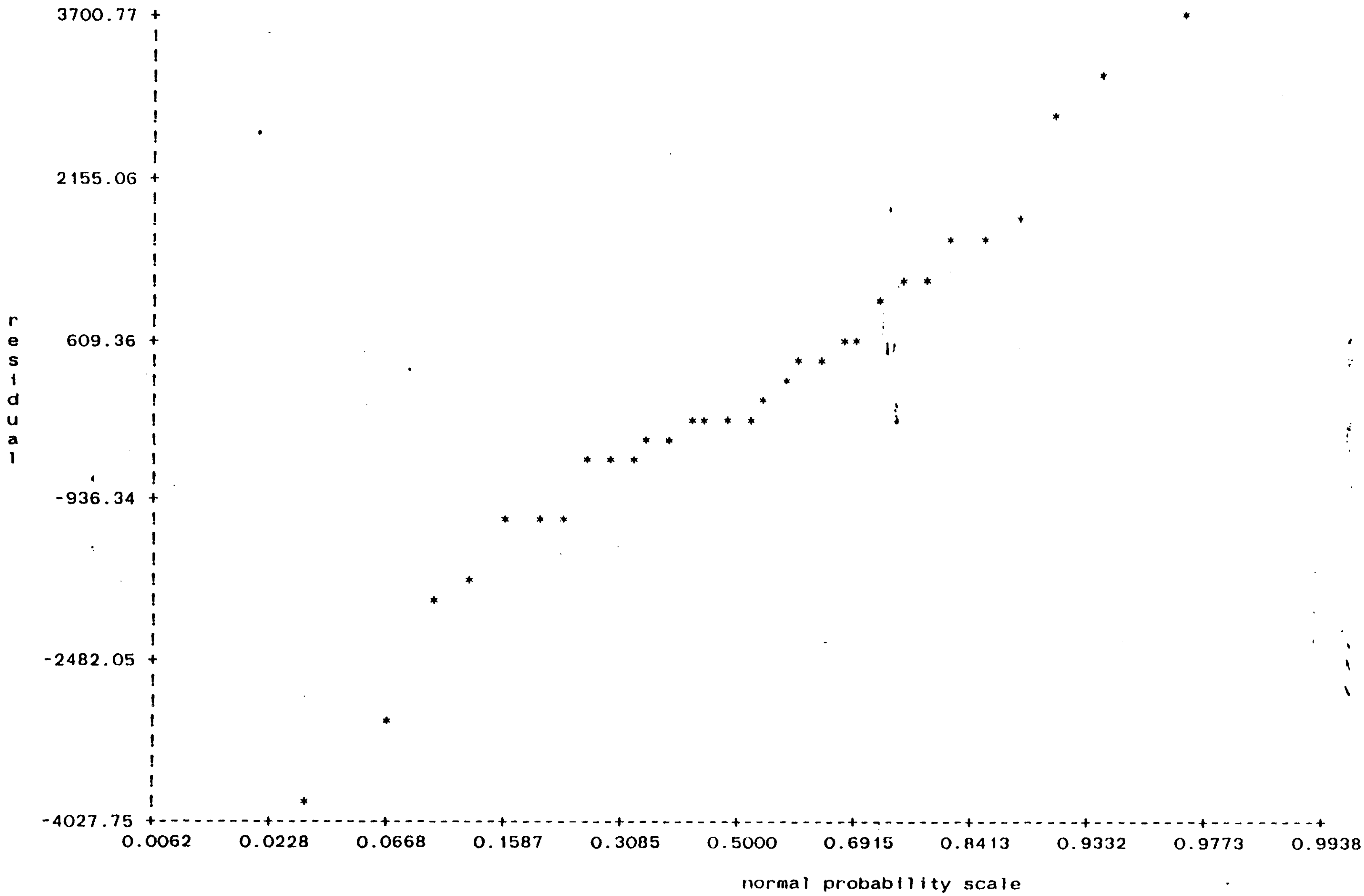
** residual statistics for the second half of the data:

```
mean ...................    912.0363
std dev ................   2645.0356
mean square error ...... 0.75755E+07
correlation at lag 1 ...      0.1968
            at lag 2 ...     -0.2061
            at lag 3 ...     -0.0400
```

** durbin-watson test:

there is a lagged autoregressive term
not reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00016 * residual ; r2 = 0.90731

station atbara iteration 1

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	2676.26074	486.242714
2	1.81355	0.248001

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
5700.00	5505.40	194.60	4710.00	6031.33	-1321.33	8160.00	6539.12	1620.88
7650.00	5523.54	2126.46	8130.00	4779.98	3350.02	5300.00	4350.17	949.83
6990.00	6285.23	704.77	2350.00	3751.70	-1401.70	7180.00	5523.54	1656.46
3060.00	4232.29	-1172.29	13200.00	12034.18	1165.82	4430.00	4925.06	-495.06
3620.00	4580.49	-960.49	4650.00	5922.52	-1272.52	6040.00	6049.47	-9.47
5520.00	4761.84	758.16	7900.00	6285.23	1614.77	6100.00	4997.61	1102.39
6080.00	7173.87	-1093.87	3950.00	4707.44	-757.44	4580.00	6339.63	-1759.63
4350.00	5596.08	-1246.08	4670.00	5033.88	-363.88	7240.00	7355.22	-115.22
4170.00	6974.38	-2804.38	5520.00	4598.62	921.38	6330.00	6176.41	153.59
3640.00	4261.30	-621.30	7420.00	7808.61	-388.61	5040.00	5324.05	-284.05

** residual statistics:

mean	-0.0004
std dev	1297.1947
mean square error	0.16301E+07
correlation at lag 1 ...	0.2256
at lag 2 ...	0.2430
at lag 3 ...	-0.1706

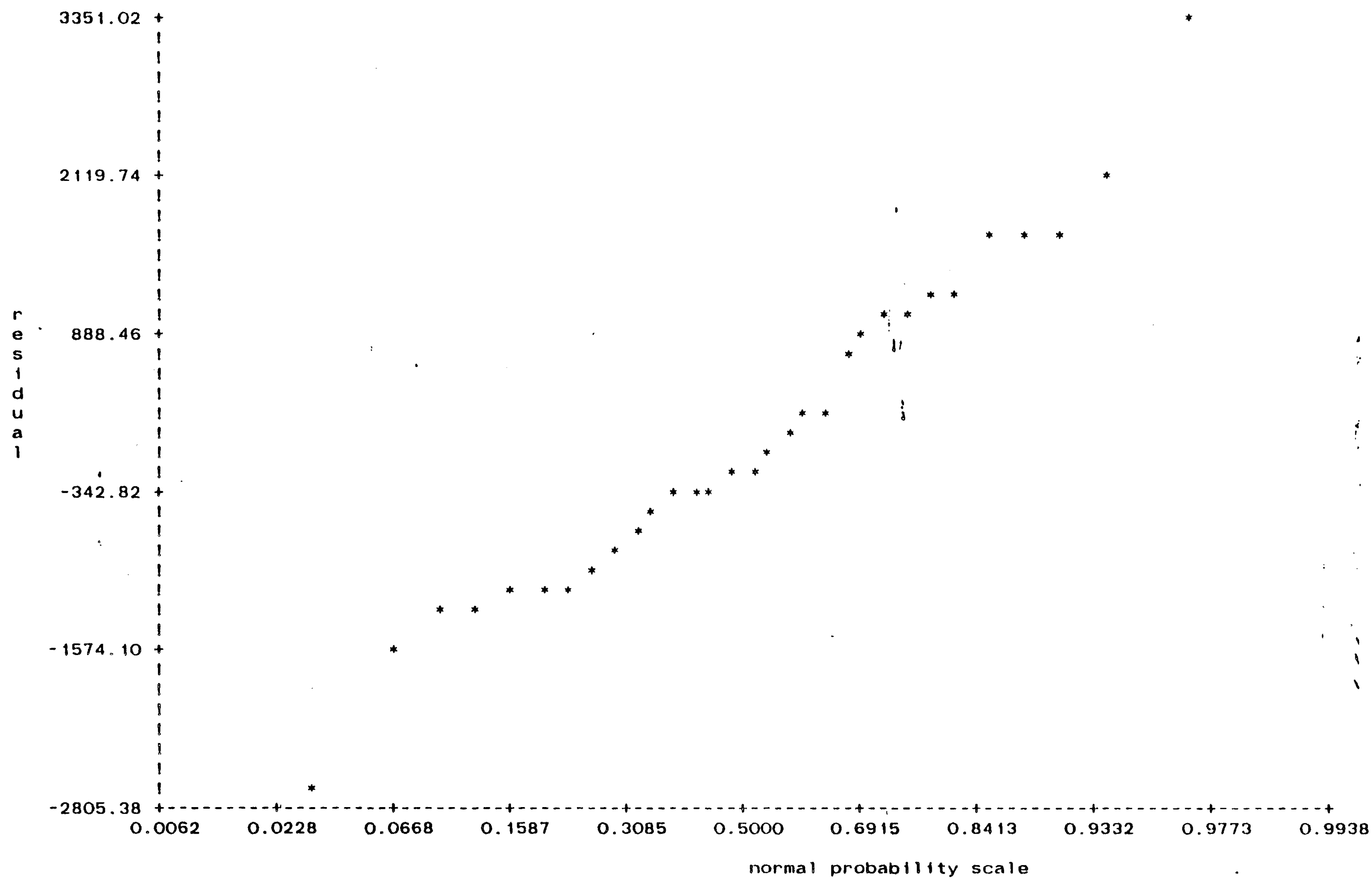
** residual statistics for the second half of the data:

mean	158.8169
std dev	1494.6393
mean square error	0.21863E+07
correlation at lag 1 ...	0.0493
at lag 2 ...	-0.3220
at lag 3 ...	-0.1447

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00021 * residual ; r2 = 0.93908

station karthum iteration 1

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	12288.99365	1597.499573
2	1.43571	0.176859
7	2.80376	1.638374
13	-0.37585	0.116520

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
16300.00	16765.59	-465.59	9490.00	12888.33	-3398.33	17400.00	14758.02	2641.98
25600.00	20343.87	5256.13	15300.00	12798.28	2501.72	17500.00	15979.66	1520.34
15900.00	16507.06	-607.06	7520.00	10338.37	-2818.37	19000.00	17569.29	1430.71
8060.00	11821.06	-3761.06	20200.00	20470.71	-270.71	17700.00	18037.45	-337.45
12900.00	15533.24	-2633.24	16800.00	17570.05	-770.05	13200.00	15864.92	-2664.92
14600.00	13437.64	1162.36	16000.00	14450.72	1549.28	16500.00	16153.32	346.68
15000.00	16147.64	-1147.64	13300.00	13546.70	-246.70	18900.00	16588.79	2311.21
16200.00	14288.66	1911.34	17100.00	18667.89	-1567.89	18600.00	21732.12	-3132.12
14700.00	16130.27	-1430.27	14800.00	12654.99	2145.01	15600.00	14714.41	885.59
13200.00	12027.31	1172.69	18200.00	18418.69	-218.69	20300.00	20370.30	-70.30

** residual statistics:

mean	0.0033
std dev	2048.8561
mean square error	0.40666E+07
correlation at lag 1 ...	0.2370
at lag 2 ...	-0.1197
at lag 3 ...	-0.2281

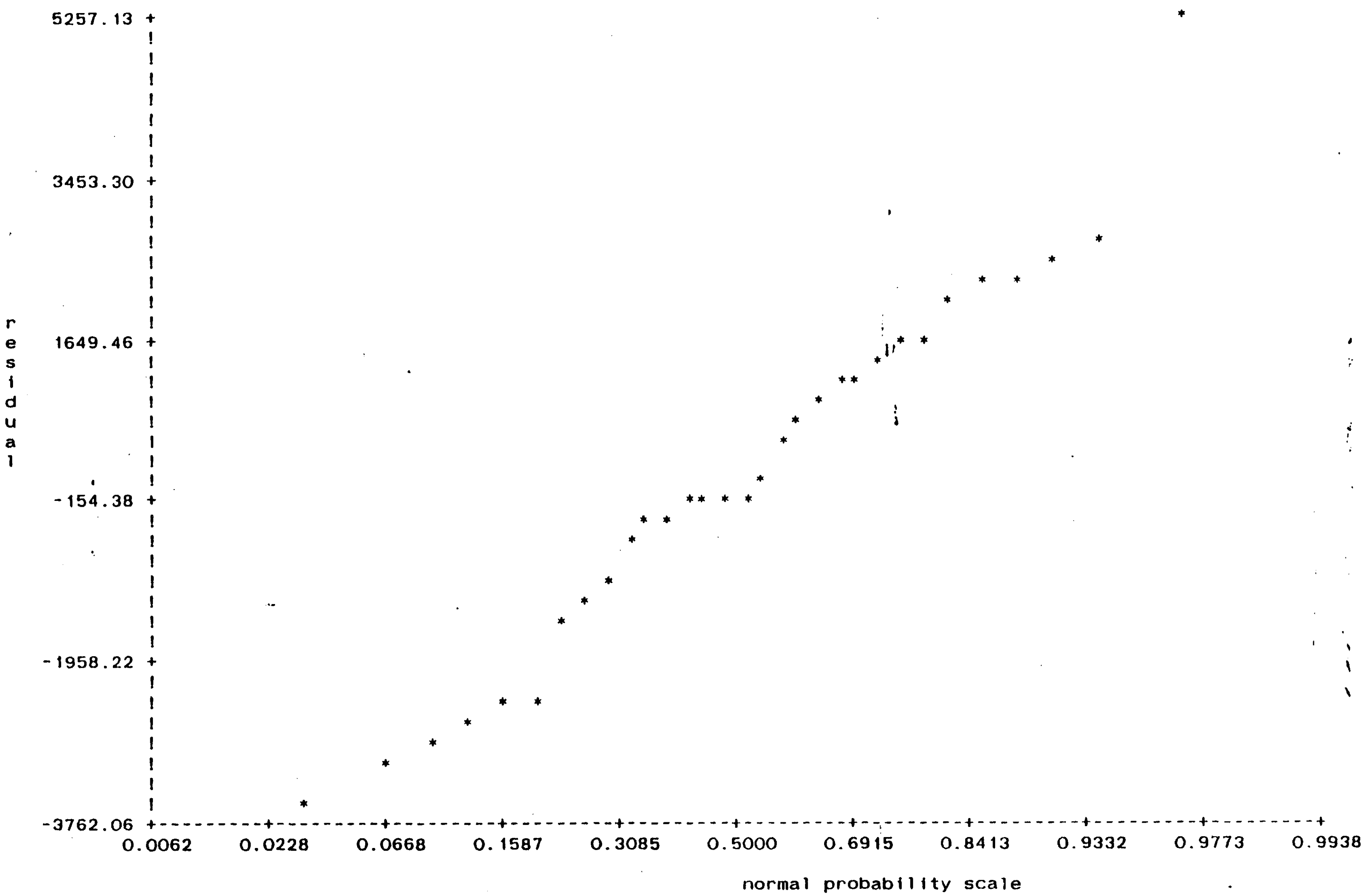
** residual statistics for the second half of the data:

mean	1069.4914
std dev	1931.2976
mean square error	0.47165E+07
correlation at lag 1 ...	-0.1237
at lag 2 ...	-0.3233
at lag 3 ...	0.0881

** durbin-watson test:

there is a lagged autoregressive term
reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00013 * residual ; r2 = 0.94873

station malakal iteration 1

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	255.17631	199.207401
2	1.04758	0.080065

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
2860.00	2905.56	-45.56	2810.00	2748.42	61.58	2850.00	2748.42	101.58
3500.00	3345.54	154.46	2910.00	2957.94	-47.94	2790.00	2916.03	-126.03
2920.00	2675.09	244.91	2620.00	2612.24	7.76	2730.00	2528.43	201.57
2820.00	2811.28	8.72	2910.00	2874.13	35.87	3230.00	3272.21	-42.21
3800.00	3743.62	56.38	3160.00	3198.88	-38.88	2630.00	2748.42	-118.42
2500.00	2570.33	-70.33	2440.00	2465.57	-25.57	2940.00	2832.23	107.77
2490.00	2538.90	-48.90	2660.00	2727.47	-67.47	2680.00	2675.09	4.91
2560.00	2612.24	-52.24	2850.00	2863.66	-13.66	2870.00	3062.70	-192.70
2630.00	2706.52	-76.52	2640.00	2675.09	-35.09	2840.00	2842.70	-2.70
3130.00	2790.32	339.68	2940.00	2968.41	-28.41	2930.00	3083.65	-153.65

** residual statistics:

mean	0.0002
std dev	115.1669
mean square error	0.12849E+05
correlation at lag 1 ...	0.0799
at lag 2 ...	-0.0663
at lag 3 ...	-0.2343

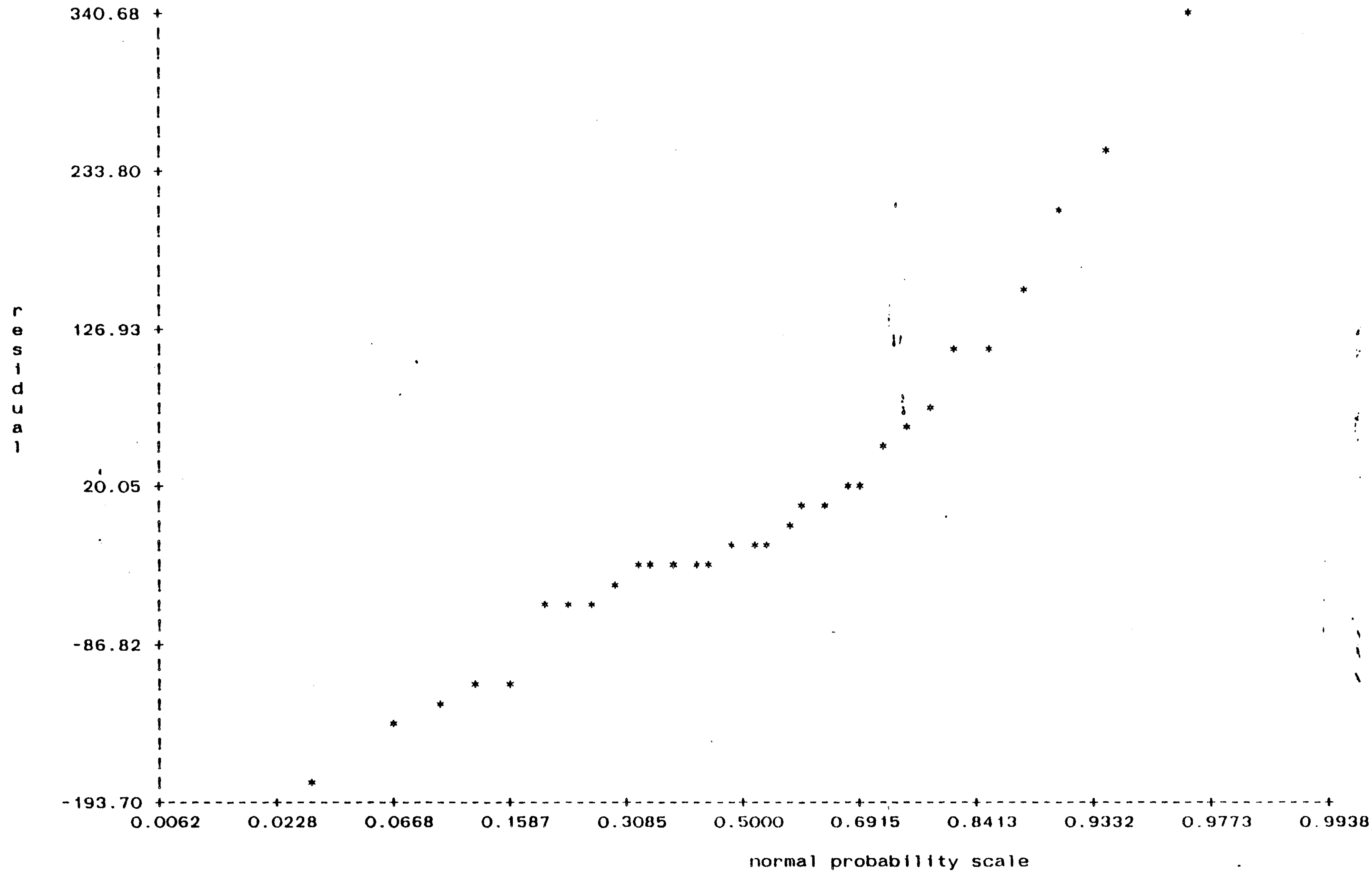
** residual statistics for the second half of the data:

mean	-12.2425
std dev	157.2011
mean square error	0.24060E+05
correlation at lag 1 ...	0.1551
at lag 2 ...	-0.1223
at lag 3 ...	0.3577

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00224 * residual ; r2 = 0.85300

station mongalla iteration 1

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	416.55655	161.946762
2	1.24005	0.111122
4	-0.29683	0.112151

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
3640.00	3954.96	-314.96	3350.00	3271.02	78.98	3380.00	3027.83	352.17
3060.00	3317.46	-257.46	2970.00	2585.11	384.89	2270.00	2569.35	-299.35
2920.00	2790.77	129.23	2440.00	2797.30	-357.30	2810.00	2394.16	415.84
2620.00	2527.46	92.54	4080.00	3769.62	310.38	5420.00	5304.29	115.71
4010.00	4032.46	-22.46	2780.00	3359.54	-579.54	2560.00	2665.25	-105.25
1830.00	2084.61	-254.61	1560.00	1583.18	-23.18	2850.00	2583.79	266.21
1720.00	1833.69	-113.69	1860.00	1855.33	4.67	3130.00	2735.43	394.57
2340.00	2554.17	-214.17	2330.00	2404.63	-74.63	1950.00	1958.95	-8.95
2040.00	2097.60	-57.60	3300.00	3156.39	143.61	3720.00	3316.40	403.60
2680.00	2861.41	-181.41	3080.00	2773.55	306.45	2130.00	2549.29	-419.29

** residual statistics:

mean	0.0004
std dev	264.9151
mean square error	0.67987E+05
correlation at lag 1 ...	-0.2803
at lag 2 ...	0.2249
at lag 3 ...	-0.2466

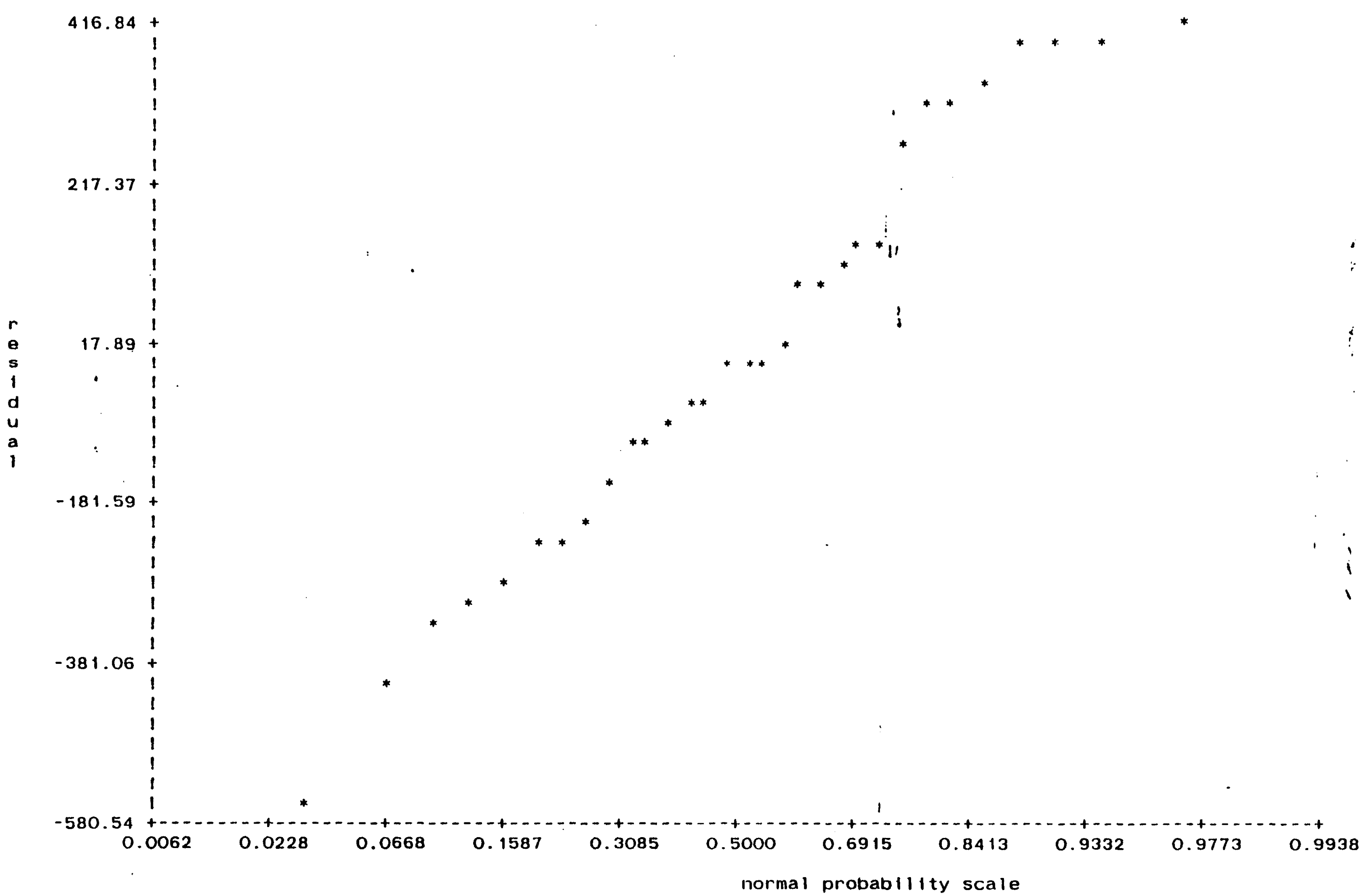
** residual statistics for the second half of the data:

mean	163.3986
std dev	348.7764
mean square error	0.14356E+06
correlation at lag 1 ...	-0.2189
at lag 2 ...	0.0299
at lag 3 ...	-0.3270

** durbin-watson test:

there is not a lagged autoregressive term
the test is inconclusive; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00104 * residual ; r2 = 0.97815

** residual correlation matrix of gls estimation, (iteration 1):

	wadi hal	atbara	karthum	malakal	mongalla
wadi hal	1.000	0.533	0.601	0.180	0.460
atbara	0.533	1.000	0.587	0.203	0.317
karthum	0.601	0.587	1.000	0.238	0.164
malakal	0.180	0.203	0.238	1.000	0.280
mongalla	0.460	0.317	0.164	0.280	1.000

** 96.52 maximum percentaje of crosscorrelation difference between two consecutive iterations, at iteration 1

----
station wadi hal iteration 2

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	15745.27258	1960.182190
3	1.17467	0.344126
4	1.47010	0.160403
15	-2.10803	1.019994
57	-0.18353	0.066948

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
19400.00	18782.66	617.34	12800.00	16059.53	-3259.53	21700.00	17843.79	3856.21
22100.00	21760.90	339.10	17700.00	15987.27	1712.73	16500.00	17739.62	-1239.62
20800.00	21234.46	-434.46	7680.00	11783.59	-4103.59	22900.00	21136.56	1763.44
12300.00	14248.03	-1948.03	27100.00	26409.38	690.62	19600.00	18722.95	877.05
15600.00	16111.37	-511.37	19200.00	20389.45	-1189.45	20700.00	20420.37	279.63
17900.00	15295.74	2604.26	19300.00	19323.78	-23.78	22500.00	19393.40	3106.60
19600.00	19941.68	-341.68	15700.00	16010.20	-310.20	21600.00	20102.87	1497.13
18300.00	18859.65	-559.65	19900.00	21985.06	-2085.06	25400.00	26134.10	-734.10
19700.00	19948.17	-248.17	16900.00	15946.05	953.95	20200.00	18916.49	1283.51
14400.00	14278.05	121.95	22100.00	23205.46	-1105.46	22900.00	23692.13	-792.13

** residual statistics:

```
mean ...................     -0.0089
std dev ................   1671.7175
mean square error ...... 0.27073E+07
correlation at lag 1 ...     -0.2425
            at lag 2 ...      0.2096
            at lag 3 ...     -0.2742
```

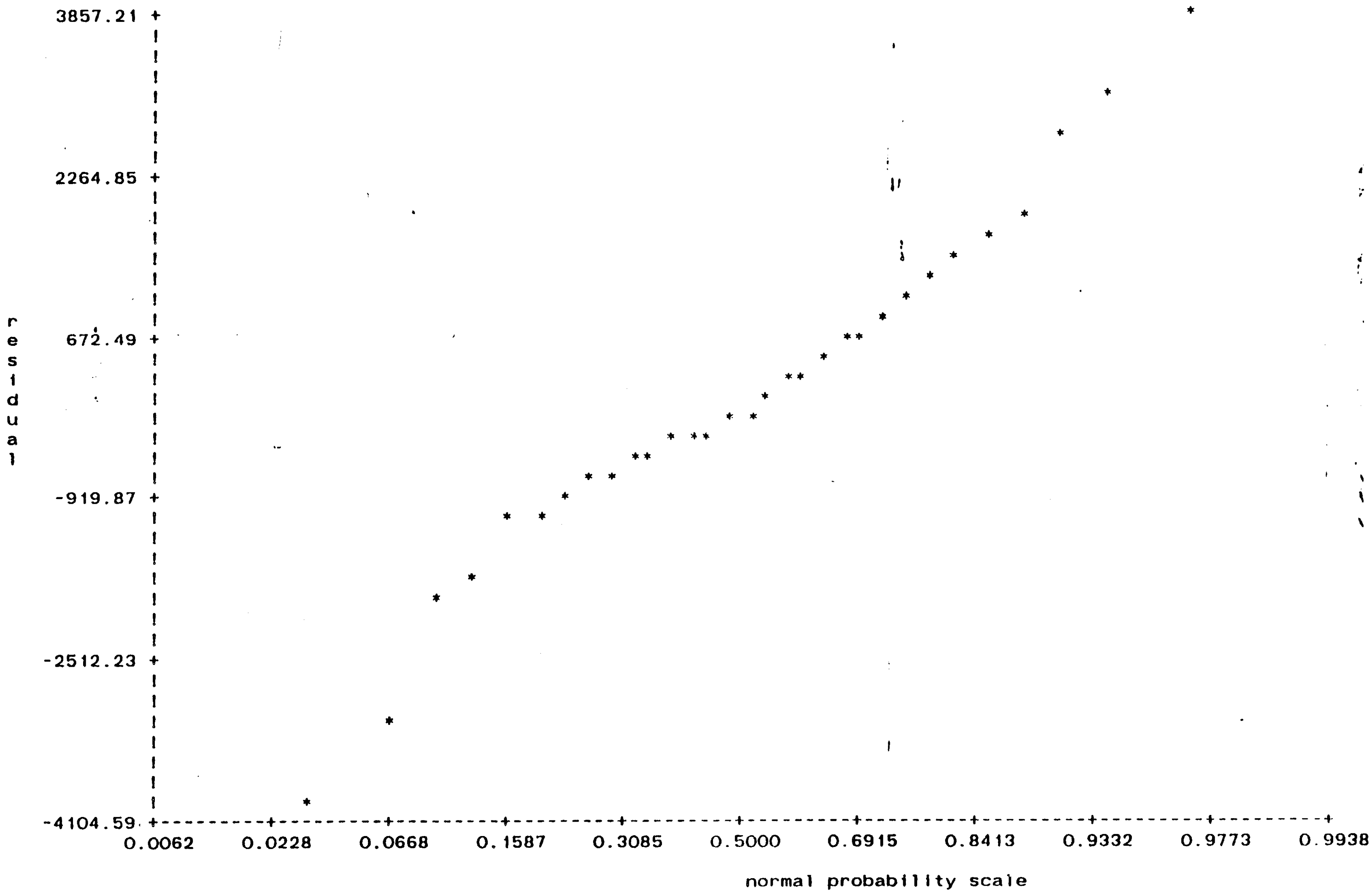
** residual statistics for the second half of the data:

```
mean ...................    892.8792
std dev ................   2602.3183
mean square error ...... 0.73251E+07
correlation at lag 1 ...      0.1825
            at lag 2 ...     -0.2141
            at lag 3 ...     -0.0417
```

** durbin-watson test:

```
there is a lagged autoregressive term
not reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%
```

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00016 * residual ; r2 = 0.91076

station atbara iteration 2

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	2732.34647	470.612392
2	1.78081	0.237428

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
5700.00	5510.40	189.60	4710.00	6026.84	-1316.84	8160.00	6525.46	1634.54
7650.00	5528.21	2121.79	8130.00	4798.08	3331.92	5300.00	4376.03	923.97
6990.00	6276.15	713.85	2350.00	3788.36	-1438.36	7180.00	5528.21	1651.79
3060.00	4260.28	-1200.28	13200.00	11921.31	1278.69	4430.00	4940.55	-510.55
3620.00	4602.19	-982.19	4650.00	5919.99	-1269.99	6040.00	6044.65	-4.65
5520.00	4780.27	739.73	7900.00	6276.15	1623.85	6100.00	5011.78	1088.22
6080.00	7148.75	-1068.75	3950.00	4726.85	-776.85	4580.00	6329.58	-1749.58
4350.00	5599.45	-1249.45	4670.00	5047.40	-377.40	7240.00	7326.83	-86.83
4170.00	6952.86	-2782.86	5520.00	4620.00	900.00	6330.00	6169.30	160.70
3640.00	4288.77	-648.77	7420.00	7772.03	-352.03	5040.00	5332.32	-292.32

** residual statistics;

```
mean .................. -0.0004
std dev ............... 1298.6275
mean square error ...... 0.16337E+07
correlation at lag 1 ... 0.2158
            at lag 2 ... 0.2464
            at lag 3 ... -0.1790
```

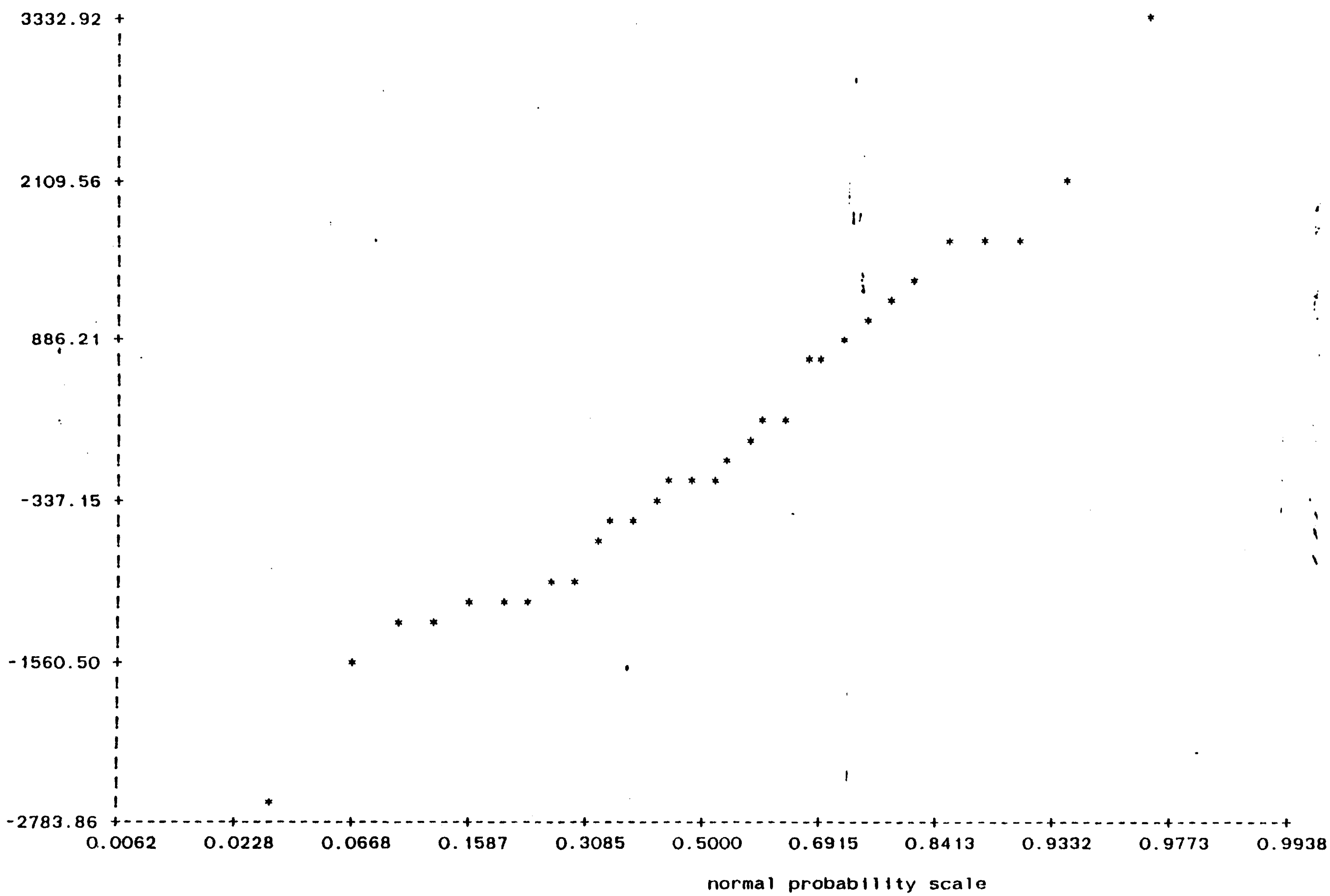
** residual statistics for the second half of the data:

```
mean .................. 154.7052
std dev ............... 1488.0323
mean square error ...... 0.21660E+07
correlation at lag 1 ... 0.0503
            at lag 2 ... -0.3234
            at lag 3 ... -0.1442
```

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00021 * residual ; r2 = 0.94190

station karthum iteration 2

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	11762.31616	1540.815399
2	1.44219	0.172407
7	2.50932	1.539058
13	-0.33428	0.111792

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
16300.00	16537.27	-237.27	9490.00	12864.46	-3374.46	17400.00	14536.07	2863.93
25600.00	20328.75	5271.25	15300.00	12966.94	2333.06	17500.00	15896.37	1603.63
15900.00	16503.52	-603.52	7520.00	10345.57	-2825.57	19000.00	17329.45	1670.55
8060.00	11905.50	-3845.50	20200.00	20164.77	35.23	17700.00	18097.45	-397.45
12900.00	15547.48	-2647.48	16800.00	17490.83	-690.83	13200.00	15968.23	-2768.23
14600.00	13354.29	1245.71	16000.00	14446.32	1553.68	16500.00	16180.64	319.36
15000.00	16176.61	-1176.61	13300.00	13523.29	-223.29	18900.00	16517.53	2382.47
16200.00	14448.70	1751.30	17100.00	18779.08	-1679.08	18600.00	21869.36	-3269.36
14700.00	16234.66	-1534.66	14800.00	12682.13	2117.87	15600.00	14733.07	866.93
13200.00	12067.23	1132.77	18200.00	18379.92	-179.92	20300.00	20519.20	-219.20

** residual statistics:

mean	-0.0008
std dev	2076.4876
mean square error	0.41771E+07
correlation at lag 1 ...	0.2000
at lag 2 ...	-0.1094
at lag 3 ...	-0.2103

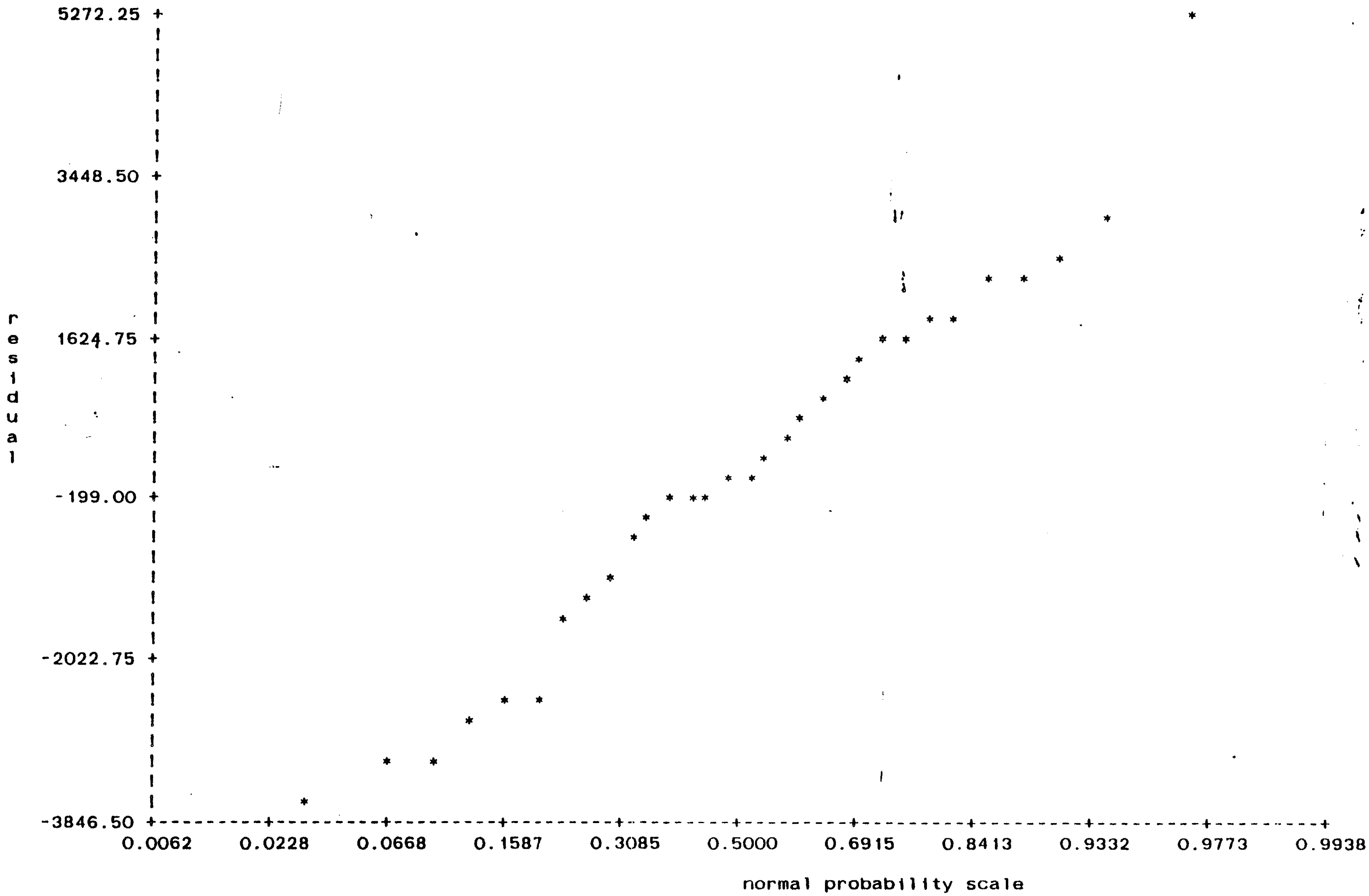
** residual statistics for the second half of the data:

mean	1011.2258
std dev	1902.3185
mean square error	0.44917E+07

** durbin-watson test:

there is a lagged autoregressive term
reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00013 * residual ; r2 = 0.94791

station malakal iteration 2

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	232.74107	197.507372
2	1.05665	0.079373

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
2860.00	2906.06	-46.06	2810.00	2747.57	62.43	2850.00	2747.57	102.43
3500.00	3349.86	150.14	2910.00	2958.90	-48.90	2790.00	2916.63	-126.63
2920.00	2673.60	246.40	2620.00	2610.20	9.80	2730.00	2525.67	204.33
2820.00	2810.97	9.03	2910.00	2874.36	35.64	3230.00	3275.89	-45.89
3800.00	3751.38	48.62	3160.00	3201.93	-41.93	2630.00	2747.57	-117.57
2500.00	2567.94	-67.94	2440.00	2462.27	-22.27	2940.00	2832.10	107.90
2490.00	2536.24	-46.24	2660.00	2726.43	-66.43	2680.00	2673.60	6.40
2560.00	2610.20	-50.20	2850.00	2863.80	-13.80	2870.00	3064.56	-194.56
2630.00	2705.30	-75.30	2640.00	2673.60	-33.60	2840.00	2842.67	-2.67
3130.00	2789.83	340.17	2940.00	2969.46	-29.46	2930.00	3085.69	-155.69

** residual statistics:

mean	0.0003
std dev	115.2924
mean square error	0.12877E+05
correlation at lag 1 ...	0.0813
at lag 2 ...	-0.0653
at lag 3 ...	-0.2390

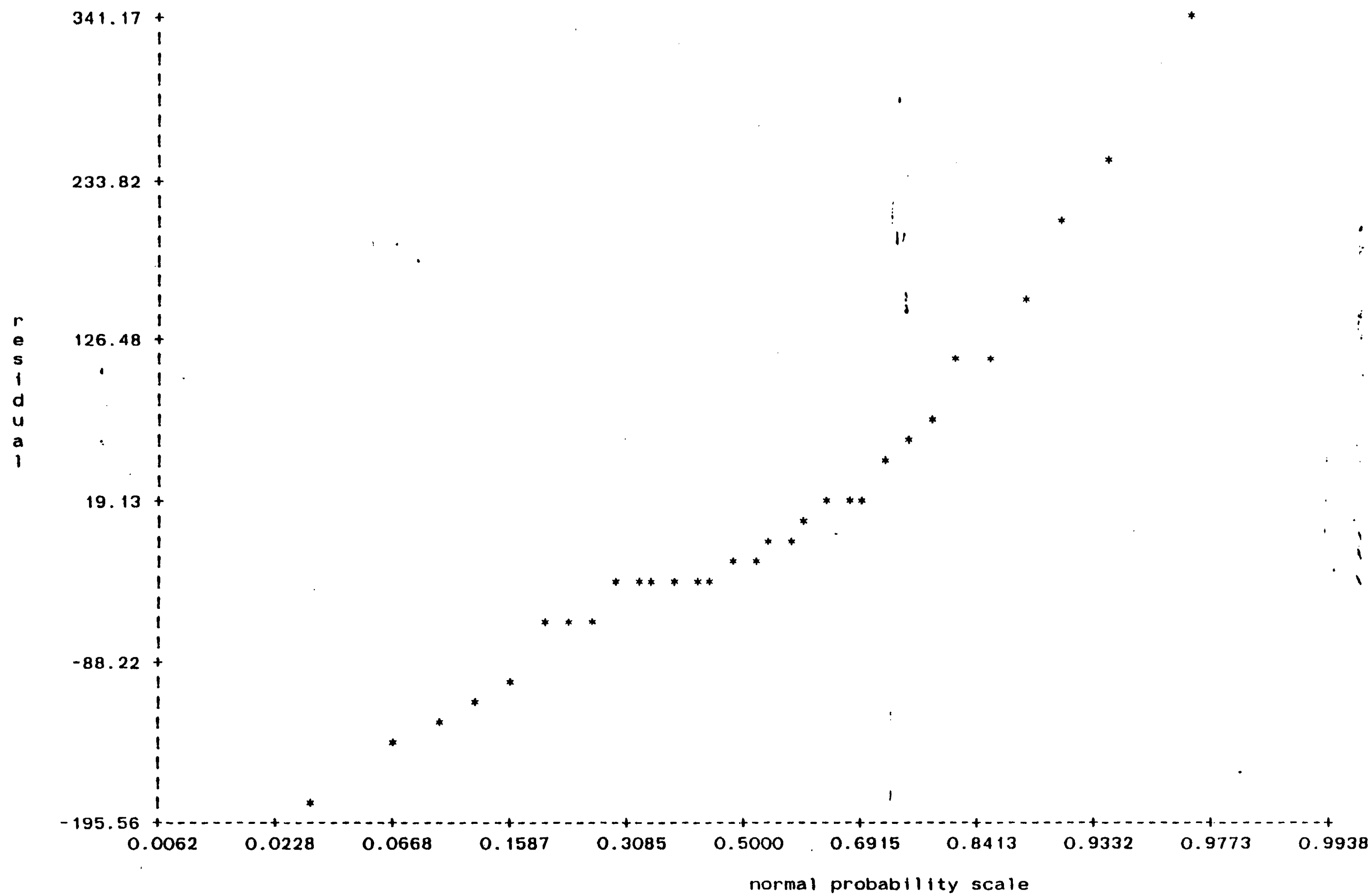
** residual statistics for the second half of the data:

mean	-12.3706
std dev	156.0705
mean square error	0.23720E+05
correlation at lag 1 ...	0.1384
at lag 2 ...	-0.1398
at lag 3 ...	0.3585

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00223 * residual ; r2 = 0.85055

station mongalla iteration 2

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	406.37036	157.392132
2	1.21040	0.105661
4	-0.26110	0.107686

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
3640.00	3943.47	-303.47	3350.00	3278.46	71.54	3380.00	3017.90	362.10
3060.00	3316.92	-256.92	2970.00	2593.78	376.22	2270.00	2564.37	-294.37
2920.00	2769.91	150.09	2440.00	2797.18	-357.18	2810.00	2389.93	420.07
2620.00	2533.50	86.50	4080.00	3750.54	329.46	5420.00	5302.62	117.38
4010.00	4059.48	-49.48	2780.00	3355.13	-575.13	2560.00	2664.27	-104.27
1830.00	2068.61	-238.61	1560.00	1580.88	-20.88	2850.00	2562.72	287.28
1720.00	1844.30	-124.30	1860.00	1858.55	1.45	3130.00	2723.62	406.38
2340.00	2557.00	-217.00	2330.00	2456.55	-126.55	1950.00	1976.01	-26.01
2040.00	2102.75	-62.75	3300.00	3146.53	153.47	3720.00	3313.60	406.40
2680.00	2864.34	-184.34	3080.00	2776.29	303.71	2130.00	2555.10	-425.10

** residual statistics:

```
mean ..................     0.0001
std dev ...............   267.4868
mean square error ...... 0.69313E+05
correlation at lag 1 ...   -0.2737
            at lag 2 ...    0.2142
            at lag 3 ...   -0.2569
```

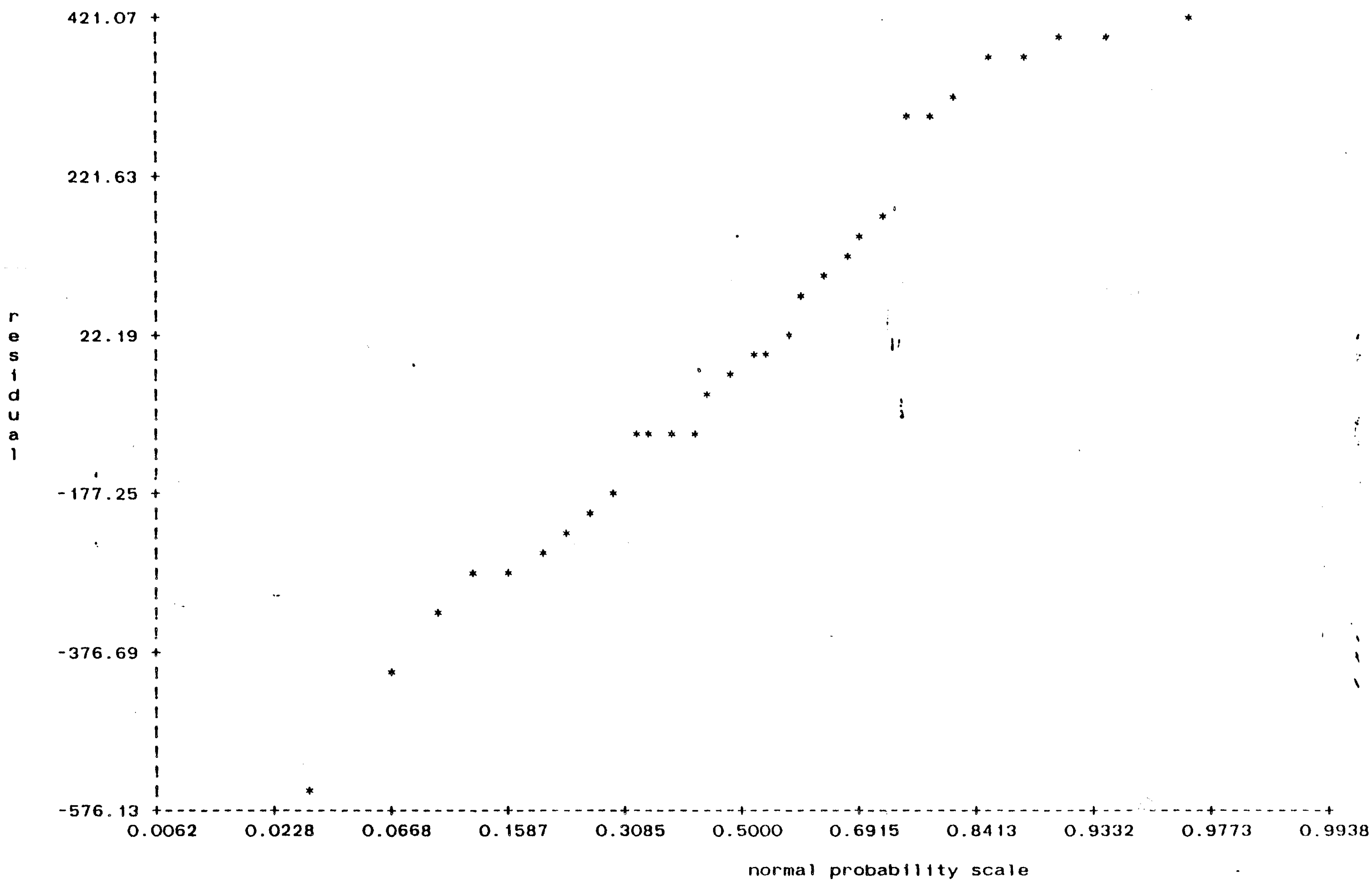
** residual statistics for the second half of the data:

```
mean ..................   161.7572
std dev ...............   349.4139
mean square error ...... 0.14347E+06
correlation at lag 1 ...   -0.2165
            at lag 2 ...    0.0173
            at lag 3 ...   -0.3154
```

** durbin-watson test:

there is not a lagged autoregressive term
the test is inconclusive; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00103 * residual ; r2 = 0.97754

** residual correlation matrix of gls estimation, (iteration 2):

	wadi hal	atbara	karthum	malakal	mongalla
wadi hal	1.000	0.544	0.612	0.194	0.502
atbara	0.544	1.000	0.594	0.201	0.336
karthum	0.612	0.594	1.000	0.257	0.193
malakal	0.194	0.201	0.257	1.000	0.290
mongalla	0.502	0.336	0.193	0.290	1.000

** 18.11 maximum percentaje of crosscorrelation difference between two consecutive iterations, at iteration 2

---

station wadi hal iteration 3

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	15640.17273	1945.115112
3	1.14170	0.338947
4	1.47927	0.158687
15	-2.07896	1.013883
57	-0.18012	0.066103

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
19400.00	18760.99	639.01	12800.00	16035.58	-3235.58	21700.00	17787.12	3912.88
22100.00	21812.85	287.15	17700.00	16008.88	1691.12	16500.00	17756.61	-1256.61
20800.00	21208.76	-408.76	7680.00	11796.75	-4116.75	22900.00	21092.09	1807.91
12300.00	14267.00	-1967.00	27100.00	26280.52	819.48	19600.00	18794.66	805.34
15600.00	16158.89	-558.89	19200.00	20386.51	-1186.51	20700.00	20418.10	281.90
17900.00	15296.09	2603.91	19300.00	19286.20	13.80	22500.00	19406.86	3093.14
19600.00	19930.26	-330.26	15700.00	16012.90	-312.90	21600.00	20082.15	1517.85
18300.00	18863.99	-563.99	19900.00	22026.64	-2126.64	25400.00	26163.18	-763.18
19700.00	19953.99	-253.99	16900.00	15942.77	957.23	20200.00	18894.08	1305.92
14400.00	14291.03	108.97	22100.00	23169.34	-1069.34	22900.00	23750.56	-850.56

** residual statistics:

```
mean ...................      0.0060
std dev ................   1681.4124
mean square error ...... 0.27388E+07
correlation at lag 1 ...     -0.2462
            at lag 2 ...      0.2179
            at lag 3 ...     -0.2847
```

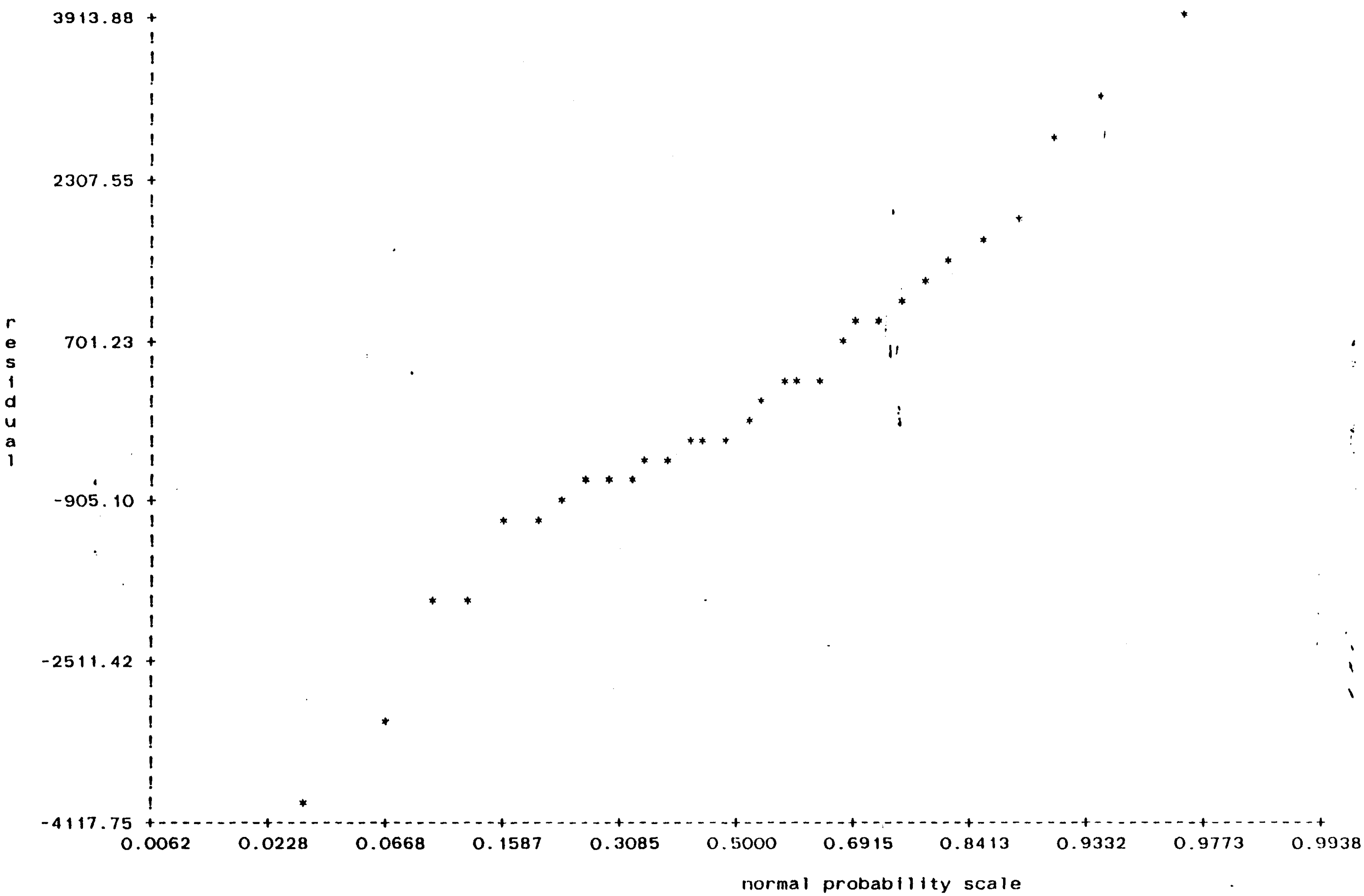
** residual statistics for the second half of the data:

```
mean ...................    888.0481
std dev ................   2593.1932
mean square error ...... 0.72709E+07
correlation at lag 1 ...      0.1789
            at lag 2 ...     -0.2148
            at lag 3 ...     -0.0398
```

** durbin-watson test:

there is a lagged autoregressive term
not reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00016 * residual ; r2 = 0.91216

station atbara iteration 3

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	2749.18558	468.918175
2	1.77098	0.236193

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
5700.00	5511.91	188.09	4710.00	6025.49	-1315.49	8160.00	6521.36	1638.64
7650.00	5529.62	2120.38	8130.00	4803.52	3326.48	5300.00	4383.80	916.20
6990.00	6273.43	716.57	2350.00	3799.37	-1449.37	7180.00	5529.62	1650.38
3060.00	4268.68	-1208.68	13200.00	11887.42	1312.58	4430.00	4945.20	-515.20
3620.00	4608.71	-988.71	4650.00	5919.23	-1269.23	6040.00	6043.20	-3.20
5520.00	4785.81	734.19	7900.00	6273.43	1626.57	6100.00	5016.03	1083.97
6080.00	7141.20	-1061.20	3950.00	4732.68	-782.68	4580.00	6326.56	-1746.56
4350.00	5600.46	-1250.46	4670.00	5051.45	-381.45	7240.00	7318.30	-78.30
4170.00	6946.40	-2776.40	5520.00	4626.42	893.58	6330.00	6167.17	162.83
3640.00	4297.02	-657.02	7420.00	7761.05	-341.05	5040.00	5334.81	-294.81

** residual statistics:

mean	-0.0003
std dev	1299.1681
mean square error	0.16351E+07
correlation at lag 1 ...	0.2128
at lag 2 ...	0.2473
at lag 3 ...	-0.1815

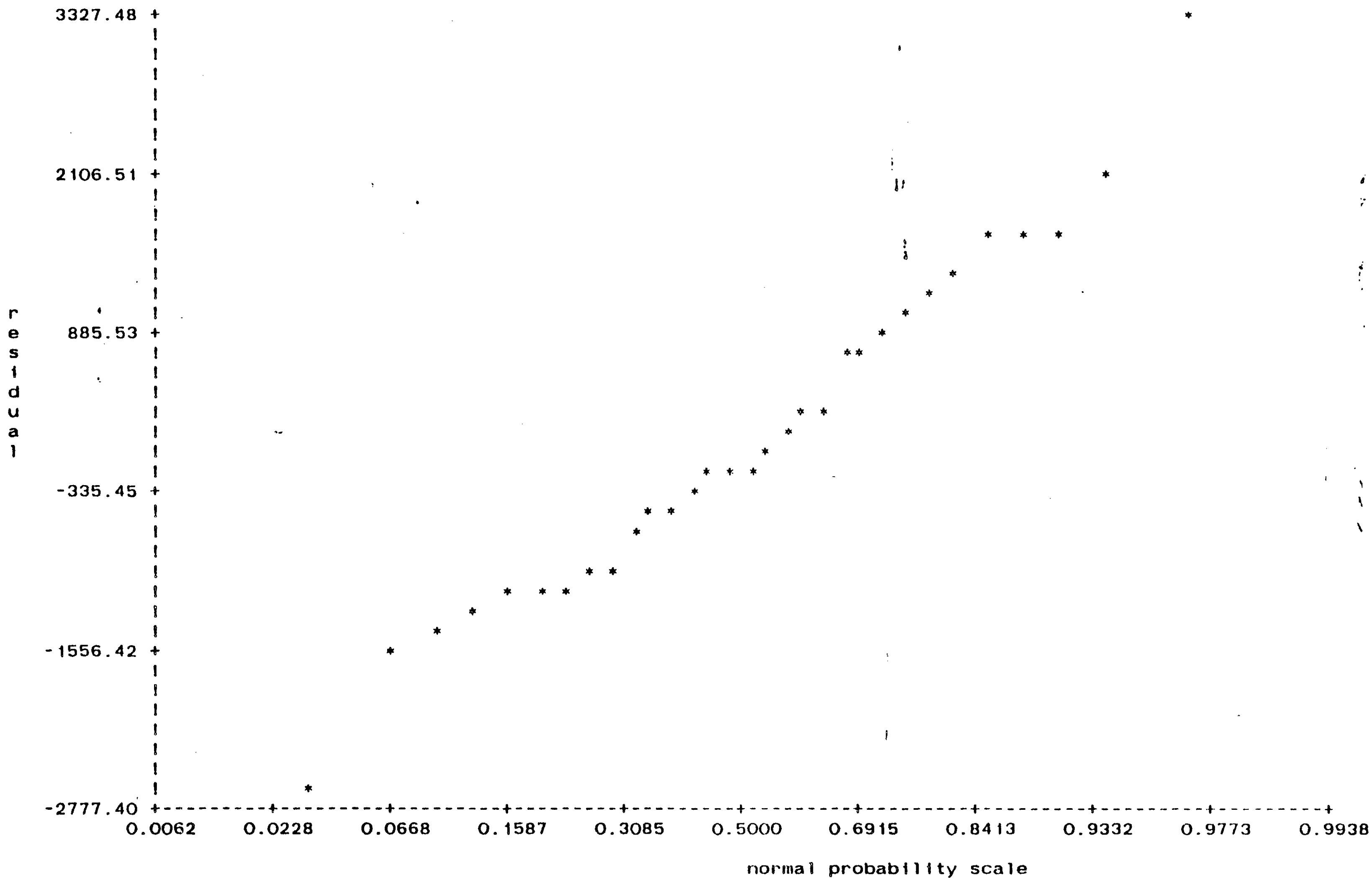
** residual statistics for the second half of the data:

mean	153.4707
std dev	1486.1147
mean square error	0.21601E+07
correlation at lag 1 ...	0.0506
at lag 2 ...	-0.3238
at lag 3 ...	-0.1440

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00021 * residual ; r2 = 0.94264

---

station karthum iteration 3

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	11604.44226	1547.226990
2	1.44638	0.173288
7	2.45350	1.539554
13	-0.32375	0.112032

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
16300.00	16479.11	-179.11	9490.00	12855.04	-3365.04	17400.00	14471.33	2928.67
25600.00	20338.79	5261.21	15300.00	13021.70	2278.30	17500.00	15878.09	1621.91
15900.00	16508.64	-608.64	7520.00	10336.53	-2816.53	19000.00	17261.42	1738.58
8060.00	11923.58	-3863.58	20200.00	20090.11	109.89	17700.00	18125.88	-425.88
12900.00	15554.89	-2654.89	16800.00	17470.29	-670.29	13200.00	15992.53	-2792.53
14600.00	13325.48	1274.52	16000.00	14439.63	1560.37	16500.00	16187.58	312.42
15000.00	16185.18	-1185.18	13300.00	13511.89	-211.89	18900.00	16497.75	2402.25
16200.00	14487.17	1712.83	17100.00	18809.01	-1709.01	18600.00	21913.13	-3313.13
14700.00	16264.39	-1564.39	14800.00	12678.72	2121.28	15600.00	14732.23	867.77
13200.00	12067.58	1132.42	18200.00	18370.28	-170.28	20300.00	20565.57	-265.57

** residual statistics:

mean	-0.0017
std dev	2084.4394
mean square error	0.42091E+07
correlation at lag 1 ...	0.1904
at lag 2 ...	-0.1069
at lag 3 ...	-0.2056

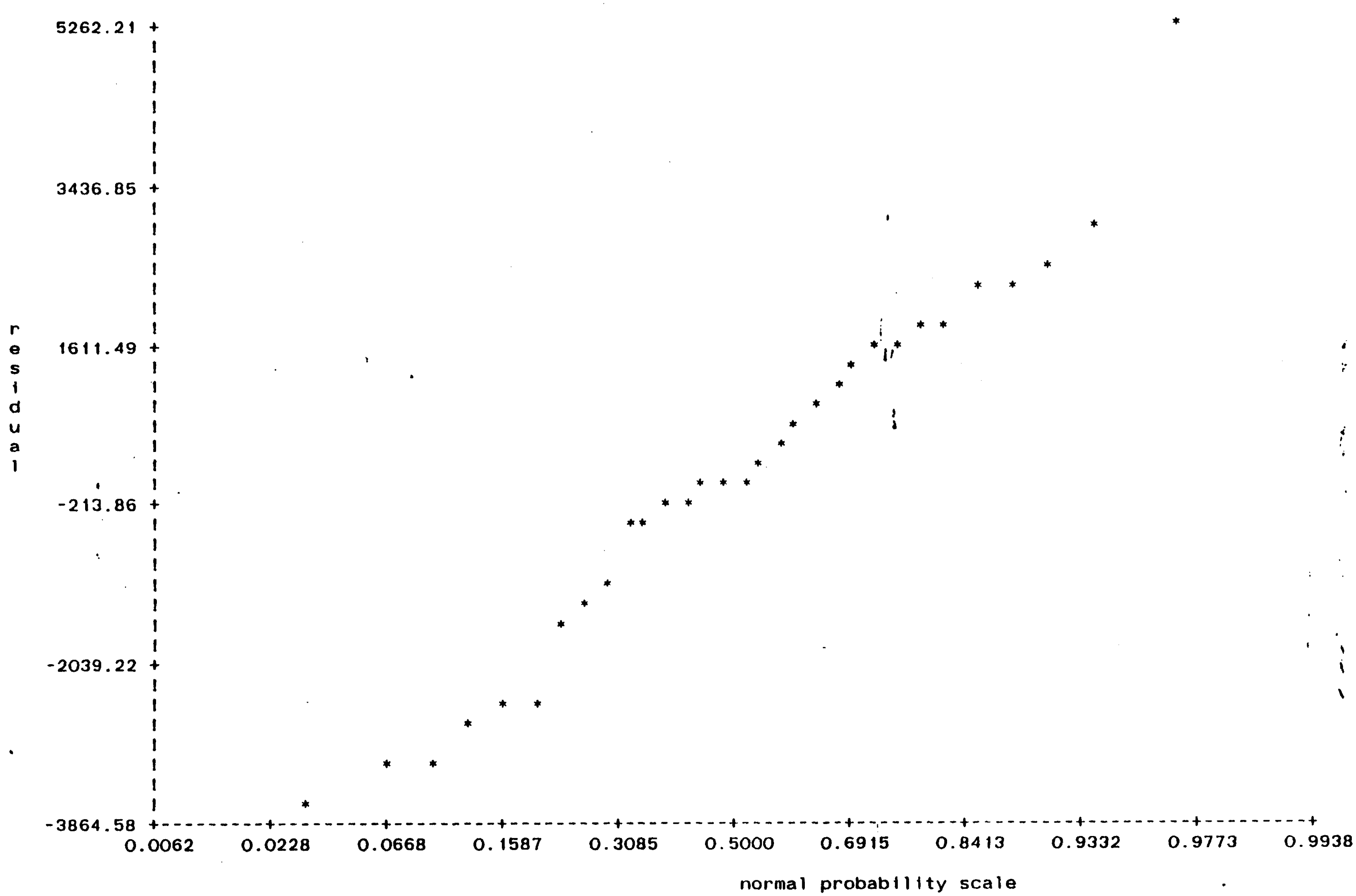
** residual statistics for the second half of the data:

mean	999.7656
std dev	1896.0247
mean square error	0.44462E+07
correlation at lag 1 ...	-0.1466
[illegible]	[illegible]

** durbin-watson test:

there is a lagged autoregressive term
not reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00013 * residual ; r2 = 0.94893

station malakal iteration 3

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	225.85228	197.003914
2	1.05943	0.079168

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
2860.00	2906.22	-46.22	2810.00	2747.30	62.70	2850.00	2747.30	102.70
3500.00	3351.18	148.82	2910.00	2959.19	-49.19	2790.00	2916.81	-126.81
2920.00	2673.14	246.86	2620.00	2609.58	10.42	2730.00	2524.82	205.18
2820.00	2810.87	9.13	2910.00	2874.44	35.56	3230.00	3277.02	-47.02
3800.00	3753.77	46.23	3160.00	3202.86	-42.86	2630.00	2747.30	-117.30
2500.00	2567.20	-67.20	2440.00	2461.26	-21.26	2940.00	2832.06	107.94
2490.00	2535.42	-45.42	2660.00	2726.12	-66.12	2680.00	2673.14	6.86
2560.00	2609.58	-49.58	2850.00	2863.84	-13.84	2870.00	3065.13	-195.13
2630.00	2704.93	-74.93	2640.00	2673.14	-33.14	2840.00	2842.65	-2.65
3130.00	2789.68	340.32	2940.00	2969.79	-29.79	2930.00	3086.32	-156.32

** residual statistics:

mean	0.0006
std dev	115.3401
mean square error	0.12888E+05
correlation at lag 1 ...	0.0817
at lag 2 ...	-0.0649
at lag 3 ...	-0.2404

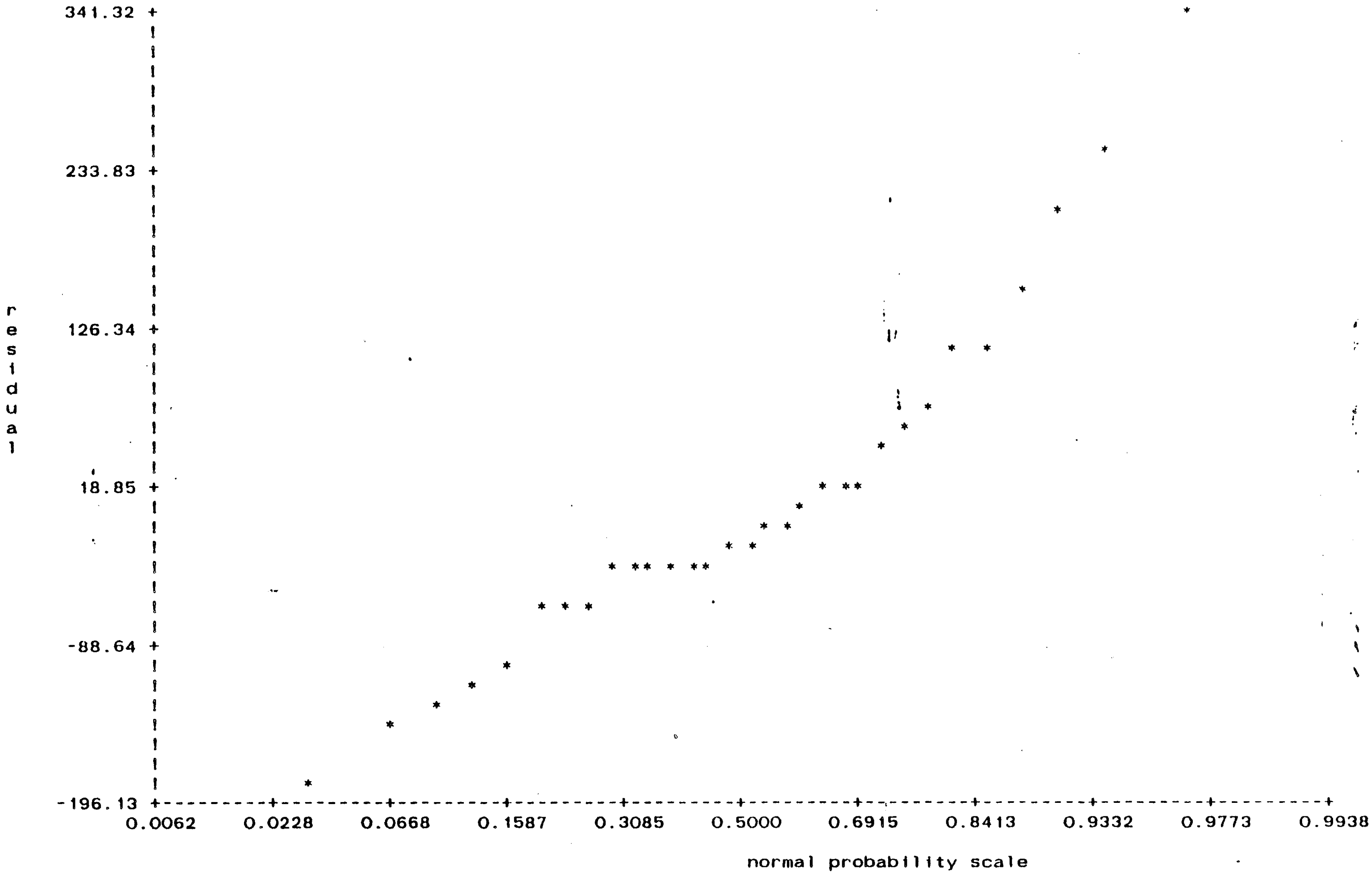
** residual statistics for the second half of the data:

mean	-12.4097
std dev	155.7331
mean square error	0.23619E+05
correlation at lag 1 ...	0.1333
at lag 2 ...	-0.1452
at lag 3 ...	0.3588

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00223 * residual ; r2 = 0.84988

station mongalla iteration 3

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	400.83868	156.190796
2	1.19907	0.103925
4	-0.24676	0.106370

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
3640.00	3939.46	-299.46	3350.00	3281.75	68.25	3380.00	3013.99	366.01
3060.00	3316.99	-256.99	2970.00	2597.17	372.83	2270.00	2562.20	-292.20
2920.00	2761.41	158.59	2440.00	2797.11	-357.11	2810.00	2387.97	422.03
2620.00	2535.79	84.21	4080.00	3743.33	336.67	5420.00	5303.39	116.61
4010.00	4071.16	-61.16	2780.00	3353.66	-573.66	2560.00	2663.79	-103.79
1830.00	2061.68	-231.68	1560.00	1579.24	-19.24	2850.00	2554.03	295.97
1720.00	1848.04	-128.04	1860.00	1859.30	0.70	3130.00	2718.77	411.23
2340.00	2557.99	-217.99	2330.00	2477.41	-147.41	1950.00	1982.44	-32.44
2040.00	2104.43	-64.43	3300.00	3142.72	157.28	3720.00	3312.75	407.25
2680.00	2865.55	-185.55	3080.00	2777.37	302.63	2130.00	2557.30	-427.30

** residual statistics:

mean 0.0000
std dev 268.7071
mean square error ...... 0.69947E+05
correlation at lag 1 ... -0.2707
at lag 2 ... 0.2096
at lag 3 ... -0.2609

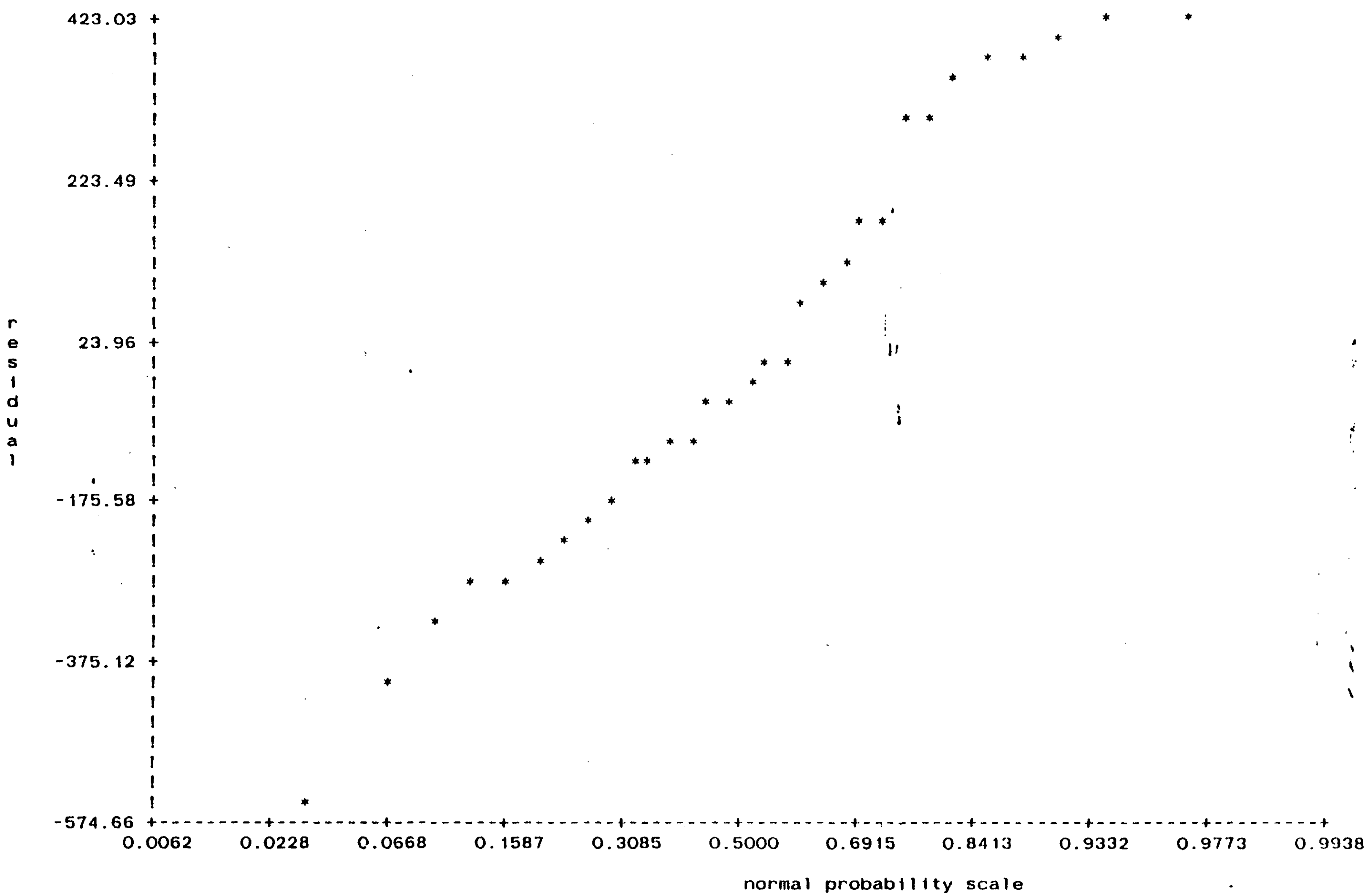
** residual statistics for the second half of the data:

mean 160.9559
std dev 349.7779
mean square error ...... 0.14347E+06
correlation at lag 1 ... -0.2151
at lag 2 ... 0.0121
at lag 3 ... -0.3107

** durbin-watson test:

there is not a lagged autoregressive term
the test is inconclusive; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00103 * residual ; r2 = 0.97705

** residual correlation matrix of gls estimation, (iteration 3):

	wadi hal	atbara	karthum	malakal	mongalla
wadi hal	1.000	0.546	0.614	0.199	0.517
atbara	0.546	1.000	0.595	0.200	0.342
karthum	0.614	0.595	1.000	0.263	0.204
malakal	0.199	0.200	0.263	1.000	0.294
mongalla	0.517	0.342	0.204	0.294	1.000

** 5.56 maximum percentaje of crosscorrelation difference between two consecutive iterations, at iteration 3

----
station wadi hal iteration 4

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	15606.61768	1940.876740
3	1.12884	0.337247
4	1.48317	0.158077
15	-2.06947	1.012603
57	-0.17912	0.065814

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
19400.00	18754.12	645.88	12800.00	16025.46	-3225.46	21700.00	17766.56	3933.44
22100.00	21832.37	267.63	17700.00	16015.71	1684.29	16500.00	17763.54	-1263.54
20800.00	21200.39	-400.39	7680.00	11799.87	-4119.87	22900.00	21078.89	1821.11
12300.00	14272.52	-1972.52	27100.00	26233.06	866.94	19600.00	18819.72	780.28
15600.00	16175.56	-575.56	19200.00	20386.35	-1186.35	20700.00	20417.57	282.43
17900.00	15295.25	2604.75	19300.00	19272.59	27.41	22500.00	19412.43	3087.57
19600.00	19924.81	-324.81	15700.00	16013.40	-313.40	21600.00	20075.15	1524.85
18300.00	18865.23	-565.23	19900.00	22043.45	-2143.45	25400.00	26175.02	-775.02
19700.00	19954.48	-254.48	16900.00	15941.20	958.80	20200.00	18885.94	1314.06
14400.00	14294.78	105.22	22100.00	23157.05	-1057.05	22900.00	23773.33	-873.33

** residual statistics:

```
mean ...................      0.0002
std dev ................   1684.9537
mean square error ...... 0.27503E+07
correlation at lag 1 ...     -0.2470
            at lag 2 ...      0.2207
            at lag 3 ...     -0.2887
```

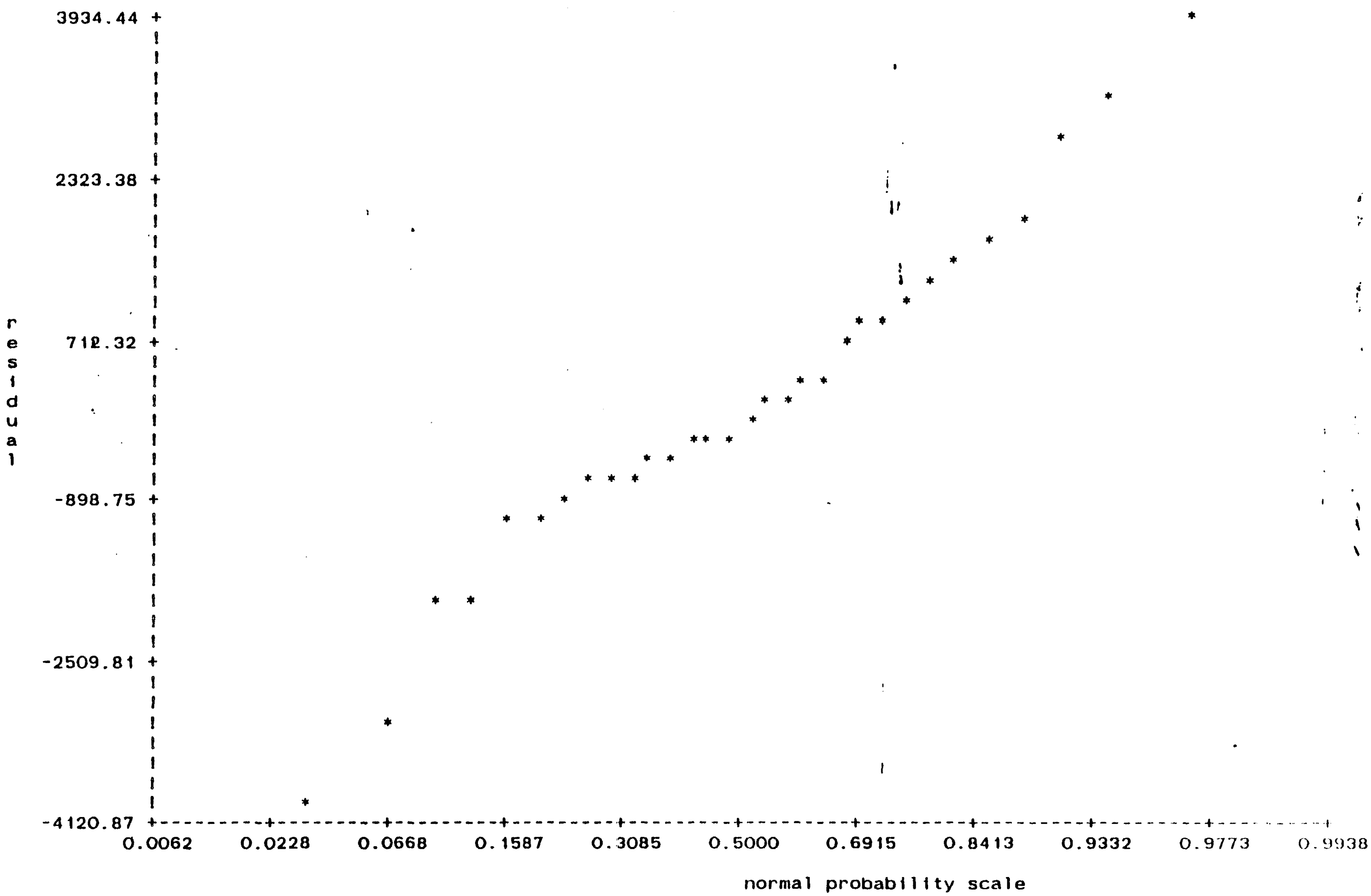
** residual statistics for the second half of the data:

```
mean ...................    886.4744
std dev ................   2590.4287
mean square error ...... 0.72543E+07
correlation at lag 1 ...      0.1776
            at lag 2 ...     -0.2149
            at lag 3 ...     -0.0389
```

** durbin-watson test:

```
there is a lagged autoregressive term
not reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%
```

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00016 * residual ; r2 = 0.91303

station atbara iteration 4

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	2754.29279	468.630093
2	1.76799	0.235965

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
5700.00	5512.36	187.64	4710.00	6025.08	-1315.08	8160.00	6520.12	1639.88
7650.00	5530.04	2119.96	8130.00	4805.17	3324.83	5300.00	4386.15	913.85
6990.00	6272.60	717.40	2350.00	3802.71	-1452.71	7180.00	5530.04	1649.96
3060.00	4271.23	-1211.23	13200.00	11877.14	1322.86	4430.00	4946.60	-516.60
3620.00	4610.69	-990.69	4650.00	5919.00	-1269.00	6040.00	6042.76	-2.76
5520.00	4787.49	732.51	7900.00	6272.60	1627.40	6100.00	5017.32	1082.68
6080.00	7138.92	-1058.92	3950.00	4734.45	-784.45	4580.00	6325.64	-1745.64
4350.00	5600.76	-1250.76	4670.00	5052.68	-382.68	7240.00	7315.72	-75.72
4170.00	6944.44	-2774.44	5520.00	4628.37	891.63	6330.00	6166.52	163.48
3640.00	4299.52	-659.52	7420.00	7757.71	-337.71	5040.00	5335.56	-295.56

** residual statistics:

mean	0.0001
std dev	1299.3421
mean square error	0.16355E+07
correlation at lag 1 ...	0.2119
at lag 2 ...	0.2476
at lag 3 ...	-0.1822

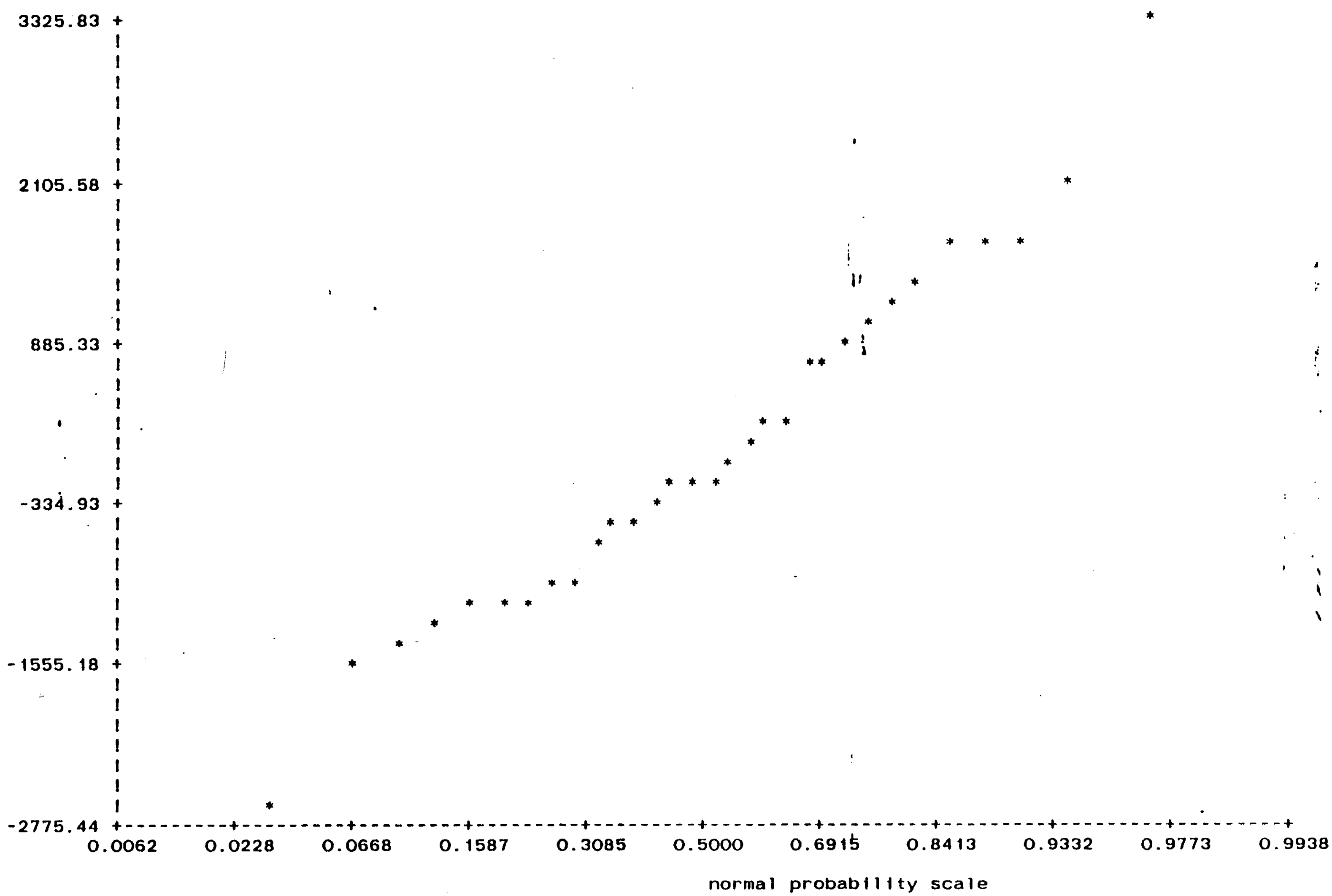
** residual statistics for the second half of the data:

mean	153.0967
std dev	1485.5392
mean square error	0.21583E+07
correlation at lag 1 ...	0.0507
at lag 2 ...	-0.3239
at lag 3 ...	-0.1440

** durbin-watson test:

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00021 * residual ; r2 = 0.94285

station karthum iteration 4

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	11555.12866	1550.234879
2	1.44784	0.173635
7	2.43974	1.541303
13	-0.32064	0.112176

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
16300.00	16462.02	-162.02	9490.00	12852.11	-3362.11	17400.00	14451.30	2948.70
25600.00	20343.33	5256.67	15300.00	13039.79	2260.21	17500.00	15873.17	1626.83
15900.00	16510.97	-610.97	7520.00	10332.86	-2812.86	19000.00	17240.32	1759.68
8060.00	11928.78	-3868.78	20200.00	20068.29	131.71	17700.00	18135.92	-435.92
12900.00	15557.66	-2657.66	16800.00	17464.06	-664.06	13200.00	15999.34	-2799.34
14600.00	13316.19	1283.81	16000.00	14437.00	1563.00	16500.00	16189.58	310.42
15000.00	16187.84	-1187.84	13300.00	13507.99	-207.99	18900.00	16491.65	2408.35
16200.00	14498.24	1701.76	17100.00	18817.71	-1717.71	18600.00	21926.64	-3326.64
14700.00	16273.53	-1573.53	14800.00	12676.53	2123.47	15600.00	14731.27	868.73
13200.00	12066.63	1133.37	18200.00	18367.23	-167.23	20300.00	20579.92	-279.92

** residual statistics:

mean	-0.0026
std dev	2086.8621
mean square error	0.42189E+07
correlation at lag 1 ...	0.1874
at lag 2 ...	-0.1062
at lag 3 ...	-0.2042

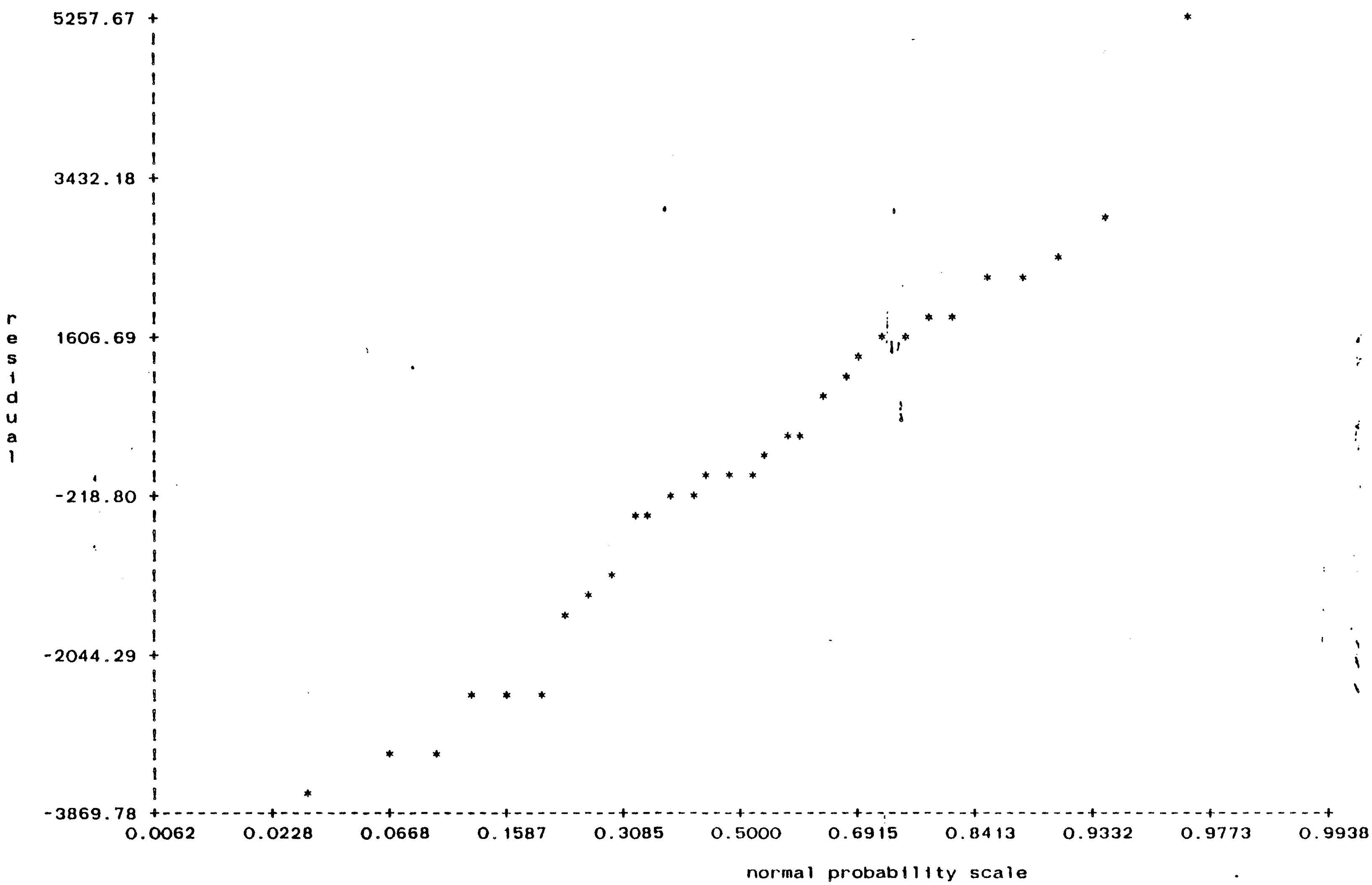
** residual statistics for the second half of the data:

mean	996.8201
std dev	1894.2310
mean square error	0.44340E+07
correlation at lag 1 ...	-0.1483
at lag 2 ...	-0.3139
at lag 3 ...	0.0893

** durbin-watson test:

there is a lagged autoregressive term
not reject the hypothesis of zero autocorrelation; significance level 5%
not reject the hypothesis of zero autocorrelation; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00013 * residual ; r2 = 0.94933

station malakal iteration 4

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	223.67250	196.845152
2	1.06032	0.079103

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
2860.00	2906.27	-46.27	2810.00	2747.22	62.78	2850.00	2747.22	102.78
3500.00	3351.60	148.40	2910.00	2959.29	-49.29	2790.00	2916.87	-126.87
2920.00	2673.00	247.00	2620.00	2609.38	10.62	2730.00	2524.56	205.44
2820.00	2810.84	9.16	2910.00	2874.46	35.54	3230.00	3277.38	-47.38
3800.00	3754.52	45.48	3160.00	3203.16	-43.16	2630.00	2747.22	-117.22
2500.00	2566.97	-66.97	2440.00	2460.94	-20.94	2940.00	2832.05	107.95
2490.00	2535.16	-45.16	2660.00	2726.02	-66.02	2680.00	2673.00	7.00
2560.00	2609.38	-49.38	2850.00	2863.86	-13.86	2870.00	3065.32	-195.32
2630.00	2704.81	-74.81	2640.00	2673.00	-33.00	2840.00	2842.65	-2.65
3130.00	2789.64	340.36	2940.00	2969.89	-29.89	2930.00	3086.52	-156.52

** residual statistics:

mean	-0.0006
std dev	115.3561
mean square error	0.12891E+05
correlation at lag 1 ...	0.0819
at lag 2 ...	-0.0648
at lag 3 ...	-0.2409

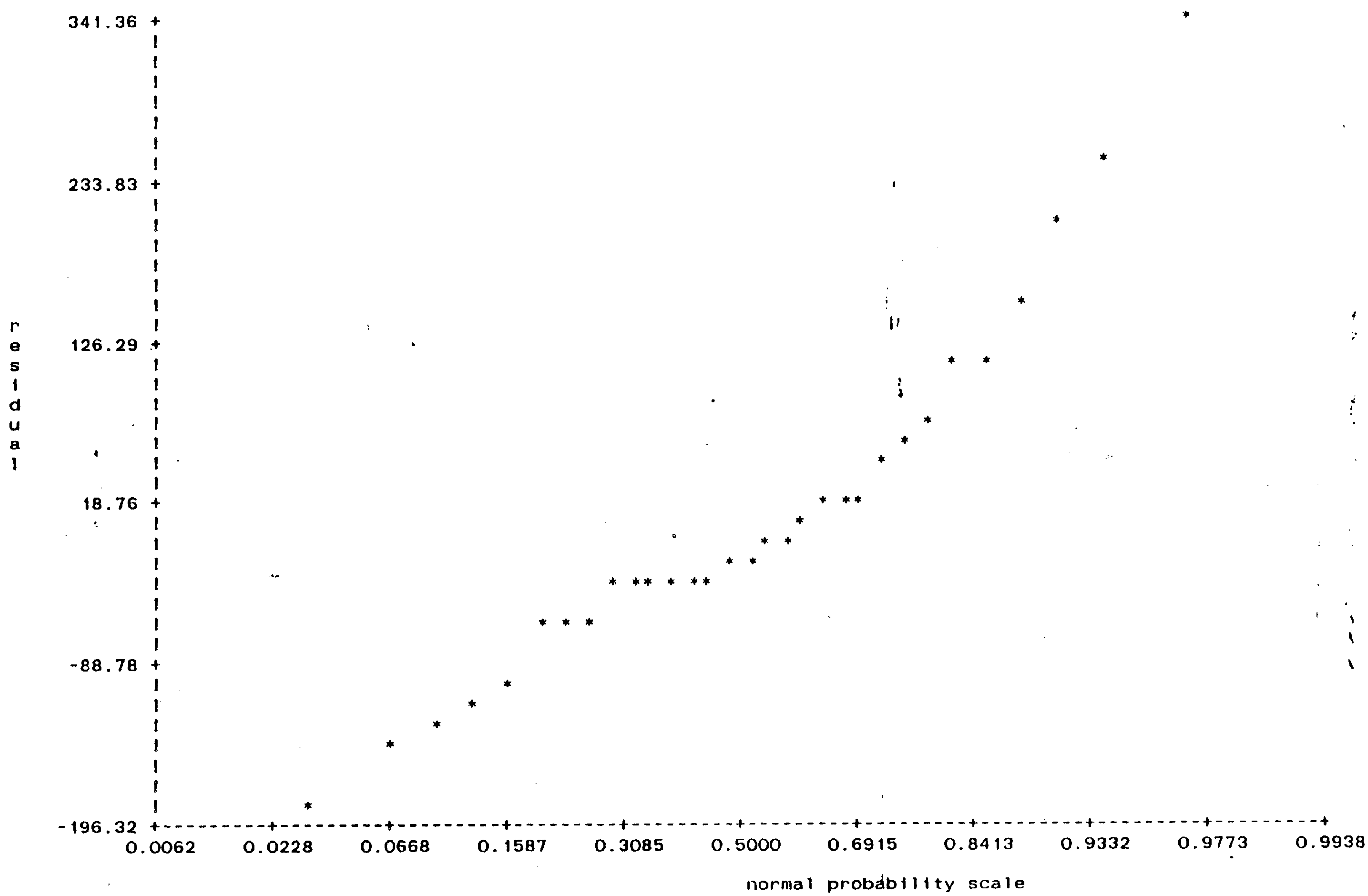
** residual statistics for the second half of the data:

mean	-12.4233
std dev	155.6272
mean square error	0.23588E+05
correlation at lag 1 ...	0.1317
at lag 2 ...	-0.1469
at lag 3 ...	0.3589

** durbin-watson test;

there is not a lagged autoregressive term
non autocorrelated; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00223 * residual ; r2 = 0.84967

station mongalla iteration 4

** gls regression results:

variable number	regression coefficient	std. error of reg. coeff.
constant	398.58836	155.833588
2	1.19462	0.103321
4	-0.24109	0.105936

** table of residuals

y value	y est.	residual	y value	y est.	residual	y value	y est.	residual
3640.00	3937.91	-297.91	3350.00	3283.06	66.94	3380.00	3012.44	367.56
3060.00	3317.03	-257.03	2970.00	2598.50	371.50	2270.00	2561.33	-291.33
2920.00	2758.05	161.95	2440.00	2797.09	-357.09	2810.00	2387.18	422.82
2620.00	2536.68	83.32	4080.00	3740.51	339.49	5420.00	5303.75	116.25
4010.00	4075.82	-65.82	2780.00	3353.09	-573.09	2560.00	2663.59	-103.59
1830.00	2058.92	-228.92	1560.00	1578.55	-18.55	2850.00	2550.58	299.42
1720.00	1849.49	-129.49	1860.00	1859.57	0.43	3130.00	2716.85	413.15
2340.00	2558.38	-218.38	2330.00	2485.65	-155.65	1950.00	1984.97	-34.97
2040.00	2105.08	-65.08	3300.00	3141.22	158.78	3720.00	3312.43	407.57
2680.00	2866.03	-186.03	3080.00	2777.80	302.20	2130.00	2558.16	-428.16

** residual statistics:

mean 0.0002
std dev 269.2202
mean square error ...... 0.70215E+05
correlation at lag 1 ... -0.2695
at lag 2 ... 0.2077
at lag 3 ... -0.2624

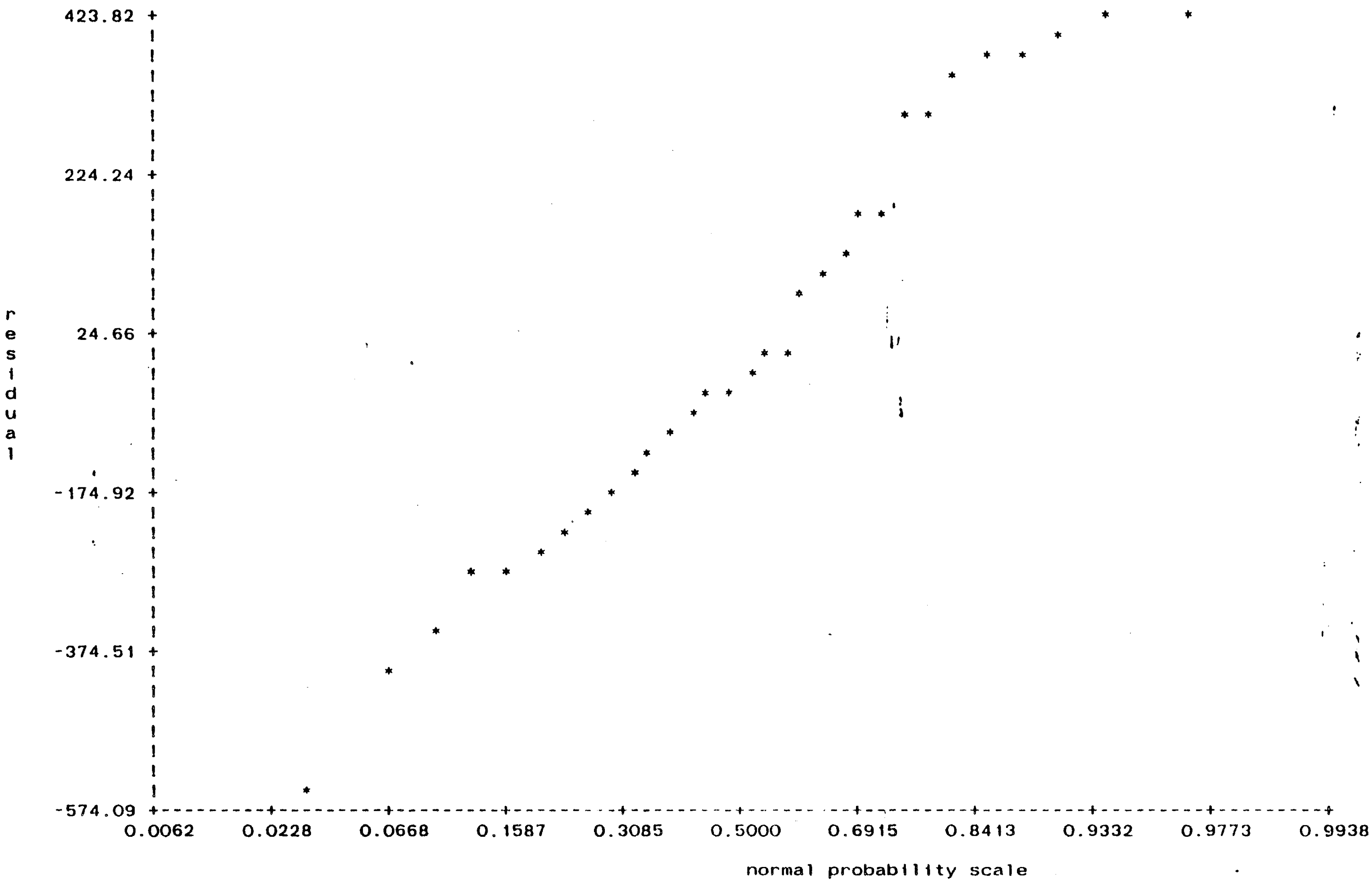
** residual statistics for the second half of the data:

mean 160.6332
std dev 349.9427
mean square error ...... 0.14348E+06
correlation at lag 1 ... -0.2145
at lag 2 ... 0.0101
at lag 3 ... -0.3089

** durbin-watson test:

there is not a lagged autoregressive term
the test is inconclusive; significance level 5%
non autocorrelated; significance level 1%

** normal probability plot



** linear regression: cdf = 0.50064 + -0.00102 * residual ; r2 = 0.97670

** residual correlation matrix of gls estimation, (iteration 4):

	wadi hal	atbara	karthum	malakal	mongalla
wadi hal	1.000	0.546	0.614	0.200	0.523
atbara	0.546	1.000	0.595	0.200	0.344
karthum	0.614	0.595	1.000	0.264	0.208
malakal	0.200	0.200	0.264	1.000	0.295
mongalla	0.523	0.344	0.208	0.295	1.000

** 1.95 maximum percentaje of crosscorrelation difference between two consecutive iterations, at iteration 4 less than the tolerance limit;therefore gls ends

Appendix D

CHANGING THE CAPACITY OF THE PROGRAM

CHANGING THE CAPACITY OF THE PROGRAM

The capacity of AUMESP depends on the number of stations NE, the number of years of data NY, the number of seasons per year NM, and the average number of predictors in the regression equations, expected by the user, NV. In the listing program that appears in Appendix A, the adopted value of NV was 15, which means that in the average the regression equations can have up to 15 coefficients. Looking at the results presented in Appendix C, this number was big enough to assure no saturation of the arrays which depend on NV.

Following, there are the arrays that have to be modified in order to change the capacity of the program.

```
COMMON/A1/DATO(NE,NM,NY)

COMMON/A3/ICAUS(NE,NE), ILAG(NE,NE)

COMMON/A4/NAME(NE,8)

COMMON/A5/KSUM(NE)

COMMON/A6/X[(NMxNE+1) x (NMxNE+2)/2]   or

          X (NVxNExNVxNE)      or     X(NVxNE,NVxNE)

COMMON/A7/RX(NMxNE+1, NMxNE+1) or RX[(NMxNE+1)x(NMxNE+1)],

          R[(NMxNE+1) x (NMxNE+2)/2]

COMMON/A8/B(NV,NE), D(NMxNE+1), T(NMxNE+1), S(NMxNE+1), L(NMxNE+1)

COMMON/A9/XBAR(NMxNE+1), STD(NMxNE+1)

COMMON/B2/IDEX(NMxNE+1)

COMMON/B3/XX(NY,NV,NE), YY(NY, NE)

COMMON/B4/SIG(NE,NE)

COMMON/B5/RY(NY,NE)

COMMON/B6/NKI(NE)

COMMON/G3/JCOEF(NE,NV)
```

Appendix E

DURBIN-WATSON STATISTIC

TABULATED VALUES

Table E1: Durbin-Watson Test. Values of d_ℓ and d_u at 5% significance level.

n	$k' = 1$		$k' = 2$		$k' = 3$		$k' = 4$		$k' = 5$	
	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U
15	1.08	1.36	0.95	1.54	0.82	1.75	0.69	1.97	0.56	2.21
16	1.10	1.37	0.98	1.54	0.86	1.73	0.74	1.93	0.62	2.15
17	1.13	1.38	1.02	1.54	0.90	1.71	0.78	1.90	0.67	2.10
18	1.16	1.39	1.05	1.53	0.93	1.69	0.82	1.87	0.71	2.06
19	1.18	1.40	1.08	1.53	0.97	1.68	0.86	1.85	0.75	2.02
20	1.20	1.41	1.10	1.54	1.00	1.68	0.90	1.83	0.79	1.99
21	1.22	1.42	1.13	1.54	1.03	1.67	0.93	1.81	0.83	1.96
22	1.24	1.43	1.15	1.54	1.05	1.66	0.96	1.80	0.86	1.94
23	1.26	1.44	1.17	1.54	1.08	1.66	0.99	1.79	0.90	1.92
24	1.27	1.45	1.19	1.55	1.10	1.66	1.01	1.78	0.93	1.90
25	1.29	1.45	1.21	1.55	1.12	1.66	1.04	1.77	0.95	1.89
26	1.30	1.46	1.22	1.55	1.14	1.65	1.06	1.76	0.98	1.88
27	1.32	1.47	1.24	1.56	1.16	1.65	1.08	1.76	1.01	1.86
28	1.33	1.48	1.26	1.56	1.18	1.65	1.10	1.75	1.03	1.85
29	1.34	1.48	1.27	1.56	1.20	1.65	1.12	1.74	1.05	1.84
30	1.35	1.49	1.28	1.57	1.21	1.65	1.14	1.74	1.07	1.83
31	1.36	1.50	1.30	1.57	1.23	1.65	1.16	1.74	1.09	1.83
32	1.37	1.50	1.31	1.57	1.24	1.65	1.18	1.73	1.11	1.82
33	1.38	1.51	1.32	1.58	1.26	1.65	1.19	1.73	1.13	1.81
34	1.39	1.51	1.33	1.58	1.27	1.65	1.21	1.73	1.15	1.81
35	1.40	1.52	1.34	1.58	1.28	1.65	1.22	1.73	1.16	1.80
36	1.41	1.52	1.35	1.59	1.29	1.65	1.24	1.73	1.18	1.80
37	1.42	1.53	1.36	1.59	1.31	1.66	1.25	1.72	1.19	1.80
38	1.43	1.54	1.37	1.59	1.32	1.66	1.26	1.72	1.21	1.79
39	1.43	1.54	1.38	1.60	1.33	1.66	1.27	1.72	1.22	1.79
40	1.44	1.54	1.39	1.60	1.34	1.66	1.29	1.72	1.23	1.79
45	1.48	1.57	1.43	1.62	1.38	1.67	1.34	1.72	1.29	1.78
50	1.50	1.59	1.46	1.63	1.42	1.67	1.38	1.72	1.34	1.77
55	1.53	1.60	1.49	1.64	1.45	1.68	1.41	1.72	1.38	1.77
60	1.55	1.62	1.51	1.65	1.48	1.69	1.44	1.73	1.41	1.77
65	1.57	1.63	1.54	1.66	1.50	1.70	1.47	1.73	1.44	1.77
70	1.58	1.64	1.55	1.67	1.52	1.70	1.49	1.74	1.46	1.77
75	1.60	1.65	1.57	1.68	1.54	1.71	1.51	1.74	1.49	1.77
80	1.61	1.66	1.59	1.69	1.56	1.72	1.53	1.74	1.51	1.77
85	1.62	1.67	1.60	1.70	1.57	1.72	1.55	1.75	1.52	1.77
90	1.63	1.68	1.61	1.70	1.59	1.73	1.57	1.75	1.54	1.78
95	1.64	1.69	1.62	1.71	1.60	1.73	1.58	1.75	1.56	1.78
100	1.65	1.69	1.63	1.72	1.61	1.74	1.59	1.76	1.57	1.78

n = number of observations.
k' = number of explanatory variables.

From Johnston, 1972, page 430.

Table E2: Durbin-Watson Test. Values of d_ℓ and d_u at 1% significance level.

n	$k' = 1$		$k' = 2$		$k' = 3$		$k' = 4$		$k' = 5$	
	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U
15	0.81	1.07	0.70	1.25	0.59	1.46	0.49	1.70	0.39	1.96
16	0.84	1.09	0.74	1.25	0.63	1.44	0.53	1.66	0.44	1.90
17	0.87	1.10	0.77	1.25	0.67	1.43	0.57	1.63	0.48	1.85
18	0.90	1.12	0.80	1.26	0.71	1.42	0.61	1.60	0.52	1.80
19	0.93	1.13	0.83	1.26	0.74	1.41	0.65	1.58	0.56	1.77
20	0.95	1.15	0.86	1.27	0.77	1.41	0.68	1.57	0.60	1.74
21	0.97	1.16	0.89	1.27	0.80	1.41	0.72	1.55	0.63	1.71
22	1.00	1.17	0.91	1.28	0.83	1.40	0.75	1.54	0.66	1.69
23	1.02	1.19	0.94	1.29	0.86	1.40	0.77	1.53	0.70	1.67
24	1.04	1.20	0.96	1.30	0.88	1.41	0.80	1.53	0.72	1.66
25	1.05	1.21	0.98	1.30	0.90	1.41	0.83	1.52	0.75	1.65
26	1.07	1.22	1.00	1.31	0.93	1.41	0.85	1.52	0.78	1.64
27	1.09	1.23	1.02	1.32	0.95	1.41	0.88	1.51	0.81	1.63
28	1.10	1.24	1.04	1.32	0.97	1.41	0.90	1.51	0.83	1.62
29	1.12	1.25	1.05	1.33	0.99	1.42	0.92	1.51	0.85	1.61
30	1.13	1.26	1.07	1.34	1.01	1.42	0.94	1.51	0.88	1.61
31	1.15	1.27	1.08	1.34	1.02	1.42	0.96	1.51	0.90	1.60
32	1.16	1.28	1.10	1.35	1.04	1.43	0.98	1.51	0.92	1.60
33	1.17	1.29	1.11	1.36	1.05	1.43	1.00	1.51	0.94	1.59
34	1.18	1.30	1.13	1.36	1.07	1.43	1.01	1.51	0.95	1.59
35	1.19	1.31	1.14	1.37	1.08	1.44	1.03	1.51	0.97	1.59
36	1.21	1.32	1.15	1.38	1.10	1.44	1.04	1.51	0.99	1.59
37	1.22	1.32	1.16	1.38	1.11	1.45	1.06	1.51	1.00	1.59
38	1.23	1.33	1.18	1.39	1.12	1.45	1.07	1.52	1.02	1.58
39	1.24	1.34	1.19	1.39	1.14	1.45	1.09	1.52	1.03	1.58
40	1.25	1.34	1.20	1.40	1.15	1.46	1.10	1.52	1.05	1.58
45	1.29	1.38	1.24	1.42	1.20	1.48	1.16	1.53	1.11	1.58
50	1.32	1.40	1.28	1.45	1.24	1.49	1.20	1.54	1.16	1.59
55	1.36	1.43	1.32	1.47	1.28	1.51	1.25	1.55	1.21	1.59
60	1.38	1.45	1.35	1.48	1.32	1.52	1.28	1.56	1.25	1.60
65	1.41	1.47	1.38	1.50	1.35	1.53	1.31	1.57	1.28	1.61
70	1.43	1.49	1.40	1.52	1.37	1.55	1.34	1.58	1.31	1.61
75	1.45	1.50	1.42	1.53	1.39	1.56	1.37	1.59	1.34	1.62
80	1.47	1.52	1.44	1.54	1.42	1.57	1.39	1.60	1.36	1.62
85	1.48	1.53	1.46	1.55	1.43	1.58	1.41	1.60	1.39	1.63
90	1.50	1.54	1.47	1.56	1.45	1.59	1.43	1.61	1.41	1.64
95	1.51	1.55	1.49	1.57	1.47	1.60	1.45	1.62	1.42	1.64
100	1.52	1.56	1.50	1.58	1.48	1.60	1.46	1.63	1.44	1.65

n = number of observations.
k' = number of explanatory variables.

From Johnston, 1972, page 431.