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C.F. CHUNG

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Resources Canada

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COMPUTER PROGRAM FOR THE LOGISTIC MODEL TO ESTIMATE THE PROBABILITY OF OCCURRENCE OF DISCRETE EVENTS

Abstract

A FORTRAN computer program has been written for obtaining the maximum likelihood estimates of unknown parameters in the logistic response model. It uses the method of scoring.

The logistic model is a more appropriate model and may give better results than the standard linear model for estimating the probability of occurrence of a discrete event as a function of several explanatory variables. The method is applied to describe the occurrence of volcanogenic massive sulphide deposits in Newfoundland in terms of 17 selected geological variables.

Résumé

Un programme informatique FORTRAN a été rédigé pour obtenir les estimations les plus probables de paramètres inconnus dans le modèle logistique des réponses. Il utilise la méthode de décompte.

Le modèle logistique est plus approprié et peut donner de meilleurs résultats que le modèle linéaire standard pour l'estimation de la probabilité de manifestation de phénomènes distincts comme fonction de plusieurs variables explicatives. La méthode utilisée sert à décrire la manifestation de gisements de sulfures en amas d'origine volcanique à Terre-Neuve en termes de 17 variables géologiques choisies.

INTRODUCTION

This study deals with the logistic analysis for estimating the probability of occurrence of an event as a function of several explanatory variables from qualitative response data. A logistic non-linear model is postulated and the unknown parameters in the model are estimated by the maximum likelihood (ML) method.

As a tool for correlating the occurrence of mineral deposits with mappable geological attributes, standard regression analysis has been widely used by, among others, Agterberg and Cabilio (1969), Sinclair and Woodsworth (1970), DeGeoffrey and Wignall (1971). Although this method is computationally simple, it has limitations for estimating the probability from qualitative response data (cf. Agterberg, 1974a).

Agterberg and Robinson (1971) and Agterberg et al. (1972) proposed the use of the linear model for estimating the probability of occurrence of mineral deposits from mappable geological attributes. In a discussion of this model, Tukey (1971) suggested that logistic analysis might be used for estimating probability of occurrence of mineral deposits. Subsequently, a logistic model was applied to systematically quantified geological variables for detecting target areas for mineral exploration by Agterberg (1974b). The parameters in this model were estimated by the iterative weighted least squares method proposed by Walker and Duncan (1967). Amemiya (1976) has shown that Walker and Duncan's method is equivalent to the method of scoring used in this paper.

The linear model and its limitations as applied to qualitative response data will be first discussed. The logistic model will then be postulated, followed by a discussion of how to estimate the unknown parameters by the ML method. The method of scoring as an algorithm for obtaining a solution from the system of the ML equations, is described. As a practical example, the logistic model is postulated for volcanogenic massive sulphide deposits in Newfoundland for resource evaluation, and the probability of occurrence of the deposits for each of the unit cells of size 10km by 10km is estimated as a logistic function of quantified litho-age units (see Leech, 1975).

LIMITATIONS OF APPLICATION OF THE LINEAR MODEL TO QUALITATIVE RESPONSE DATA

Consider an occurrence Y_i for the i-th object of an event. The random variable Y_i takes, without loss of generality, the two possible values 0 and 1 depending upon absence and presence, respectively. Let the probability of occurrence Y_i for the i-th object be θ_i.

$$\theta_i = \text{prob}(Y_i = 1) = E(Y_i) \tag{1}$$

Suppose that such binary observations are available for n objects. The problem is to develop methods of analysis for establishing any dependence of θ_i on explanatory variables representing characteristics of objects.

For assessing a dependence of θ_i on explanatory variables, let us consider the linear model:

$$\theta_i = X_i' b \qquad \text{for } i = 1, 2, \cdots, n. \tag{2}$$

where $b' = (b_o, b_1, \cdots, b_p)$ is the (p+1)-dimensional vector of unknown parameters to be estimated and $X_i' = (1, x_{i1}, x_{i2}, \cdots, x_{ip})$ are observed values of p explanatory variables for the i-th object for $i = 1, 2, \cdots, n$.

In order to estimate the unknown parameters b, the method of ordinary least squares (OLS) can be directly applied to the binary data where the observations 0 and 1 of Y_i are treated as if they were quantitative observations. The OLS estimates $\hat{b}$ of b are:

$$\hat{b} = (X'X)^{-1} X'Y \qquad \text{where}$$

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} \quad \text{and} \quad X = \begin{bmatrix} X_1' \\ X_2' \\ \vdots \\ X_n' \end{bmatrix} = \begin{bmatrix} 1 & x_{11} & \cdots & x_{1p} \\ 1 & x_{21} & \cdots & x_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \cdots & x_{np} \end{bmatrix} \tag{3}$$

However, the OLS estimates $\hat{b}$ of b retain very strong optimal properties only if the random variables Y_i follow several conditions. One of these conditions is that the variances of the Y_i's should be equal to some constant, σ^2. i.e., $\text{Var}(Y_i) = \sigma^2$ for all $i = 1, 2, \cdots, n$. However, since Y_i takes only two values 0 and 1, $Y_i^2 = Y_i$, and

$$\text{Var}(Y_i) = \theta_i(1 - \theta_i) \tag{4}$$

For this reason, there may be a serious loss of information if the OLS estimates $\hat{b}$ of b are used, in particular, if the values of $\theta_i(1 - \theta_i)$ vary considerably with i.

One possible alternative method to estimate b is to use an iterative scheme in which fitted values $\hat{\theta}_i = X_i' \hat{b}$ are obtained from (2) and (3), and then the method of weighted least squares (WLS) is employed to estimate b using weights $\hat{\theta}_i(1 - \hat{\theta}_i)$. However, now, another serious restriction on the usefulness of the linear model (2) arises from the condition:

$$0 \leq \theta_i \leq 1 \tag{5}$$

Some of the estimated probabilities $\hat{\theta}_i$ and $\hat{\theta}_{iw}$ using the OLS estimates $\hat{b}$ and the WLS estimates $\hat{b}_w$ may not satisfy the condition (5). In such cases, the method of constrained least squares could be considered to estimate b. However, not only is the problem in the mathematical programming computationally complicated, but also statistical interpretations of the estimates are severely limited when the method of constrained least squares is used for estimating b. An alternative approach consists of using a nonlinear model such as the logistic model.

THE LOGISTIC MODEL AND THE MAXIMUM LIKELIHOOD METHOD TO ESTIMATE THE UNKNOWN PARAMETERS

A simple method of representing the probability θ_i $(i = 1, 2, \cdots, n)$ of occurrence of an event in terms of explanatory variables so that the estimate of probability lies between 0 and 1, is to postulate the logistic form:

$$\theta_i = E(Y_i) = \frac{e^{X_i' b}}{1 + e^{X_i' b}} \tag{6}$$

where the X_i's and b are equivalent to those in equation (2). Equation (6) is called the logistic model. It has been advocated by Cox (1966, 1970), and Walker and Duncan (1967), among others, for estimating probabilities from qualitative response data. One of the advantages of this model is that any estimate of θ_i, whatever X_i' and b may be, satisfies the constraint (5).

In order to estimate b, Cox (1966, 1970) proposed to use the maximum likelihood (ML) method. The ML estimates $\hat{b}$ of b are obtained as follows. We may first reorder the Y_i's for computational simplicity so that the first n_1 observed Y_i's are 1 and the last $n_2 = n-n_1$ observed Y_i's are 0, i.e.,

$$\begin{aligned} Y_1 = Y_2 = \cdots = Y_{n_1} &= 1 \\ Y_{n_1+1} = \cdots = Y_n &= 0 \end{aligned} \tag{7}$$

Since Prob $(Y_i=1) = \theta_i$ and Prob $(Y_i=0) = 1-\theta_i$, the likelihood function is:

$$\prod_{i=1}^{n_1} \theta_i \prod_{j=n_1+1}^{n} (1 - \theta_j) \tag{8}$$

Substituting (6) into (8), we obtain the likelihood function

$$\frac{\prod_{i=1}^{n_1} e^{X_i' b}}{\prod_{i=1}^{n} (1 + e^{X_i' b})} = \frac{\exp\left(\sum_{i=1}^{n_1} X_i' b\right)}{\prod_{i=1}^{n} (1 + e^{X_i' b})} \tag{9}$$

Hence the log-likelihood L(b) is obtained by taking the logarithm of this equation (9):

$$L(b) = \sum_{i=1}^{n_1} X_i' b - \sum_{i=1}^{n} \log_e(1 + e^{X_i' b}) \tag{10}$$

Differentiating (10) with respect to b_s,

$$s_s(b) = \frac{\partial L(b)}{\partial b_s} = \sum_{i=1}^{n_1} x_{is} - \sum_{j=1}^{n} \frac{x_{js} e^{X_j' b}}{1 + e^{X_j' b}} \tag{11}$$

which is called the efficient score of b_s. The information matrix I(b) is obtained by differentiating $s_s(b)$ with respect to b_t where the (s, t)-th component $I_{st}(b)$ is:

$$I_{st}(b) = E\left(- \frac{\partial^2 L(b)}{\partial b_s \partial b_t} \right) = \sum_{i=1}^{n} \frac{x_{is} x_{it} e^{X_i' b}}{(1 + e^{X_i' b})^2} \tag{12}$$

The ML estimates $\hat{b}$ should satisfy the system of equations

$$s_s(\hat{b}) = (s_s(b))_{b = \hat{b}} = 0 \quad \text{for} \quad s = 0, 1, \cdots, p. \tag{13}$$

Substituting (11) into (13), we obtain the following system of equations:

$$\sum_{i=1}^{n_1} x_{is} - \sum_{j=1}^{n} \frac{x_{js} e^{X_j' \hat{b}}}{1 + e^{X_j' \hat{b}}} = 0 \quad \text{for} \quad s = 0, 1, \cdots, p. \tag{14}$$

The method of scoring (Rao, 1971) can be applied for obtaining the solutions of $\hat{b}$.

METHOD OF SCORING

The system of nonlinear equations in (14) is very complicated so that the solutions can not be obtained directly. One general method to solve the system is known as the method of scoring which is an iterative procedure. The method first takes an initial solution and then derives linear equations for additive corrections. This procedure can be repeated until the corrections become negligibly small.

Let $d^{0'}=(d_0^0, d_1^0, \cdots, d_p^0)$ be initial estimates of b. Then the first estimates d^1, in matrix notation, are given by

$$d^1 = d^0 + I^{-1}(d^0)\ s(d^0) \qquad (15)$$

where $s(d^0)$ is the (p+1)-dimensional vector with the sth component, $s_s(d^0)$ is the efficient score of b_s at $b=d^0$, and $I(d^0)$ is the information matrix at $b=d^0$. This process can be repeated with d^1 as the new initial estimates. Then the (k+1) th estimates d^{k+1} of b are obtained from

$$d^{k+1} = d^k + I^{-1}(d^k)\ s(d^k) \qquad \text{where}$$

$$s(d^k) = \begin{bmatrix} s_0(d^k) \\ s_1(d^k) \\ \vdots \\ s_p(d^k) \end{bmatrix} \quad \text{and} \quad I(d^k) = \begin{bmatrix} I_{00}(d^k) & \cdots & I_{0p}(d^k) \\ I_{10}(d^k) & \cdots & I_{1p}(d^k) \\ \vdots & \ddots & \vdots \\ I_{p0}(d^k) & \cdots & I_{pp}(d^k) \end{bmatrix} \qquad (16)$$

Substituting (11) and (12) into (16), we obtain

$$s_s(d^k) = \sum_{i=1}^{n_1} x_{is} - \sum_{j=1}^{n} \frac{x_{js}\, e^{X_j' d^k}}{1 + e^{X_j' d^k}} \qquad (17)$$

$$I_{st}(d^k) = \sum_{i=1}^{n} \frac{x_{is}x_{it}\, e^{X_i' d^k}}{(1 + e^{X_i' d^k})^2}$$

If the system (11) of ML equations has a solution, the vector $s(d^k)$ of the efficient scores vanishes for some k and the d^k are the ML estimates of b. That is,

$$\hat{b} = d^k \qquad (18)$$

The computational procedures of the program are described in the general flowchart in Figure 1. A generalized inverse matrix is substituted for the inverse matrix when the matrix is singular. In the case of singularity, the estimates $\hat{b}$ do not have meaning but the estimates $\hat{\theta}_i$ of the probabilities θ_i are meaningful.

PRACTICAL EXAMPLE

The occurrence of volcanogenic massive sulphide (Sangster, 1972) deposits in Newfoundland is considered for example. A logistic model is postulated for estimating the probability of the occurrence as a function of systematically quantified geological variables. The data on the occurrences of the volcanogenic massive sulphide (VMS) deposits and geological variables have been taken from the data base for Project Appalachia (Leech, 1975).

In this data base, the island of Newfoundland was subdivided into 1409 cells with a size of 10 km by 10 km as shown in Figure 2. For each cell, a regular grid with 400 points was superimposed and 44 geological map units were quantified and compiled by Fabbri et al. (1975), by counting the number of points occupied by these map units. The 49 VMS deposits so far discovered in Newfoundland are distributed among 21 of the 1409 cells. These 21 cells are also shown in Figure 2.

The volcanic rocks of four geologic ages (Lower Silurian, Middle-Upper Ordovician, Lower Ordovician and Cambrian) host all of the 49 known VMS deposits. Hence, for this model, only 17 litho-age units which consist of all volcanic rocks of these ages together with associated sedimentary rocks and intrusions, are selected as explanatory variables in the model from the 44 litho-age units. Geological descriptions of the selected 17 litho-age units are listed in Table 1. Only 307 of the 1409 cells contain at least one of the 17 litho-age units. The 21 cells containing one or more of the 49 known deposits are included in these 307 cells.

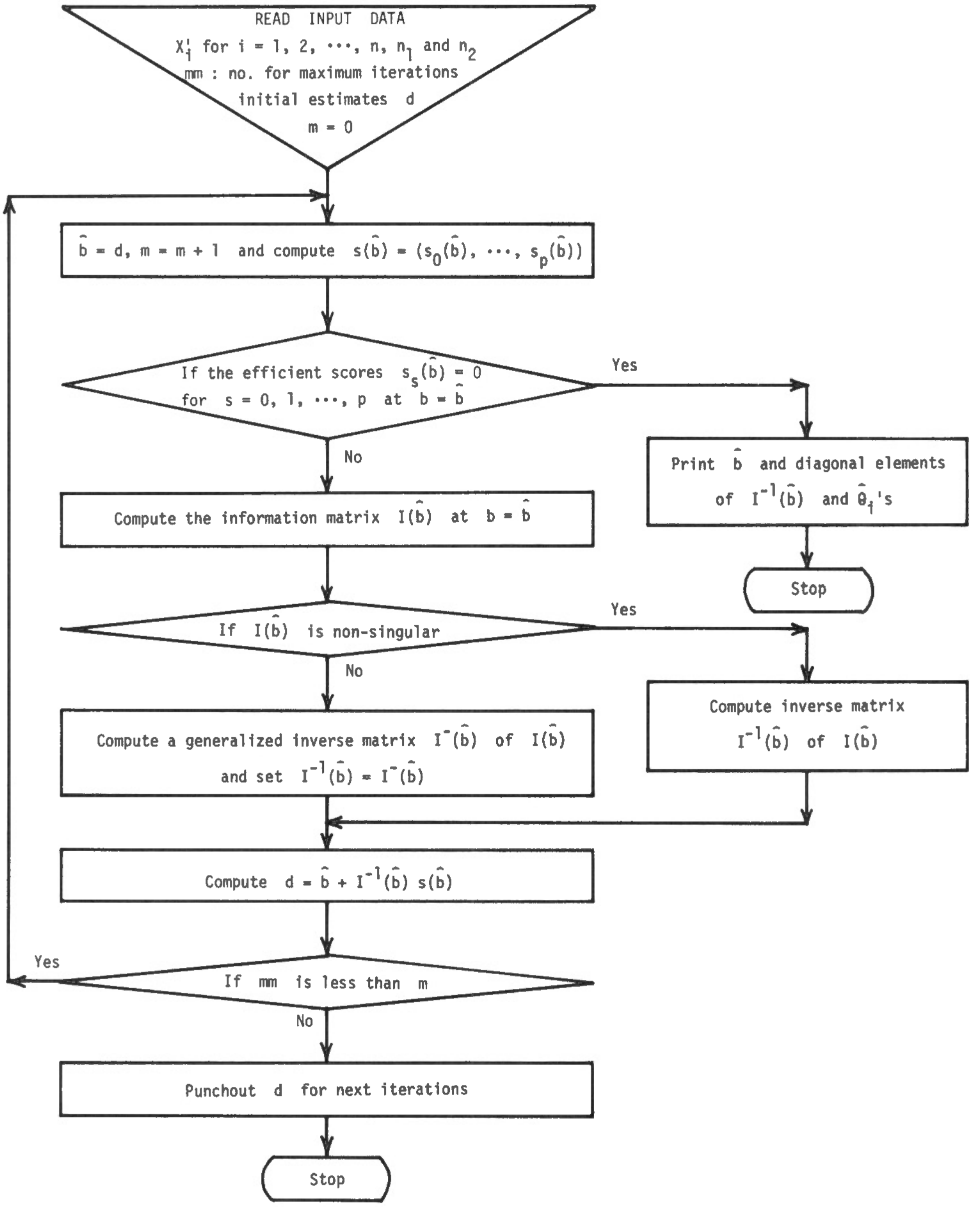

Figure 1. Flowchart of program LOGIST

Table 1

Geological description of the 17 selected litho-age units after Fabbri et al. (1975). The numbers in the boxes represent the index numbers of the explanatory variables used in the model

Rock types / Age	Pel	Gw	Va	V	Vb	Gr	Um	GD
						(Pre -Silurian)		
Lower Silurian	1	—	2	4	—	7	8	9
Middle -Upper Ordovician	3	5	—	6	—			
Lower Ordovician	10	11	—	12	13			
Cambrian	14	15	17	—	16			

Pel : Pelite (marine with or without minor siltstone and carbonate)
Gw : Greywacke - pelite, turbidite : deep water
Va : Acid volcanics greater than 50%
V : Basic volcanics; minor acid volcanics.
Vb : Basic volcanics; no reported acid volcanics.
Gr : Granite
Um : Ultramafic
GD : Gabbro-dioritic

■ contains known occurrences of VMS deposits.

● estimated probability ≥0.26.

○ estimated probability ≥0.13.

Figure 2. Probability map of the occurrence of volcanogenic massive sulphide deposits in Newfoundland. The probability is estimated from the selected systematically quantified 17 litho-age units (see text for detailed explanations) using the logistic analysis.

For any i-th cell, the vector of the observed values of the 17 explanatory variables $x'_i = (1, x_{i1}, \cdots, x_{i17})$ is known and the occurrence Y_i of the VMS deposits is recorded as 1 or 0 according to presence or absence of the known deposits for $i = 1, 2, \cdots, 307$. The data is listed in the Appendix 2.

The logistic model postulated for this example, as in (6), is that the probability θ_i of occurrence Y_i of the VMS deposits in Newfoundland satisfies the following logistic function of the 17 litho-age units:

$$\theta_i = \text{Prob}\,(Y_i = 1) = \frac{e^{x_i b}}{1 + e^{x_i b}} \tag{19}$$

where b is the unknown parameters to be estimated.

The ML estimates $\hat{b}$ of b, after using the program, are given as:

$$\hat{b} = \begin{array}{l}(-4.560,\ -7.504,\ 0.012,\ -0.031,\ -0.011,\ -0.001,\\ -0.011,\ 0.0,\ 0.003,\ 0.007,\ -2.002,\ -0.003,\\ -0.011,\ 0.013,\ -2.251,\ 0.006,\ 0.022,\ 0.004)\end{array} \tag{20}$$

after 17 iterations.

From the $\hat{b}$ in (20), the estimate $\hat{\theta}_i$ of θ_i for the i-th cell is obtained from

$$\hat{\theta}_i = \widehat{\text{Prob}\,(Y_i = 1)} = \frac{e^{x_i \hat{b}}}{1 + e^{x_i \hat{b}}} \tag{21}$$

The interpretation of the estimates $\hat{\theta}$ may be complicated because of the possible existence of undiscovered deposits. For this example, it was assumed that Y_i=0 in the i-th cell if no VMS deposit has been discovered in that cell. This would imply that $\hat{\theta}$ is not an estimate of the true probability if there remain undiscovered deposits in the study area. In other words, the $\hat{\theta}_i$ is an estimate of only part of the true probability θ_i and $\hat{\theta}$ may be small. The largest $\hat{\theta}_i$($i = 1, \cdots, 307$) is 0.75 and the average of the $\hat{\theta}_i$'s of the 21 cells containing one or more of the known VMS deposits is 0.26. The $\hat{\theta}_i$'s has been computed for the 286 cells where no VMS deposits have been discovered. Cells where the estimate $\hat{\theta}_i$ is larger than 0.26 and 0.13, are indicated by solid and open circles, respectively, in Figure 2.

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REFERENCES

Agterberg, F.P.
1974a: Geomathematics, Elsevier, N.Y., 596 p.

1974b: Automatic contouring of geological maps to detect target areas for mineral exploration; Math. Geol., v. 6, no. 4, p. 373-395.

Agterberg, F.P. and Cabilio, P.
1969: Two-stage least squares model for the relationship between mappable geological variables; Math. Geol., v. 1, no. 1, p. 37-53.

Agterberg, F.P., Chung, C.F., Fabbri, A.G., Kelly, A.M., and Springer, J.S.
1972: Geomathematical Evaluation of Copper and Zinc Potential of the Abitibi Area, Ontario and Quebec, Geol. Surv. Can., Paper 71-41, 55 p.

Agterberg, F.P. and Robinson, S.C.
1971: Mathematical Problems of Geology, Proc. Sess. Int. Stat. Inst., 38th Sym., Washington D.C., I.S.I. Bull, v. 44, p. 567-596.

Amemiya, T.
1976: The Maximum Likelihood, the Minimum Chi-square and the Nonlinear Weighted Least Squares Estimator in the General Qualitative Response Model; J. Am. Stat. Assoc., v. 71, no. 354, p. 347-351.

Cox, D.R.
1966: Some procedures connected with the Logistic Qualitative Response Curve; Research Papers in Statistics, Ed. F.N. David, Wiley, London, p. 55-71.

1970: The Analysis of Binary Data, Methuen, London, 142 p.

DeGeoffroy, J.E. and Wignall, T.K.
1971: A probabilistic appraisal of mineral resources in a portion of the Grenville Province of the Canadian Shield; Econ. Geol., v. 66, p. 466-479.

Fabbri, A.G., Divi, S.R., and Wong, A.S.
1975: A data base for mineral potential estimation in the Appalachian Region of Canada; in Report of Activities, Part C, Geol. Surv. Can., Paper 75-1C, p. 123-132

Leech, G.B.
1975: Project Appalachia; in Report of Activities, Part C, Geol. Surv. Can., Paper 75-1C, p. 121-122.

Rao, C.R.
1973: Linear statistical inference and its applications, 2nd edition, Wiley, N.Y., p. 366-374.

Sangster, D.F.
1972: Precambrian volcanogenic massive sulphide deposits in Canada: A Review; Geol. Surv. Can., Paper 72-22, 42 p.

Sinclair, A.J. and Woodsworth, G.L.
1970: Multiple Regression as a method of estimating exploration potential in an area near Terrace, B.C.; Econ. Geol., v. 65, p. 998-1003.

Tukey, J.W.
1971: Discussion on the paper titled "Mathematical Problems in Geology" by F.P. Agterberg and S.C. Robinson, I.S.I. Bull., v. 44, p. 596.

Walker, S.H. and Duncan, D.B.
1967: Estimation of the probability of an event as a function of several independent variables, Biometrika, v. 54, 1 and 2, p. 167-179.

APPENDIX I

INPUT PREPARATION

1. Identification card

Column	Format	Variable	Description
1-80	8A10	NAME	Any alphanumeric information used as output page heading.

2. Iteration control card

Column	Format	Variable	Description
1-10	F10.0	EVEL	Level of convergence
11-15	I5	ITER	Maximum permissible number of iterations
16-20	I5	ICØEF	=1, initial estimates of b are given. (See initial coefficient cards) =0, zero vector, (0, 0, •••, 0) is used as initial estimates of b.

3. Input control card

Column	Format	Variable	Description
1-5	I5	NVAR	No. of explanatory variables
6-10	I5	N1	No. of samples with Y(I)=1 (see text)
11-15	I5	N2	No. of samples with Y(I)=0 (see text)
16-20	I5	ITAPE	=1 if data block is stored on tape or desk. When ITAPE=1, unit 99 is reserved for data block. =0 if data block is on punched cards.
21-80	6A10	FØRM	Format of the data block. For example, (8F10.0)

4. Output control card

Column	Format	Variable	Description
1-5	I5	IPRØB	=1, printout of observed and estimated values. =0, no action taken
6-10	I5	ICØ	=1, final estimates $\hat{b}$ will be stored in unit 97 so that the user can catalogue the file for further studies =0, no action taken.

5. Initial coefficients cards

When ICØEF=0 (see iteration control card), no card is required. Skip this section and do not provide any card. However, if ICØEF=1, then INT ((NVAR+1)/8) +1 cards should be provided for (NVAR+1) initial coefficient under the format (8F10.0) where INT (•) is the function which takes only integer portion of the number (•), i.e. INT (1.92) =1.

6. Data block

Consists of N = N1 + N2 records on tape or disc file or N sets of cards. Each of N records or N sets of punched cards should contain observed values of NVAR explanatory variables under the format FØRM which was specified in input control card. First N1 records are for observations with Y(I) = 1 and the following N2 records are for observations with Y(I) = 0.

APPENDIX II

Example of input and selected output

Example of input data

The input consists of 4 control cards (see Input Data Description) and Data Block of 307 records which are read from Unit 99. Each of the 307 records contains the x-y coordinates of the cell and information on the 17 litho-age units (see Practical Example for explanations). The Input Control card specifies reading of the information on 17 litho-age units from Unit 99.

(i) Listing of 4 control cards

```
LOGISTIC ANALYSIS, VMS DEPOSITS, NEWFOUNDLAND
0.1          30    0
   17   21  286    1    (6X,17F3.0)
    0    1
```

(ii) Listing of Data Block

```
26 45   0  0  0  0  0  0 39 28 41  0  0  0219  0  5 64  0          000001
25 45   0  0  0  0  0  0  6 20 44  0  0  0 71  0259  0  0          000002
26 63   0  0  0  0242 92  0 49  0  0  0  0  0  0  0  0  0          000003
28 50   0  0  0  0  0255 17  0  0  0  0128  0  0  0  0  0          000004
29 50   0  0  0  0 23203  0  0  0  0  0168  0  0  0  0  0          000005
30 51   0  0  0  0  0378 22  0  0  0  0  0  0  0  0  0  0          000006
30 52   0  0  0  0  0349 51  0  0  0  0  0  0  0  0  0  0          000007
18 61   0  0  0  0  0288  0  0  0  0  0  0  0  0  0  0  0          000008
26 53   0 32 15 11 25137  0  0  4  0  0  0  0  0  0  0  0          000009
26 46   0  0  0  0  0  0117  0  1  0  0  0  0  0  0254 28          000010
26 48   0167  0  0  0  0 88  0  0  0  0 58  0  0  0  0  0          000011
25 49   0317  0  0  0  0  0  0  0  0  0 67  0  0  0  0  0          000012
20 58   0336  0 19  0  0  0  0  0  0  0  0  0  0  0  0  0          000013
21 58   0328  0 25  0  0  0  0  0  0  0  0  0  0  0  0  0          000014
28 47   0  0  0  0  0  0  0  9  5  0  0 28  0  0  3 23  0          000015
10 55   0  0  0  0  0  0  4  5 90  0 66 93  0  0  0  0  0          000016
29 30   0  0  0  0  0  0  0 25  2  0 13147  0  0  0  0  0          000017
27 49   0  0  0  0  0  0  0  0  0  0  0394  0  0  0  0  0          000018
29 46   0  0  0  0  0  0  0  4  0  0  0184  0  0  0  0150          000019
26 49   0 11  0  0  0  0 16  0  0  0  0354  0  0  0  0  0          000020
26 50   0 19  0 30  0  0  0  0  0  0  0205  0  0  0  0  0          000021
15 67   0  0  0 46130  0  0  0  0  0  0  0  0  0  0  0  0          000022
32 53   0  0  0 52187  2  0  0  0  0  0  0  0  0  0  0  0          000023
14 67   0  0  0 80233  0  0  0  0  0  0  0  0  0  0  0  0          000024
28 57   0  0  0143253  0  0  0  0  0  0  0  0  0  0  0  0          000025
27 60   0  0  0 56 75  0  0  8  0  0  0  0  0  0  0  0  0          000026
37 50  31  0  0 27105  4  0  0  0  0  0  0  0  0  0  0  0          000027
25 60  29  0  0 98 92  0  0  0  0  0  0  0  0  0  0  0  0          000028
24 60123 92  0 65 16  0  0  0  0  0  0  0  0  0  0  0  0          000029
23 52   0122  0134  0  0  0  0  0  0  0  0  0  0  0  0  0          000030
27 59   0195  0107  0  0  0  0  0  0  0  0  0  0  0  0  0          000031
22 61 54124  0 70  3  0  0  0  0  0  0  0  0  0  0  0  0          000032
24 56   0 35  0112  0 17  0  0  0  0  0  0  0  0  0  0  0          000033
24 52   0153  0247  0  0  0  0  0  0  0  0  0  0  0  0  0          000034
24 53   0170  0230  0  0  0  0  0  0  0  0  0  0  0  0  0          000035
23 53   0 84  0 95  0  0  0  0  0  0  0  0  0  0  0  0  0          000036
21 53   0100  0124  0  0  0  0  0  0  0  0  0  0  0  0  0          000037
22 53   0 22  0 45  0  0  0  0  0  0  0  0  0  0  0  0  0          000038
24 55   0 64  0 83  0  7  0  0  0  0  0  0  0  0  0  0  0          000039
23 61149 18  0  9 50  0  0  0  0  0  0  0  0  0  0  0  0          000040
25 59   0131  0 50 73  0  0  0  0  0  0  0  0  0  0  0  0          000041
23 58   0179  0  0166 10  0  0  0  0  0  0  0  0  0  0  0          000042
11 70   0147  0  0 68  0  0  0  0  0  0  0  0  0  0  0  0          000043
23 60   1232  0 11115  0  0  0  0  0  0  0  0  0  0  0  0          000044
36 53   0  0 66 33  4  0  0  0  0  0  0  0  0  0  0  0  0          000045
24 54   0 32  0165  0  0  0  0  0  0  0  0  0  0  0  0  0          000046
26 59   0 30  0 96  4  0  0  0  0  0  0  0  0  0  0  0  0          000047
27 58   0 15  0 96 21  0  0  0  0  0  0  0  0  0  0  0  0          000048
28 58   0 90  0203  0  0  0  0  0  0  0  0  0  0  0  0  0          000049
29 56   0  0  0193 43  0  0  0  0  0  0  0  0  0  0  0  0          000050
29 57   0  0  0 80 24  0  0  0  0  0  0  0  0  0  0  0  0          000051
24 51   0 62  0214  0  0  0  0  0  0  0  0 22  0  0  0  0          000052
25 53   0100  0274  0  5  0  0  0  0  0  0  0  0  0  0  0          000053
20 53   0  3  0  7  0  0  0  0  0  0  0  0  0  0  0  0  0          000054
33 53   0  0  0230 22  0  0  0  0  0  0  0  0  0  0  0  0          000055
```

```
38 48  0  0  0 37  4  0  0  0  0  0  0  0  0  0  0  0  0                000056
23 54  0  0  0 10  0  0  0  0  0  0  0  0  0  0  0  0  0                000057
39 46  0  0  0  3  0  0  0  0  0  0  0  0  0  0  0  0  0                000058
38 49  7  0  0 20  0  0  0  0  0  0  0  0  0  0  0  0  0                000059
14 68  0  0  0 53  0  0  0  0  0  0  0  0  0  0  0  0  0                000060
15 68  0  0  0 41  0  0  0  0  0  0  0  0  0  0  0  0  0                000061
13 68  0  0  0 48  0  0  0  0  0  0  0  0  0  0  0  0  0                000062
31 55  0  0  0 34  0  0  0  0  0  0  0  0  0  0  0  0  0                000063
32 54  0  0  0 22  0  0  0  0  0  0  0  0  0  0  0  0  0                000064
33 54  0  0  0 57  0  0  0  0  0  0  0  0  0  0  0  0  0                000065
34 54  0  0  0 58  0  0  0  0  0  0  0  0  0  0  0  0  0                000066
35 54  0  0  0 37  0  0  0  0  0  0  0  0  0  0  0  0  0                000067
39 47  0  0  0 66  0  0  0  0  0  0  0  0  0  0  0  0  0                000068
40 46  0  0  0 81  0  0  0  0  0  0  0  0  0  0  0  0  0                000069
30 56  0  0  0 16  0  0  0  0  0  0  0  0  0  0  0  0  0                000070
34 55  0  0  0 16  0  0  0  0  0  0  0  0  0  0  0  0  0                000071
27 29  0  0  0  0  0  0  0 28  0296  0 66  0  0  0  0  0                000072
11 55  0  0  0  0  0  0  0 15  8  3246  2  0  0  0  0  0                000073
29 28  0  0  0  0  0  0  0  0  0  9366  5  0  0  0  0  0                000074
13 51  0  0  0  0  0  0  0 87  0  0295 18  0  0  0  0  0                000075
10 52  0  0  0  0  0  0  0  9  0  0 14  0 13  0  0  0  0                000076
12 53  0  0  0  0  0  0  0190134  0 41 16  0  0  0  0  0                000077
29 45  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0232                000078
28 45  0  0  0  0  0  0  3  0  0  0  0  0  0  0  0  0228                000079
30 45  0  0  0  0  0  0  0  0 20  0  0  0  0  0  0  0287                000080
30 46  0  0  0  0  0  0  0  0  0  0  0  3  0  0  0  0 29                000081
27 46  0  0  0  0  0  0  0 10  0  0  0 29  0  0  0 41320                000082
28 46  0  0  0  0  0  0  0  6  8  0  0 44  0  0  2  0340                000083
24 35  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 35  0                000084
25 36  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 20  0                000085
25 35  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 52  0                000086
24 34  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 61  0                000087
26 44  0  0  0  0  0  0  0  0 29  0  0  0 22  0 90  0  0                000088
24 47  0  0  0  0  0  0  2 37  3  0  0  0 44  0310  0  0                000089
14 57  0  0  0  0  0  0  0  0  0  0  0  1  0  0399  0  0                000090
22 51  0  8  0  0  0  0  0 66  0  0  0  0  0  0 63  0  0                000091
35 55  0  0 64  7  0  0  0  0  0  0  0  0  0  0  0  0  0                000092
24 50  0 24  0  0  0  0244  0  0  0  0  0 45  0  0  0  0                000093
19 71  0  0  0  0  0  0251  0  0  0  0  0 99  0  0  0  0                000094
20 71  0  0  0  0  0  0324  0  0  0  0  0 76  0  0  0  0                000095
18 71  0  0  0  0  0  0209  0  0  0  0  0 23  0  0  0  0                000096
27 47  0  0  0  0  0  0149  0  0  0  0 29  0  0  0 83139                000097
25 47  0 37  0  0  0  0308  2  3  0  0  0 39  0  0  0  0                000098
26 47  0 46  0  0  0  0316  0  0  0  0  0  0  0  0 16  0                000099
23 71  0  0  0  0  0  0242  0  0  0  0  0 12  0  0  0  0                000100
36 48  0  0  0  0  0  0126  0  0  0  0 39  0  0  0  0  0                000101
34 51  0  0  0  0 20  2149  0  0  0  0  0  0  0  0  0  0                000102
35 52  0  0  0  0 53  3278  0  0  0  0  0  0  0  0  0  0                000103
37 48  0  0  0  0 23  0 38  0  0  0  0 27  0  0  0  0  0                000104
36 49  0  0  0  0 45 15104  0  0  0  0200  0  0  0  0  0                000105
35 50  0  0  0  0 65 24  0  0  0  0  0134  0  0  0  0  0                000106
34 50  0  0  0  0 32  1  0  0  0  0  0269  0  0  0  0  0                000107
32 50  0  0  0  0 10 35  0  0  0  0  0338  0  0  0  0  0                000108
37 54  0  0321  0  0 28  0  0 51  0  0  0  0  0  0  0  0                000109
38 53  0  0303  0  0 34  0  2 47  0 14  0  0  0  0  0  0                000110
40 51  0  0152  0  0 10  6  0  0  0  4  0  0  0  0  0  0                000111
38 51 99  0 84  0  0 34  0  0  0  0  0  0  0  0  0  0  0                000112
39 52  0  0325  0  0 16  0  0  0  0 17  0  0  0  0  0  0                000113
36 54  0  0218  2  0  0  0  0  0  0  0  0  0  0  0  0  0                000114
38 54  0  0 57  0  0 53  0  4 52  0234  0  0  0  0  0  0                000115
40 52  0  0 81  0  0  9 32  0  0  0278  0  0  0  0  0  0                000116
14 64  0  0  0  0  0 50  0  0  0  0 96  0  0  0  0  0  0                000117
39 53  0  0 49  0  0 15  0  5  0  0331  0  0  0  0  0  0                000118
37 55  0  0175  0  0 22  0  0 79  0124  0  0  0  0  0  0                000119
13 65  0  0  0  0 45 89  0  0  0  0 55  0  0  0  0  0  0                000120
18 63  0  0 35  0115157  0  0  0  0  0  0  0  0  0  0  0                000121
15 64  0  0  5  0 99145  0  0  0  0  0  0  0  0  0  0  0                000122
19 66  0  0  0  0 13 15  0  0  0  0  0  0  0  0  0  0  0                000123
26 52  0 63  0  4  0 88  0  0  0  0  0  0  0  0  0  0  0                000124
28 52  0  0  0  0165227  0  0  0  0  0  0  0  0  0  0  0                000125
29 51  0  0  0  0183217  0  0  0  0  0  0  0  0  0  0  0                000126
31 50  0  0  0  0 81202  0  0  0  0  0 12  0  0  0  0  0                000127
```

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31 53  0  0  0  0109224  0  0  0  0  0  0  0  0  0  0  0               000128
15 63  0  0  0  0  0 18  0  0  0  0  4  0  0  0  0  0  0               000129
17 63  0  0 37  0 70288  0  0  0  0  0  0  0  0  0  0  0               000130
35 53  0  0  0 36 42100  0  0  0  0  0  0  0  0  0  0  0               000131
20 61  0  0  0  0 71307  0  0  0  0  0  0  0  0  0  0  0               000132
30 53  0  0  0  0 77323  0  0  0  0  0  0  0  0  0  0  0               000133
21 59  0 18  0  0 26259  0  0  0  0  0  0  0  0  0  0  0               000134
19 67  0  0  0  0  7 32  0  0  0  0  0  0  0  0  0  0  0               000135
25 54  0  0  0113  0155  0  0  0  0  0  0  0  0  0  0  0               000136
30 55  0  0  0 48  0 78  0  0  0  0  0  0  0  0  0  0  0               000137
39 51  0  0 56  0  0210  0  0  0  0  0  0  0  0  0  0  0               000138
17 62  0  0 38  0  0358  0  0  0  0  4  0  0  0  0  0  0               000139
27 51  0  0 29  0 25309  0  0  0  0  0  0  0  0  0  0  0               000140
16 62  0  0  8  0  0 93  0  0  0  0  0  0  0  0  0  0  0               000141
16 63  0  0 15  0  0284  0  0  0  0  0  0  0  0  0  0  0               000142
29 55  0  0  0  3  0 55  0  0  0  0  0  0  0  0  0  0  0               000143
18 62  0  0  0  0  0352  0  0  0  0  0  0  0  0  0  0  0               000144
18 66  0  0  0  0  1100  0  0  0  0  0  0  0  0  0  0  0               000145
19 60  0  0  0  0  0 44  0  0  0  0  0  0  0  0  0  0  0               000146
19 61  0  0  0  0  0385  0  0  0  0  0  0  0  0  0  0  0               000147
19 62  0  0  0  0  0338  0  0  0  0  0  0  0  0  0  0  0               000148
20 60  0  0  0  0 12272  0  0  0  0  0  0  0  0  0  0  0               000149
25 55  0  0  0  0  0137  0  0  0  0  0  0  0  0  0  0  0               000150
29 52  0  0  0  0  0371  0  0  0  0  0  0  0  0  0  0  0               000151
29 53  0  0  0  0  0176  0  0  0  0  0  0  0  0  0  0  0               000152
29 54  0  0  0  0  0 79  0  0  0  0  0  0  0  0  0  0  0               000153
30 54  0  0  0  0 10276  0  0  0  0  0  0  0  0  0  0  0               000154
31 54  0  0  0  0  0152  0  0  0  0  0  0  0  0  0  0  0               000155
18 60  0  0  0  0  0 31  0  0  0  0  0  0  0  0  0  0  0               000156
28 53  0  0  0  0  0 21  0  0  0  0  0  0  0  0  0  0  0               000157
26 62  0  0  0  0189 41  0 38101  0  0  0  0  0  0  0  0               000158
26 55  0  0 79  0162 11  0  0  5  0  0  0  0  0  0  0  0               000159
26 56  0  0 23  0374  3  0  0  0  0  0  0  0  0  0  0  0               000160
26 54  0  0 78  0 36 36  0  0  0  0  0  0  0  0  0  0  0               000161
36 52  5  0  8 11 60  0111  0  0  0  0  0  0  0  0  0  0               000162
35 51  0  0  0  0 93 29 44  0  0  0  0  0  0  0  0  0  0               000163
15 65  0  0  0  0319  6  0  0  0  0  0  0  0  0  0  0  0               000164
17 66  0  0  0  0201  8  0  0  0  0  0  0  0  0  0  0  0               000165
24 58  0 11  0  0389  0  0  0  0  0  0  0  0  0  0  0  0               000166
25 65  0  0  0  0390 10  0  0  0  0  0  0  0  0  0  0  0               000167
26 58  0  8  0  0258  0  0  0  0  0  0  0  0  0  0  0  0               000168
26 64  0  0  0  0365 35  0  0  0  0  0  0  0  0  0  0  0               000169
32 52  0  0  0  0258 15  0  0  0  0  0  0  0  0  0  0  0               000170
36 50  0  0  0  0327 20  0  0  0  0  0  0  0  0  0  0  0               000171
28 51  0  0 31  0303 66  0  0  0  0  0  0  0  0  0  0  0               000172
16 64  0  0 10  0225 48  0  0  0  0  0  0  0  0  0  0  0               000173
22 62 82  0  0 15276  0  0  0  0  0  0  0  0  0  0  0  0               000174
21 61  0 78  0  0138 34  0  0  0  0  0  0  0  0  0  0  0               000175
25 56  0 49  3  0 53 27  0  0  0  0  0  0  0  0  0  0  0               000176
22 60  0 66  0  0271 23  0  0  0  0  0  0  0  0  0  0  0               000177
20 62  0 14  0  0176 26  0  0  0  0  0  0  0  0  0  0  0               000178
21 62  0 46  0  0127  0  0  0  0  0  0  0  0  0  0  0  0               000179
24 59  0 76  0  0275 14  0  0  0  0  0  0  0  0  0  0  0               000180
13 67  0  0  0 32263  0  0  0  0  0  0  0  0  0  0  0  0               000181
31 51  0  0  0  0267 61  4  0  0  0  0  0  0  0  0  0  0               000182
31 52  0  0  0  0286 60  2  0  0  0  0  0  0  0  0  0  0               000183
37 49  0  0  0  3153 10  0  0  0  0  0  3  0  0  0  0  0               000184
25 57  0 37  0  0359  0  0  0  0  0  0  0  0  0  0  0  0               000185
28 60  0 23  0  0190  0  0  0  0  0  0  0  0  0  0  0  0               000186
29 60  0 20  0  0190  0  0  0  0  0  0  0  0  0  0  0  0               000187
34 53  0  0  0  0 91 17  0  0  0  0  0  0  0  0  0  0  0               000188
25 64  0  0  0  0134105  0 33  0  0  0  0  0  0  0  0  0               000189
19 63  0  0  8  0256112  0  0  0  0  0  0  0  0  0  0  0               000190
22 59  0  0  0  0235133  0  0  0  0  0  0  0  0  0  0  0               000191
32 51  0  0  0  0240115  0  0  0  0  0  6  0  0  0  0  0               000192
33 51  0  0  0  0 50 34  0  0  0  0  0  2  0  0  0  0  0               000193
21 60  0  0  0  0206180  0  0  0  0  0  0  0  0  0  0  0               000194
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27 52  0  0  0  0195132  0  0  0  0  0  0  0  0  0  0  0        000195
14 65  0  0  0  0217159  0  0  0  0  0  0  0  0  0  0  0        000196
21 52  0 34  0  0  0  0  0 13  0  0  0  0  0  0 22  0  0        000197
20 48 61 43  0  0  0  0  0  0  0  0  0  0  0  5  0  0  0        000198
20 47 44 19  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000199
23 50  0121  0 29  0  0 22 21  0  0  0  0 40  0145  0  0        000200
21 48  0 30  0  0  0  0  0  0  0  0  0  0  0  0 30  0  0        000201
20 50  0 12  0  0  0  0  0  0  0  0  0  0  0  0 37  0  0        000202
24 49  0161  0 23  0  0151  0  0  0  0  0 23  0 23  0  0        000203
20 49 21 34  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000204
23 57  0144  0 71  0  0  0  0  0  0  0  0  0  0  0  0  0        000205
21 47  4 52  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000206
22 52  0275  0 25  0  0  0 17  0  0  0  0  0  0  0  0  0        000207
26 60  0 65  0  0 19  0  0  0  0  0  0  0  0  0  0  0  0        000208
23 56  0 56  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000209
25 51  0307  0 42  0  0  0  0  0  0  0  0  0  0  0  0  0        000210
22 58  0206  0 12 22  4  0  0  0  0  0  0  0  0  0  0  0        000211
19 59  0 47  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000212
28 59  0396  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000213
29 58  0 41  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000214
29 59  0282  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000215
11 69  0119  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000216
10 69  0 29  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000217
22 56  0 69  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000218
21 57  0119  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000219
21 56  0 37  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000220
20 59  0245  0  9  0  5  0  0  0  0  0  0  0  0  0  0  0        000221
20 57  0136  0 24  0  0  0  0  0  0  0  0  0  0  0  0  0        000222
10 70  0289  0  0 24  0  0  0  0  0  0  0  0  0  0  0  0        000223
 9 70  0 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000224
19 58  0 18  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000225
 9 71  0 14  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000226
23 55  0  9  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000227
24 57  0275  0 42 74  0  0  0  0  0  0  0  0  0  0  0  0        000228
25 52  0302  0 98  0  0  0  0  0  0  0  0  0  0  0  0  0        000229
22 57  0 34  0 11  0  0  0  0  0  0  0  0  0  0  0  0  0        000230
10 71  0  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000231
12 69  0  5  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0        000232
23 51  0226  0 12  0  0  0 32  0  0  0  0 27  0 17  0  0        000233
26 51  0140  0  9  0 85  0  0  0  0  0  0  0  0  0  0  0        000234
25 48  0150  0  0  0  0 51  0  0  0  0  0  0  0  0  0  0        000235
15 61  0  0  0  0  0  0  0  0  0  0 10 98  0  0  0  0  0        000236
13 60  0  0  0  0  0  0  0  0  0  0 69308  0  0 18  0  0        000237
 8 56  0  0  0  0  0  0  0  0  0  0  8 18  0  0  0  0  0        000238
14 60  0  0  0  0  0  0  0  0  0  0  9283  0  0  0  0  0        000239
10 54  0  0  0  0  0  0  3  0  0  0  4 20  0  0  0  0  0        000240
 9 54  0  0  0  0  0  0  8  0 12  0  7 31  0  0  0  0  0        000241
28 29  0  0  0  0  0  0  0193  0 37  0170  0  0  0  0  0        000242
28 30  0  0  0  0  0  0  0 43  0  0  0 92  0  0  0  0  0        000243
27 30  0  0  0  0  0  0  0 58  0  0  0 70  0  0  0  0  0        000244
10 53  0  0  0  0  0  0  4  6 21  0  0 31  8  0  0  0  0        000245
29 47  0  0  0  0  0  0  0  0  0  0  0  6  0  0  0  0  0        000246
33 50  0  0  0  0  0  1  0  0  0  0  0353  0  0  0  0  0        000247
28 49  0  0  0  0  0  0  0  0  0  0  0330  0  0  0  0  0        000248
35 49  0  0  0  0  0  0  0  0  0  0  0265  0  0  0  0  0        000249
15 58  0  0  0  0  0  0  0  0  0  0  0159  0  0  0  0  0        000250
29 49  0  0  0  0  0  0  0  0  0  0  0352  0  0  0  0  0        000251
35 48  0  0  0  0  0  0  0  0  0  0  0 51  0  0  0  0  0        000252
28 48  0  0  0  0  0  0  0  0  0  0  0 82  0  0  0  0  0        000253
34 49  0  0  0  0  0  0  0  0  0  0  0 45  0  0  0  0  0        000254
15 59  0  0  0  0  0  0  0  0  0  0  0 59  0  0  0  0  0        000255
30 49  0  0  0  0  0  0  0  0  0  0  0 75  0  0  0  0  0        000256
29 48  0  0  0  0  0  0  0  0  0  0  0 27  0  0  0  0  0        000257
14 59  0  0  0  0  0  0  0  0  0  0  0340  0  0 35  0  0        000258
27 48  0  0  0  0  0  0 28  0  0  0  0270  0  0  0  0  0        000259
13 59  0  0  0  0  0  0  0  0  0  0  0163  0  0237  0  0        000260
15 57  0  0  0  0  0  0  0  0  0  0  0 79  0  0120  0  0        000261
```

```
14 58  0  0  0  0  0  0  0  0  0  0  0129  0  7210  0  0                000262
28 28  0  0  0  0  0  0  0  8  0 95 18 31  0  0  0  0  0                000263
 7 58  0  0  0  0  0  0  0  0  0  0  7  2  0  0  0  0  0                000264
15 60  0  0  0  0  0  0  0  0  0  0 50  9  0  0  0  0  0                000265
14 61  0  0  0  0  0  0  0  0  0  0248 55  0  0  0  0  0                000266
 8 59  0  0  0  0  0  0  0  0 12  0227 81  0  0  0  0  0                000267
 9 56  0  0  0  0  0  0  0 15 40  0209 47  0  0  0  0  0                000268
 7 59  0  0  0  0  0  0  0  0  0  0102 32  0  0  0  0  0                000269
13 50  0  0  0  0  0  0  0  2 56  0206 36  0  6  0  0  0                000270
 9 55  0  0  0  0  0  0 33  0 66  0109 45  0  0  0  0  0                000271
11 53  0  0  0  0  0  0  0 13 64  0 76120  0  0  0  0  0                000272
11 51  0  0  0  0  0  0 21  0117  0129 50  6  0  0  0  0                000273
12 51  0  0  0  0  0  0  0212 99  0 16 72  1  0  0  0  0                000274
 9 58  0  0  0  0  0  0  0180 49  0 35 75  0  0  0  0  0                000275
 9 57  0  0  0  0  0  0  0190 91  0 72 47  0  0  0  0  0                000276
29 29  0  0  0  0  0  0  0119  1  0120160  0  0  0  0  0                000277
10 56  0  0  0  0  0  0  0181175  0  6 38  0  0  0  0  0                000278
11 52  0  0  0  0  0  0  0  5229  0 40123  1  0  0  0  0                000279
12 52  0  0  0  0  0  0  0 19229  0 19133  0  0  0  0  0                000280
 8 58  0  0  0  0  0  0  0 48226  0 30 46  0  0  0  0  0                000281
11 50  0  0  0  0  0  0  4  0 20  0  9  6  1  0  0  0  0                000282
 8 57  0  0  0  0  0  0  0  4 56  0 30 23  0  0  0  0  0                000283
12 50  0  0  0  0  0  0 44 68129  0  4 53 24  0  0  0  0                000284
18 54  0  0  0  0  0  0  0  0  0  0  0  0  6  0  0  0  0                000285
18 72  0  0  0  0  0  0  0  0  0  0  0  0  4  0  0  0  0                000286
19 57  0  3  0  0  0  0  0  0  0  0  0  0  8  0  0  0  0                000287
18 55  0  0  0  0  0  0  0  0  0  0  0  0174  0  0  0  0                000288
16 57  0  0  0  0  0  0  0  0  0  0  0  0 82  0  0  0  0                000289
18 56  0  0  0  0  0  0  0  0  0  0  0  0133  0  0  0  0                000290
17 57  0  0  0  0  0  0  0  0  0  0  0  0 56  0  0  0  0                000291
17 56  0  0  0  0  0  0  0  0  0  0  0  0 88  0  0  0  0                000292
19 56  0  0  0  0  0  0  0  0  0  0  0  0 24  0  0  0  0                000293
19 54  0  0  0  0  0  0  0  0  0  0  0  0 21  0  0  0  0                000294
19 72  0  0  0  0  0  0  0  0  0  0  0  0 23  0  0  0  0                000295
19 55  0  0  0  0  0  0  0  0  0  0  0  0  8  0  0  0  0                000296
22 71  0  0  0  0  0  0  0  0  0  0  0  0 14  0  0  0  0                000297
20 72  0  0  0  0  0  0  0  0  0  0  0  0 12  0  0  0  0                000298
16 58  0  0  0  0  0  0  0  0  0  0  0  9 28  0  0  0  0                000299
25 50  0129  0  0  0  0  0  0  0  0  0 70180  0  0  0  0                000300
23 49  0  0  0  0  0  0  0 51  0  0  0  0 31  0 32  0  0                000301
25 46  0  0  0  0  0  0176  9 12  0  0  0 99  0104  0  0                000302
24 48  0 56  0  0  0  0 46  0  0  0  0  0 81  0171  0  0                000303
27 45  0  0  0  0  0  0129 20  0  0  0  0  0  0 16191 44                000304
17 61  0  0  2  0  0 54  0  0  0  0 44  0  0  0  0  0  0                000305
30 50  0  0  0  0 14278  0  0  0  0  0 79  0  0  0  0  0                000306
27 50  0  0  0  0  0175 23  0  0  0  0174  0  0  0  0  0                000307
```

Example of selected output

In order to save space, a part of output has been omitted from the full output for the run specified in the input.

```
LOGISTIC ANALYSIS, VMS DEPOSITS, NEWFOUNDLAND

LEVEL OF CONVERGENCE =          .1000000000

MAXIMUM PERMISSIBLE NO. OF ITERATIONS = 30

NUMBER OF VARIABLES                   =   17

NUMBER OF OBSERVATIONS WITH Y(I)=1 =    21

NUMBER OF OBSERVATIONS WITH Y(I)=0 =   286

ITAPE =  1           INPUT FORMAT =    (6X,17F3.0)

IPROB  = 0           ICO    =  1

AS A STARTING POINT, ALL COEFFICIENTS ARE SET EQUAL TO ZERO.


    1   TH ITERATICN

THE INPUT MATRIX HAS FULL RANK        18

SCORES-----ITERATION WILL CEASE WHEN ALL SCORES ARE LESS THAN THE GIVEN LEVEL OF CONVERGENCE.

  -.132500000000E+03  -.355000000000E+03  -.317950000000E+04  -.117250000000E+04  -.233500000000E+04

  -.577350000000E+04  -.391650000000E+04  -.166250000000E+04  -.963500000000E+03  -.102850000000E+04

  -.220000000000E+03  -.197850000000E+04  -.246950000000E+04  -.654000000000E+03  -.900000000000E+01

  -.907000000000E+03  -.790000000000E+02  -.720500000000E+03

 1 TH ESTIMATES OF COEFFICIENTS

  -.207481970741E+01   .105881755093E-04   .312654751221E-02  -.190685196247E-03  -.807077182694E-03

  -.123669657949E-03   .279849431648E-02  -.350287243629E-03  -.604616171763E-03   .113665164554E-02

  -.743733493896E-03  -.113785587834E-03   .403588727885E-02   .462046579239E-02  -.497866815205E-01

   .950798744707E-03   .110174300000E-01   .402465683346E-03

NUMBER OF SCORES WHICH ARE GREATER THAN SPECIFIED LEVEL OF CONVERGENCE =    18
```

⋮

```
    8   TH ITERATICN
THE INPUT MATRIX HAS FULL RANK        18
SCORES-----ITERATION WILL CEASE WHEN ALL SCORES ARE LESS THAN THE GIVEN LEVEL OF CONVERGENCE.
  -.176499477018E-01  -.403339811061E+00  -.446825286279E+00  -.577594140794E-01  -.271262781801E+00
  -.299254601310E+00  -.305692898306E+00  -.862048410090E-02  -.145075807256E+01  -.120399666757E-01
  -.293166315143E+00  -.634956933072E-01  -.136855339837E+01  -.161759482580E-03  -.569474729695E-02
  -.139657553173E+00  -.193497380678E-04  -.255526711044E-04
 8 TH ESTIMATES OF COEFFICIENTS
  -.456232093766E+01  -.123917381668E+00   .117211577606E-01  -.311128213549E-01  -.105627099720E-01
  -.172246698146E-02   .106560772865E-01   .206484457493E-04   .350281796204E-02   .652533395475E-02
  -.110708232505E+00  -.335030178721E-02   .116028049656E-01   .126761605023E-01  -.921148942879E+00
   .606701879595E-02   .218447551764E-01   .439734470456E-02
NUMBER OF SCORES WHICH ARE GREATER THAN SPECIFIED LEVEL OF CONVERGENCE =    9
                                                     .
                                                     .
                                                     .
   12   TH ITERATICN
THE INPUT MATRIX HAS FULL RANK        18
SCORES-----ITERATION WILL CEASE WHEN ALL SCORES ARE LESS THAN THE GIVEN LEVEL OF CONVERGENCE.
  -.155443914666E-01  -.269668151836E-01  -.278008218533E+01  -.514988289848E-02  -.138838207578E+00
  -.137956775030E+01  -.160419944077E-01  -.680042562417E-01  -.539302472089E-01  -.127158491614E-02
  -.110261525778E-01  -.508034237128E-01  -.496121505130E-01  -.339517599059E-03  -.106381549911E-03
  -.295637377712E-02  -.310752711812E-04  -.383697188227E-04
12 TH ESTIMATES OF COEFFICIENTS
  -.455953815905E+01  -.248879812094E+01   .118095857312E-01  -.311703097405E-01  -.106950928217E-01
  -.146241859098E-02   .106253916227E-01   .157963732633E-04   .343549953034E-02   .650614087463E-02
  -.423699237599E+00  -.314770593971E-02   .115860054860E-01   .126449228921E-01  -.150665005183E+01
   .606126706442E-02   .218434671853E-01   .439155731402E-02
NUMBER OF SCORES WHICH ARE GREATER THAN SPECIFIED LEVEL OF CONVERGENCE =    3
                                                     .
                                                     .
                                                     .
```

```
   17  TH ITERATION

THE INPUT MATRIX HAS FULL RANK        18

SCORES-----ITERATION WILL CEASE WHEN ALL SCORES ARE LESS THAN THE GIVEN LEVEL OF CONVERGENCE.

  -.219562254529E-03  -.182470269994E-03  -.423330885023E-01  -.174509295903E-10  -.200717226062E-02

  -.209840736334E-01  -.291038304567E-10  -.236468622461E-10  -.554166511392E-03  -.297228203635E-03

  -.111215079707E-03  -.910962480566E-02  -.851859367685E-04  -.545696821064E-11  -.724765546491E-06

  -.162621672644E-04  -.181898940355E-11  0.

17 TH ESTIMATES OF COEFFICIENTS

  -.455960259706E+01  -.750378679627E+01   .118105065942E-01  -.311791442394E-01  -.106954430960E-01

  -.146018762793E-02   .106255274642E-01   .157154076343E-04   .342940142662E-02   .650151887344E-02

  -.200213128684E+01  -.310242847869E-02   .115851486628E-01   .126459605760E-01  -.225063198809E+01

   .606176593586E-02   .218440915409E-01   .439209742969E-02

NUMBER OF SCORES WHICH ARE GREATER THAN SPECIFIED LEVEL OF CONVERGENCE =     0



LOGISTIC ANALYSIS, VMS DEPOSITS, NEWFOUNDLAND

FINAL ESTIMATES OF COEFFICIENTS

  -.455960259706E+01  -.750378679627E+01   .118105065942E-01  -.311791442394E-01  -.106954430960E-01

  -.146018762793E-02   .106255274642E-01   .157154076343E-04   .342940142662E-02   .650151887344E-02

  -.200213128684E+01  -.310242847869E-02   .115851486628E-01   .126459605760E-01  -.225063198809E+01

   .606176593586E-02   .218440915409E-01   .439209742969E-02

VARIANCES  OF COEFFICIENTS

     .7041171225D+00     .5481896345D+04     .1147320284D-04     .2392495509D-02     .2619142688D-03

     .3288984948D-04     .8773802306D-05     .5161662427D-04     .1076276229D-03     .5873726674D-04

     .2997969833D+04     .1893678555D-03     .9081931101D-05     .4868979769D-04     .2071088370D+06

     .2469946971D-04     .6539275232D-04     .3878407110D-04
```

```
STANDARD DEVIATIONS OF COEFFICIENTS
   .839116870573E+00   .740398294520E+02   .338721166186E-02   .489131425027E-01   .161837655925E-01
   .573496726078E-02   .296206048316E-02   .718447105017E-02   .103743733718E-01   .766402418689E-02
   .547537198078E+02   .137610993555E-01   .301362424682E-02   .697780751312E-02   .455092119271E+03
   .496985610518E-02   .808657852981E-02   .622768585444E-02
******  WARNING  *********


IF AT LEAST ONE OF THE VARIANCES IS PRINTED 0., ESTIMATES OF COEFFICIENTS THEMSELVES ARE NOT MEANINGFUL
DUE TO USE OF THE GENERALIZED INVERSE MATRIX.  HOWEVER, THE FOLLOWING ESTIMATES OF PROBABILITIES (PRINTED
ONLY IF REQUESTED) ARE MEANINGFUL.
```

APPENDIX III

Listing of Program LOGIST

```
      PROGRAM LOGIST(INPUT,OUTPUT,TAPE10,TAPE99,TAPE97,PUNCH)
C        *         *         *         *         *
C
C                   LOGISTIC ANALYSIS
C
C        C. F. CHUNG, GEOMATHEMATICS SECTION
C
C      GEOLOGICAL SURVEY OF CANADA, OTTAWA, CANADA
C
C                       AUGUST, 1977
C
C        *         *         *         *         *
      COMMON X(20),B(20),NS(20),D(20,20)
      DIMENSION NAME(8),FORM(6),T(20),V(20),F(20)
      DOUBLE PRECISION D
C        *         *         *         *         *
C   READ TITLE ANC INPUT. OUTPUT CONTROL CARDS
C        *         *         *         *         *
      READ 1,NAME
    1 FORMAT(8A10)
      READ 2, EVEL,ITER,ICOEF
    2 FORMAT(F10.0,3I5)
      READ 3,NVAR,N1,N2,ITAPE,FORM
    3 FORMAT(4I5,6A10)
      N=N1+N2
      READ 3,IPROB,ICO
C        *         *         *         *         *
C   PRINT TITLE AND INPUT, OUTPUT CONTROL STATEMENTS
C        *         *         *         *         *
      PRINT 5,NAME
    5 FORMAT(1H1,8A10)
      PRINT 6, EVEL,ITER
    6 FORMAT(1H0,"LEVEL OF CONVERGENCE =     ",F15.10,//,1X,
     1          "MAXIMUM PERMISSIBLE NO. OF ITERATIONS =",I3)
      PRINT 7,NVAR,N1,N2
    7 FORMAT(1H0,"NUMBER OF VARIABLES                   = ",I5,//,1X,
     1           "NUMBER OF OBSERVATIONS WITH Y(I)=1 = ",I5,//,1X,
     2           "NUMBER OF OBSERVATIONS WITH Y(I)=0 = ",I5)
      PRINT 8,ITAPE,FORM
    8 FORMAT(1H0,"ITAPE =",I3,10X,"INPUT FORMAT = ",7A10)
      PRINT 9,IPROB,ICO
    9 FORMAT(1H0,"IPROB  =",I2,10X,"ICO    =",I3)
      M=NVAR+1
      IF(ICOEF.EQ.0)GO TO 10
      READ 11,(B(I),I=1,M)
   11 FORMAT(8F10.0)
      PRINT 12
   12 FORMAT(1H0,"GIVEN INITIAL COEFFICIENTS AS STARTING POINT")
      PRINT 13,(B(I),I=1,M)
   13 FORMAT(1H0,5E20.12)
      GO TO 30
   10 PRINT 14
   14 FORMAT(1H0,"AS A STARTING POINT, ALL COEFFICIENTS ARE SET EQUAL TO
     1 ZERO.")
      DO 20 I=1,M
      B(I)=0.0
   20 CONTINUE
   30 DO 40 I=1,M
      T(I)=0.0
   40 CONTINUE
      REWIND 10
      X(1)=1.0
C        *         *         *         *         *
```

```
C   READ INPUT DATA BLOCK
C        *         *         *         *         *
      IF(ITAPE.EQ.1)GO TO 80
      DO 70 I=1,N
      READ FORM,(V(J),J=1,NVAR)
      DO 50 K=1,NVAR
      L=K+1
      X(L)=V(K)
   50 CONTINUE
      WRITE(10)  (X(J),J=1,M)
      IF(I.GT.N1)GO TO 70
      DO 60 K=1 ,M
      T(K)=T(K)+X(K)
   60 CONTINUE
   70 CONTINUE
      GO TO 120
   80 REWIND 99
      DO 110 I=1,N
      READ(99,FORM)(V(J),J=1,NVAR)
      DO 90 K=1,NVAR
      L=K+1
      X(L)=V(K)
   90 CONTINUE
      WRITE(10)  (X(J),J=1,M)
      IF(I.GT.N1)GO TO 110
      DO 100 K=1,M
      T(K)=T(K)+X(K)
  100 CONTINUE
  110 CONTINUE
      REWIND 99
C        *         *         *         *         *
C   START ITERATION
C        *         *         *         *         *
  120 REWIND 10
      ISTEP=1
  130 CONTINUE
C        *         *         *         *         *
C   CALL SUBROUTINE LOGIT FOR COMPUTATION
C        *         *         *         *         *
      CALL LOGIT(M,N,ISTEP,V,T)
      REWIND 10
      PRINT 15
   15 FORMAT(1H0,"SCORES-----ITERATION WILL CEASE WHEN ALL SCORES ARE LE
     1SS THAN THE GIVEN LEVEL OF CONVERGENCE.")
      PRINT 13,(V(I),I=1,M)
      PRINT 16,ISTEP
   16 FORMAT(1H0,I2," TH ESTIMATES OF COEFFICIENTS")
      PRINT 13,(B(I),I=1,M)
      ILEVEL=0
      DO 140 I=1,M
      C=ABS(V(I))
      IF(C.LT. EVEL)GO TO 140
      ILEVEL=ILEVEL+1
  140 CONTINUE
      PRINT 17,ILEVEL
   17 FORMAT(1H0,"NUMBER OF SCORES WHICH ARE GREATER THAN SPECIFIED LEVE
     1L OF CONVERGENCE = ",I5)
      IF(ILEVEL.EQ.0)GO TO 160
      ISTEP=ISTEP+1
      IF(ISTEP.GT.ITER)GO TO 150
      GO TO 130
  150 PRINT 18
   18 FORMAT(1H0,"THE SOLUTION CAN NOT BE OBTAINED FOR THE GIVEN LEVEL O
     1F CONVERGENCE AND THE MAXIMUM PERMISSIBLE NUMBER OF ITERATIONS",/,
     21X,"HOWEVER, THIS PROGRAM WILL PRODUCE PUNCHED OUTPUTS(CARDS) OF
     3THE LAST ESTIMATES OF BETA WHICH CAN BE USED FOR THE",/,1X,"INITIA
```

```
     4L COEFFICIENTS FOR NEXT JOB")                                     MAIN 130
      PUNCH 19,(B(I),I=1,M)                                             MAIN 131
   19 FORMAT(8F10.5)                                                    MAIN 132
      GO TO 220                                                         MAIN 133
C        *         *         *         *         *                      MAIN 134
C   STOP ITERATION, PRINT ESTIMATES(ML ESTIMATES) AND VARIANCES         MAIN 135
C        *         *         *         *         *                      MAIN 136
  160 PRINT 5,NAME                                                      MAIN 137
      PRINT 27                                                          MAIN 138
      PRINT 13,(B(I),I=1,M)                                             MAIN 139
      IF(ICO.NE.1)GO TO 772                                             MAIN 140
      REWIND 97                                                         MAIN 141
      WRITE(97,771)(B(I),I=1,M)                                         MAIN 142
  771 FORMAT(5E20.12)                                                   MAIN 143
      REWIND 97                                                         MAIN 144
  772 PRINT 21                                                          MAIN 145
   21 FORMAT(1H0,"VARIANCES  OF COEFFICIENTS")                          MAIN 146
      PRINT 22,(D(I,I),I=1,M)                                           MAIN 147
   22 FORMAT(1H0,5D20.10)                                               MAIN 148
      PRINT 24                                                          MAIN 149
   24 FORMAT(1H0,"STANDARD DEVIATIONS OF COEFFICIENTS")                 MAIN 150
      DO 170 I=1,M                                                      MAIN 151
      F(I)=DSQRT(D(I,I))                                                MAIN 152
  170 CONTINUE                                                          MAIN 153
      PRINT 13,(F(I),I=1,M)                                             MAIN 154
      PRINT 25                                                          MAIN 155
      IF(IPROB.EQ.0)GO TO 220                                           MAIN 156
C        *         *         *         *         *                      MAIN 157
C   PRINT ESTIMATED PROBABILITY                                         MAIN 158
C        *         *         *         *         *                      MAIN 159
      PRINT 5,NAME                                                      MAIN 160
      M1=1                                                              MAIN 161
      M2=N1                                                             MAIN 162
      PRINT 26                                                          MAIN 163
  180 DO 200 I=M1,M2                                                    MAIN 164
      READ(10)(X(J),J=1,M)                                              MAIN 165
      XX=0.                                                             MAIN 166
      DO 190 K=1,M                                                      MAIN 167
      XX=XX+X(K)*B(K)                                                   MAIN 168
  190 CONTINUE                                                          MAIN 169
      EX=EXP(XX)                                                        MAIN 170
      THE=EX/(1.0+EX)                                                   MAIN 171
      JJ=I-M1+1                                                         MAIN172A
      PRINT 31,JJ,THE                                                   MAIN172B
  200 CONTINUE                                                          MAIN 173
      IF(M2.EQ.N)GO TO 210                                              MAIN 174
      M1=N1+1                                                           MAIN 175
      M2=N                                                              MAIN 176
      PRINT 28                                                          MAIN 177
      GO TO 180                                                         MAIN 178
  210 REWIND 10                                                         MAIN 179
   25 FORMAT(1H0,"******  WARNING  *********",///,1X,"IF AT LEAST ONE OFMAIN 180
     1 THE VARIANCES IS PRINTED 0., ESTIMATES OF COEFFICIENTS THEMSELVESMAIN 181
     2 ARE NOT MEANINGFUL",//,1X,                    "DUE TO USE OF THE MAIN 182
     3GENERALIZED INVERSE MATRIX.  HOWEVER, THE FOLLOWING ESTIMATES OF PMAIN 183
     4ROBABILITIES (PRINTED",//,1X,                  "ONLY IF REQUESTED)MAIN 184
     5 ARE MEANINGFUL.")                                                MAIN 185
   26 FORMAT(1H0,"ESTIMATED PROBABILITIES OF OBSERVATIONS WITH Y(I)=1") MAIN 186
   27 FORMAT(1H0,"FINAL ESTIMATES OF COEFFICIENTS")                     MAIN 187
   28 FORMAT(1H0,"ESTIMATED PROBABILITIES OF OBSERVATIONS WITH Y(I)=0") MAIN 188
   31 FORMAT(1H ,I5,10X,F12.9)                                          MAIN 189
  220 STOP                                                              MAIN 190
      END                                                               MAIN 191

      SUBROUTINE LOGIT(M,N,IS,V,T)                                      LOGI 001
      COMMON X(20),B(20),NS(20),D(20,20)                                LOGI 002
      DIMENSION T(20),V(20),F(20)                                       LOGI 003
```

```
      DOUBLE PRECISION D                                           LOGI 004
      DO 2 J=1,M                                                   LOGI 005
      DO 1 I=1,M                                                   LOGI 006
      D(I,J)=0.0                                                   LOGI 007
    1 CONTINUE                                                     LOGI 008
      F(J)=0.0                                                     LOGI 009
    2 CONTINUE                                                     LOGI 010
      DO 6 K=1,N                                                   LOGI 011
      READ(10)       (X(I),I=1,M)                                  LOGI 012
      C=0.0                                                        LOGI 013
      DO 3 J=1,M                                                   LOGI 014
      C=C+B(J)*X(J)                                                LOGI 015
    3 CONTINUE                                                     LOGI 016
      C=EXP(C)                                                     LOGI 017
      DD=1.0/(1.0+C)                                               LOGI 018
      DO 4 J=1,M                                                   LOGI 019
      F(J)=F(J)-C*DD*X(J)                                          LOGI 020
    4 CONTINUE                                                     LOGI 021
      DO 5  I=1,M                                                  LOGI 022
      DO 5  J=1,M                                                  LOGI 023
      D(I,J)=D(I,J)+X(I)*X(J)*C*DD*DD                              LOGI 024
    5 CONTINUE                                                     LOGI 025
    6 CONTINUE                                                     LOGI 026
      REWIND 10                                                    LOGI 027
      DO 7 J=1,M                                                   LOGI 028
      F(J)=T(J)+F(J)                                               LOGI 029
    7 CONTINUE                                                     LOGI 030
      PRINT 13                                                     LOGI 031
      PRINT 8,IS                                                   LOGI 032
    8 FORMAT(1H0,I5,2X,2HTH,1X,"ITERATION")                        LOGI 033
      CALL GENINV(M)                                               LOGI 034
      DO 11 J=1,M                                                  LOGI 035
      C=0.0                                                        LOGI 036
      IF(NS(J).EQ.-1)GO TO 10                                      LOGI 037
      DO 9 I=1,M                                                   LOGI 038
      IF(NS(I).EQ.-1)GO TO 9                                       LOGI 039
      C=C +D(I,J)*F(I)                                             LOGI 040
    9 CONTINUE                                                     LOGI 041
   10 V(J)=C                                                       LOGI 042
   11 CONTINUE                                                     LOGI 043
      DO 12 J=1,M                                                  LOGI 044
      B(J)=B(J)+V(J)                                               LOGI 045
   12 CONTINUE                                                     LOGI 046
   13 FORMAT(1H0)                                                  LOGI 047
      DO 14 J=1,M                                                  LOGI 048
      IF(NS(J).EQ.-1)D(J,J)=0.0                                    LOGI 049
      V(J)=F(J)                                                    LOGI 050
   14 CONTINUE                                                     LOGI 051
      RETURN                                                       LOGI 052
      END                                                          LOGI 053

      SUBROUTINE GENINV(M)                                         GINV 001
      COMMON C(20),F(20),NS(20),A(20,20)                           GINV 002
      DIMENSION B(20,20)                                           GINV 003
      DOUBLE PRECISION A,XX                                        GINV 004
      DO 2 I=1,M                                                   GINV 005
      NS(I)=-1                                                     GINV 006
      DO 1 J=1,M                                                   GINV 007
      B(I,J)=A(I,J)                                                GINV 008
    1 CONTINUE                                                     GINV 009
    2 CONTINUE                                                     GINV 010
    3 DO 4 I=1,M                                                   GINV 011
      C(I)=0.0                                                     GINV 012
    4 CONTINUE                                                     GINV 013
      DO 5 I=1,M                                                   GINV 014
      XX=DABS(A(I,I))                                              GINV 015
      IF((XX.LE.1.0D-7).OR.(NS(I).EQ.1))GO TO 5                    GINV 016
```

```
      K=I                                                               GINV 017
      GO TO 6                                                           GINV 018
    5 CONTINUE                                                          GINV 019
      GO TO 11                                                          GINV 020
    6 XX=A(K,K)                                                         GINV 021
      NS(K)=1                                                           GINV 022
      C(K)=1.0/XX                                                       GINV 023
      DO 7 J=1,M                                                        GINV 024
      A(K,J)=A(K,J)/XX                                                  GINV 025
    7 CONTINUE                                                          GINV 026
      DO 9 I=1,M                                                        GINV 027
      IF(I.EQ.K)GO TO 9                                                 GINV 028
      XX=A(I,K)                                                         GINV 029
      C(I)=-XX*C(K)                                                     GINV 030
      DO 8 J=1,M                                                        GINV 031
      A(I,J)=A(I,J)-A(K,J)*XX                                           GINV 032
    8 CONTINUE                                                          GINV 033
    9 CONTINUE                                                          GINV 034
      DO 10 I=1,M                                                       GINV 035
      A(I,K)=C(I)                                                       GINV 036
   10 CONTINUE                                                          GINV 037
      GO TO 3                                                           GINV 038
   11 K=0                                                               GINV 039
      DO 12 I=1,M                                                       GINV 040
      IF(NS(I).EQ.-1)GO TO 12                                           GINV 041
      K=K+1                                                             GINV 042
   12 CONTINUE                                                          GINV 043
      IF(K.NE. M)GO TO 14                                               GINV 044
      PRINT 13,M                                                        GINV 045
   13 FORMAT(1H0,"THE INPUT MATRIX HAS FULL RANK",I10)                  GINV 046
      GO TO 16                                                          GINV 047
   14 PRINT 15,K                                                        GINV 048
   15 FORMAT(1H0,"THE INPUT MATRIX HAS RANK",I10)                       GINV 049
   16 DO 22 K=1,M                                                       GINV 050
      IF(NS(K).EQ.-1)GO TO 22                                           GINV 051
      DO 18 I=1,M                                                       GINV 052
      CC=0.0                                                            GINV 053
      IF(NS(I).EQ.-1)GO TO 18                                           GINV 054
      DO 17 J=1,M                                                       GINV 055
      IF(NS(J).EQ.-1)GO TO 17                                           GINV 056
      CC=CC+A(K,J)*B(J,I)                                               GINV 057
   17 CONTINUE                                                          GINV 058
      C(I)=CC                                                           GINV 059
   18 CONTINUE                                                          GINV 060
      DO 19 L=1,M                                                       GINV 061
      IF(L.EQ.K)GO TO 19                                                GINV 062
      CC=ABS(C(L))                                                      GINV 063
      IF(CC.LE.1.0E-3)GO TO 19                                          GINV 064
      GO TO 20                                                          GINV 065
   19 CONTINUE                                                          GINV 066
   22 CONTINUE                                                          GINV 067
      GO TO 23                                                          GINV 068
   20 PRINT 21                                                          GINV 069
   21 FORMAT(1H0,"WARNING - -  ERRONEOUS INVERSE MATRIX")               GINV 070
   23 RETURN                                                            GINV 071
      END                                                               GINV 072
```