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SIMULAT: A COMPUTER PROGRAM FOR THE PROSPECT BY PROSPECT METHOD OF ESTIMATING PETROLEUM RESOURCES USING MONTE CARLO SIMULATION

by

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CONTENTS

SUMMARY

The Fortran program SIMULAT provides a way of estimating hydrocarbon resources assessed by the prospect by prospect method. Data are input either as single values or as ranges of weighted values, and resource estimates are produced in the form of cumulative probability curves for the individual prospects dealt with, and for groups of prospects.

1. INTRODUCTION

There are three main problems in estimating the volume of undiscovered oil and gas resources by the prospect by prospect method. Firstly, the chance that a prospect will contain any oil or gas at all (existence risk) must be estimated. Secondly, we must estimate the volume of hydrocarbons that will be found in the event of a discovery. Thirdly, the potential resource volumes of all the prospects in a region must be added, taking into account the chances of making a discovery at each prospect.

Methods of determining existence risk have been described by Megill (1971, p.102-104) and Newendorp (1975, p.311-319). The method of determining the volume of hydrocarbons that a prospect may contain, is explained conceptually in Newendorp (1975, p. 369-436). A computer program is not generally available to handle the required Monte Carlo simulation although exploration companies have used these methods for many years. This paper is written to summarize the basis for and to provide a description of a computer program developed at BMR in 1977.

Existence risk

A petroliferous area must have: source rocks; a favourable thermal history; reservoir rocks; a sealed trap; a favourable sequence of trap development with respect to maturation; and protection of accumulated hydrocarbons from escape or destruction. A probability may be assigned to the likelihood that each of these critical factors occurs favourably at a prospect. The overall chance of hydrocarbon discovery (existence risk) is then obtained by multiplying the individual probabilities (risks) together. In this manner we may deduce that a prospect has, for example, one chance in ten of containing hydrocarbons. We may also estimate the probability that the prospect will contain either all gas or all oil. If the chance of finding gas rather than oil is 3:1

then, following the preceding example, the probability of a gas discovery is 0.075 and the probability of an oil discovery is 0.025.

Existence risk = risk factor 1 x risk factor 2 x risk factor 3 x ....

Cumulative probability curve of resources for a single prospect

Oil and gas resources of discovered fields can be calculated using equations (Moody, 1961) such as:

$$Vo = \frac{Vr \times \emptyset \times (1 - Sw) \times Ro}{FVF} \qquad 1.$$

$$Vg = \frac{Vr \times \emptyset \times (1 - Sw) \times Rg}{Bg} \qquad 2.$$

where $$Bg = \frac{14.7}{P + 14.7} \times \frac{T}{520} \times Z \qquad 3.$$

Vr can be calculated by either Vr = A x h x TF or Vr = Vt x NP x TF. The variables used in the above expressions are defined as follows:

Vr - reservoir volume
Vo - oil volume
NP - fraction net pay
Ø - porosity
Ro - oil recovery factor
P - reservoir pressure (p.s.i.g.)
Z - gas deviation factor
FVF- formation volume factor
Bg - gas expansion factor
Vt - trap volume
Vg - gas volume
TF - fraction trap fill
Sw - water saturation
Rg - gas recovery factor
T - reservoir temperature (degrees Rankine)
A - reservoir area
h - reservoir thickness

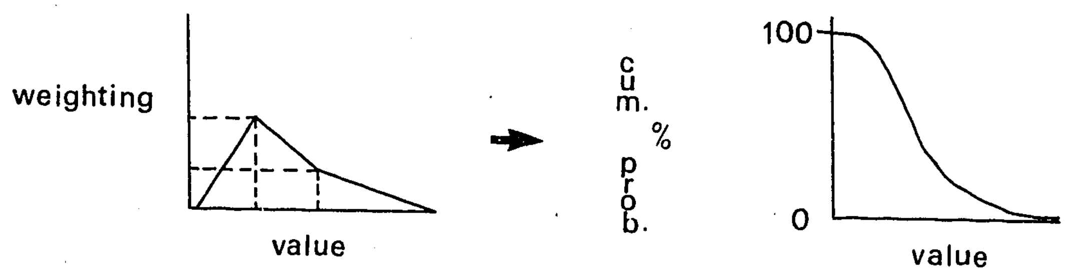
The variables on the right hand side of equations 1, 2, and 3, are regarded in the first instance, as independent.

However, the values to be assigned to each of the independent variables in an undrilled prospect are uncertain, and accordingly, instead of a single value, a range of values must be assigned to cover the uncertainty. The range is first conceived of as a frequency distribution and then converted to a cumulative probability distribution (see Fig. 1).

A Monte Carlo simulation pass is carried out by the random selection of a value for each independent variable (through the cumulative probability axis) and these values are substituted in equations 1 and 2 to obtain a single resource estimate. This process is repeated a large number of times (say 2000); the resulting values of the resource estimates being compiled into a frequency distribution, which is then converted to a cumulative probability distribution of resources for the prospect. The distribution only applies if the prospect contains petroleum.

The variables used on the right hand side of equations 1, 2, and 3 have been treated as independent. Certain degrees of dependence do occur amongst some of the parameters. For example, water saturation generally increases as porosity decreases; oil recovery factor generally increases as net pay thickness increases, etc. A basis for attacking this problem is given in Newendorp (1975, p.406-431) but has not been incorporated in the existing program. If one or more variables used in the resource formulae are dependent then the formulae must be modified to eliminate such variables. A modification of the computer program is then necessary as SIMULAT is designed to use predetermined formulae.

1.

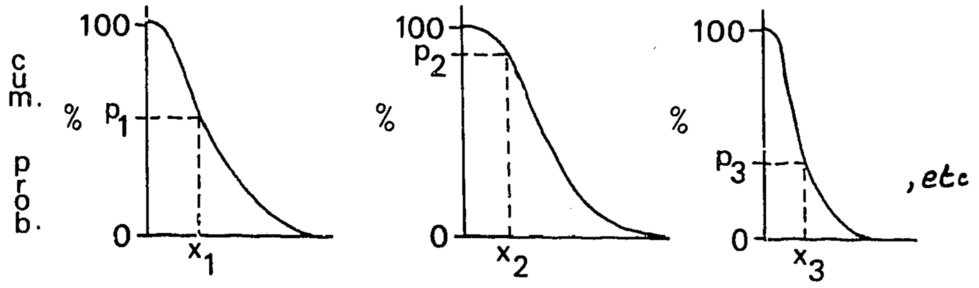


Frequency distribution

Cumulative probability distribution

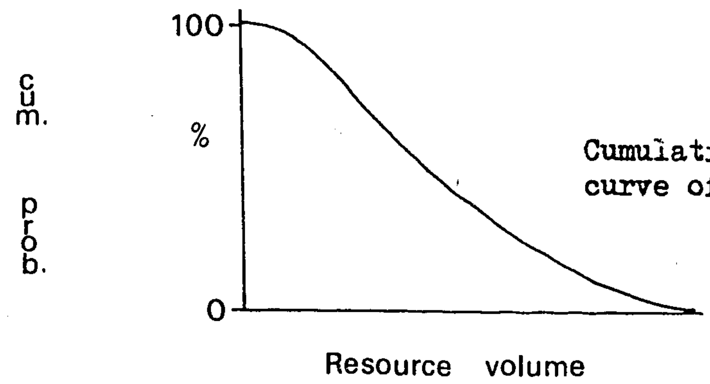
EACH VARIABLE USED IN RESOURCE CALCULATION

2.



variable 1, 2, 3,

Values of p_1, p_2, p_3, . . . are chosen at random to select values x_1, x_2, x_3, where variables 1, 2, 3, .. may be V, Ø, Sw, etc. The values selected are substituted in the resource volume formulae to obtain a resource value. The process is repeated 2000 times and the values obtained used to produce a cumulative probability curve.



Cumulative probability curve of resources

Figure 1: Steps taken in producing a sumulative probability curve of resources for a single prospect.

Addition of resources contained in undrilled prospects

Resources of all prospects in a region must be 'added' to obtain an estimate of the total hydrocarbon resources of the region. The existence risks of each of the prospects may be different and, as well, some of the factors which make up those risks may be interrelated (i.e. dependent) from prospect to prospect.

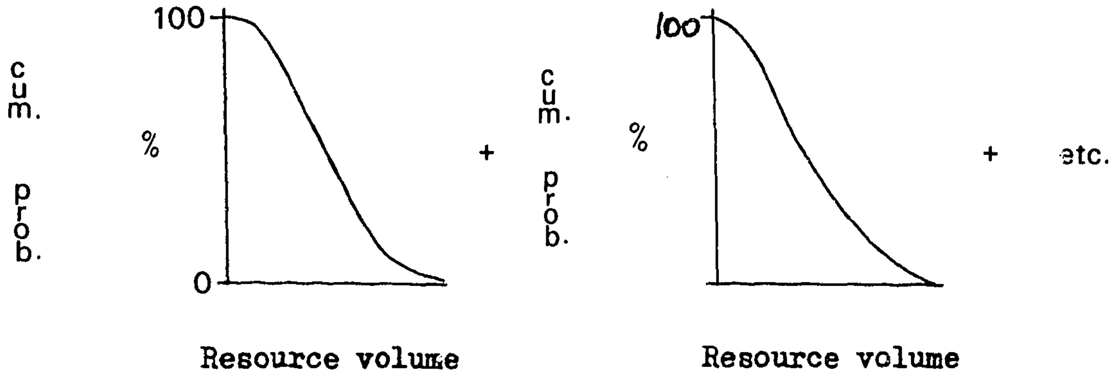
In the simplest case (Fig. 2) all the risks are treated as independent. Firstly, a random number between 0 and 1 is chosen and compared with the existence risk. If the number chosen is higher than the existence risk value, then a zero is assigned as the resource value. Otherwise, a resource value is chosen by selecting a number at random via the probability axis of the cumulative probability distribution for the prospect.

The values obtained for all prospects are summed arithmetically and the process repeated a large number of times (say 2000). The summed resource values are then compiled into a risked cumulative probability distribution of resources.

The following procedure should be carried out if some of the critical risk factors are dependent from prospect to prospect:

1. The group of prospects must be broken down into sub-groups, each of which has common dependent existence risks. A dependent risk is calculated for the sub-group by multiplying together the common dependent risks.

2. Independent existence risks are calculated for each prospect in the sub-group. The resources of the prospects in the group are then summed using these independent risks as in Figure 2 to produce a



Prospect 1 Existence risk + Prospect 2 Existence risk + etc.

1. A random number (n) ranging from 0 to 1 is chosen for each prospect and compared with the existence risk value (e)

$n \leq e$ $\qquad$ $n > e$

2. (A resource volume is chosen at random from each cum. prob. distribution.) (0 is chosen for resource volume)

3. Sum resources obtained from all prospects.

4. Repeat process 1. to 3., 2000 times.

5. The summed resource values are used to produce a risked cumulative probability distribution of resources.

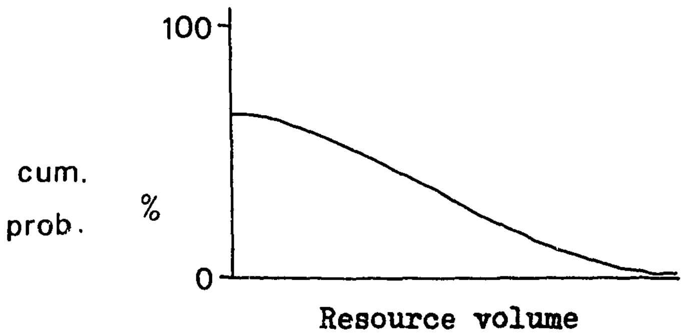


Figure 2. Steps used in adding resources - all existence risk factors independent.

partially risked cumulative probability distribution of resources.

3. The partially risked cumulative probability distribution for the sub-group is fully risked by multiplying the partially risked probabilities by the dependent risks.

4. The fully risked cumulative probability distributions for each sub-group are summed to obtain a risked cumulative probability distribution for the resources of the group of prospects.

A separate computer program is being developed to handle steps (3) and (4), which lie outside the scope of SIMULAT.

2. PROGRAM DESCRIPTION

SIMULAT is a program written in extended Fortran IV for use on the C.S.I.R.O. Cyber 76 computer. It consists of a main program SIMULAT and the subroutines CUMPROB and RANGE. Most of the computation is carried out in the main program including all the Monte Carlo simulations. CUMPROB converts frequency distributions, in the form of strings of weighted values, into a cumulative probability distribution of 20 points using linear interpolation between the input points. RANGE constructs a cumulative probability distribution of 20 or 100 points from a frequency distribution of 200 points.

Program structure

The structure of the program can be broken into two main sections:

Section A.

1. CUMPROB produces a cumulative probability distribution of 20 points for each input factor from a range of weighted values. When only one weighted value is supplied for a factor, the algorithm is bypassed. The 15, 50, 85 percent values from the cumulative probability distribution of each input factor are printed to use as a check on the input data.

2. A Monte Carlo simulation is performed to produce unrisked cumulative probability distributions of 20 points for both recoverable oil and gas resources of a prospect. 2000 passes are made for each simulation, as this number was found to produce consistent results during trials. Mean resource values are also computed.

3. The independent risks are input and compounded to produce existence risks for both oil and gas.

Section B

The resources of all prospects are summed, taking into account the existence risks, by a Monte Carlo simulation and presented as a 100 point risked cumulative probability distribution.

One hundred points are required to give adequate description of regions with low chances of containing petroleum. Even so, fewer than five points will be available to describe the non zero part of the risked cumulative probability curve of resources in regions where there is less than a five percent chance of discovering oil or gas.

Data deck structure

Card No.	Use	Format
1	Decides whether card punched output required (01 if card output is required)	I2
2	Describes number of prospects processed	I2
3-13	Labels (one per card) for each factor used in the volumetric determinations	2A 10
14-22	Labels (one per card) for each critical risk factor	2A 10
23	Prospect title card	8A 10
24 - X	Description of reservoir data with each factor on one card (or more if format sufficient). The values must be presented in ascending order. The format is as follows	
	number of data points	I10,
	data value	F10,
	weighting	F10,
	data value, etc.	F10, etc.
X + 1	INDEPENDENT RISKING	8A 10.
X + 2	Number of independent risk factors	I2
	The independent risk factors	8F 10
	Cards 24 onward are repeated for each prospect	

considered

An example data deck is displayed in Appendix 1.

(X represents variable number of cards required).

3. REFERENCES

MEGILL, R.E., 1971 - AN INTRODUCTION TO EXPLORATION ECONOMICS. Petroleum Publishing Co., Tulsa.

MOODY, G.B., 1961 - PETROLEUM EXPLORATION HANDBOOK - McGraw-Hill, New York.

NEWENDORP, P.D., 1975 - DECISION ANALYSIS FOR PETROLEUM EXPLORATION. Petroleum Publishing Co., Tulsa.

NEWENDORP, P.D., and CAMPBELL, J.M., 1970 - DECISION METHODS FOR PETROLEUM INVESTMENTS (pages 130-150). John M. Campbell & Co., Norman, 'klahoma.

APPENDIX 1

SAMPLE EXECUTION DECK

APPENDIX 1 - SAMPLE EXECUTION DECK

```
*CY,CPDMRXVA,SIML
SIML(T10)
COMMENT.*********************E.J.RIESZ*****************EXT352*******************
LIMIT(0)
FTN(SL)
LGO.
7 EOS

      PROGRAM SIMULAT (INPUT,OUTPUT,PUNCH,TAPE61=OUTPUT)                SML 001
C
C  SIMULAT CONVERTS STRINGS OF WEIGHTED VALUES FOR FACTORS IN REC. OIL & GAS
C  VOLUME FORMULAE INTO CUM. PROB. DISTRIBUTIONS FOR RESOURCES IN INDIVIDIAL
C  PROSPECTS, EXISTENCE RISKS, AND ADDS DISTRIB'S USING MONTE CARLO SIMULATION
C  TO PRODUCE CUM. PROB. DISTRIB'S OF RESOURCES FOR A GROUP OF PROSPECTS.
C  EXISTENCE RISK FACTORS ARE ASSUMED INDEPENDENT. PROGRAM PROSADD MUST BE USED
C  IN CONJUNCTION WITH SIMULAT TO ADD RESOURCES FROM A GROUP OF PROSPECTS WHEN
C  SOME EXISTENCE RISK FACTORS ARE TAKEN AS DEPENDENT FROM PROSPECT TO PROSPECT.
C
      DIMENSION TITLE(20),F(101),OIL(21,40),GAS(21,40),RISK(40),ORISK(40 SML 002
     1),GRISK(40),OSRES(101),FOSRES(101),GSRES(101),FGSRES(101),FOIL(21) SML 003
     2,FGAS(21)                                                          SML 004
      COMMON LABEL(2,20),CPROB(20,21),XN(3000),XCUM(3000),R(101)        SML 005
C
C  IF NPUNCH = 1, CARD DECK OF SUMMED CUM. PROB. DISTRIB. IS PRODUCED.
C
      READ 1,NPUNCH                                                     SML 006
    1 FORMAT(I2)                                                        SML 007
C
C  NPLAYS IS NO. OF PROSPECTS TO BE SUMMED.
C
      READ 1,NPLAYS                                                     SML 008
      READ 2,((LABEL(J,I),J=1,2),I=1,20)                                SML 009
    2 FORMAT(2A10)                                                      SML 010
      LIM=2000. $ SMAXO=0. $SMAXG=0. $ SMOMN=0.
      SMGMN=0. $ SXOM=0. $ SXGM=0.                                      SML 012
C
C     LIM CONTROLS MAXIMUM NO. OF COMPUTATIONS IN SIMULATION
C
      DO 200 KK=1,NPLAYS                                                SML 013
      READ 4,(TITLE(I),I=1,8)                                           SML 014
    4 FORMAT(8A10)                                                      SML 015
      PRINT 5,(TITLE(I),I=1,8)                                          SML 016
    5 FORMAT(1H1,/,30X,8A10)                                            SML 017
      CALL CUMPROB                                                      SML 018
C
C MAX. & MIN. RESOURCE VALUES ARE COMPUTED SEPARATELY
C
      OIL(1,KK)=CPROB(1,1)*CPROB(2,1)*CPROB(3,1)*CPROB(4,1)*(1-CPROB(5,2 SML 019
     11))*CPROB(6,1)/CPROB(11,21)                                       SML 020
      OIL(21,KK)=CPROB(1,21)*CPROB(2,21)*CPROB(3,21)*CPROB(4,21)*(1-CPRO SML 021
     1B(5,1))*CPROB(6,21)/CPROB(11,1) $ SMAXO=SMAXO+OIL(21,KK)          SML 022
      GAS(1,KK)=CPROB(1,1)*CPROB(2,1)*CPROB(3,1)*CPROB(4,1)*(1-CPROB(5,2 SML 023
     11))*CPROB(7,1)*35.3*(14.73+CPROB(8,1))/CPROB(9,21)/CPROB(10,21)   SML 024
      GAS(21,KK)=CPROB(1,21)*CPROB(2,21)*CPROB(3,21)*CPROB(4,21)*(1-CPRO SML 025
     1B(5,1))*CPROB(7,21)*35.3*(14.73+CPROB(8,21))/CPROB(9,1)/CPROB(10,1 SML 026
     2) $ SMAXG=SMAXG+GAS(21,KK)                                        SML 027
      DO 10 I=1,3000                                                    SML 028
   10 XN(I)=0.        $  QM=0. $ OILMN=0. $ GASMN=0. $ XOM=0. $ XGM=0.  SML 029
C
C SCALING IS USED TO GIVE A RANGE OF 3000 VALUES
C
      SCALE1=OIL(21,KK)                                                 SML 030
      IF(SCALE1.EQ.0.)GO TO 17                                          SML 031
C
C  MONTE CARLO SIMULATION PREFORMED
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C
      DO 14 I=1,LIM                                                     SML 032
      DO 12 J=1,11                                                      SML 033
      II=RANF(D)*20.+1.5                                                SML 034
   12 F(J)=CPROB(J,II)                                                  SML 035
      IQ=F(1)*F(2)*F(3)*F(4)*(1-F(5))*F(6)/F(11)/SCALE1*3000            SML 036
      QM=QM+IQ                                                          SML 037
      IF(IQ.LT.1) IQ=1                                                  SML 038
      XN(IQ)=XN(IQ)+1                                                   SML 039
   14 XOM=QM*SCALE1/3000./LIM  $  FXOM=XOM*6.2898                       SML 040
      CALL RANGE(LIM,20)                                                SML 041
      DO 15 I=1,19                                                      SML 042
      OIL(I+1,KK)=R(I)*SCALE1/30.                                       SML 043
   15 FOIL(I)=OIL(I,KK)*6.2898                                          SML 044
      FOIL(20)=OIL(20,KK)*6.2898 $ FOIL(21)=OIL(21,KK)*6.2898           SML 045
      DO  16 I=1,3000                                                   SML 046
   16 XN(I)=0.  $   QM=0.                                               SML 047
   17 SCALE2=GAS(21,KK)                                                 SML 048
      IF(SCALE2.EQ.0.) 23,18                                            SML 049
   18 DO 21 I=1,LIM                                                     SML 050
      DO 19 J=1,10                                                      SML 051
      II=RANF(D)*20.+1.5                                                SML 052
   19 F(J)=CPROB(J,II)                                                  SML 053
      IQ=F(1)*F(2)*F(3)*F(4)*(1-F(5))*F(7)*35.3*(14.73+F(8))/F(9)/F(10)/ SML 054
     1SCALE2*3000                                                       SML 055
      QM=QM+IQ                                                          SML 056
      IF(IQ.LT.1) IQ=1                                                  SML 057
      XN(IQ)=XN(IQ)+1                                                   SML 058
   21 XGM=QM*SCALE2/3000./LIM  $  FXGM=XGM*.035315                      SML 059
      CALL RANGE(LIM,20)                                                SML 060
      DO 22 I=1,19                                                      SML 061
      GAS(I+1,KK)=R(I)*SCALE2/30.                                       SML 062
   22 FGAS(I)=GAS(I,KK)*.035315                                         SML 063
      FGAS(20)=GAS(20,KK)*.035315 $ FGAS(21)=GAS(21,KK)*.035315         SML 064
   23 PRINT 24,(TITLE(I),I=1,8)                                         SML 065
   24 FORMAT(1H1,/,30X,8A10,/,10X,29HUNRISKED MEAN RESOURCE VALUES)     SML 066
      PRINT 25, XOM,FXOM,XGM,FXGM                                       SML 067
   25 FORMAT(10X,45HMEAN REC.OIL RES.-MILL.CU.METRES.-MILLION BBL./,    SML 068
     130X,F12.0,3X,F12.0,/,                                             SML 069
     210X,47HMEAN REC.GAS RES.-MILL.CU.METRES.  -BILLION  CF,/,         SML 070
     330X,F12.0,3X,F12.0)                                               SML 071
      DO 26  I=1,21                                                     SML 072
   26 F(I)=1.05-I/20.   $ F(21)=0.0001                                  SML 073
      PRINT28,(F(I),OIL(I,KK),FOIL(I),GAS(I,KK),FGAS(I),I=1,21)         SML 074
   28 FORMAT(20X,26H*** UNRISKED RESOURCES ***,/,1X,9HCUM.PROB.,5X,22HOI SML 075
     1L.- MILL. CU. METRES,7X,10HMILL. BBL.,5X,22HGAS - MILL. CU. METRES SML 076
     2,11X,6HB.C.F.,21(/,F10.3,2(10X,2(5X,F12.0))))                     SML 077
C
C  THE EXISTENCE RISK FACTORS FOR A PROSPECT ARE INPUT AND COMPOUNDED
C
      READ 4,(TITLE(I),I=9,16)                                          SML 078
      READ 1,NRISK                                                      SML 079
      READ 32 ,(RISK(I),I=1,NRISK)                                      SML 080
   32 FORMAT(8F10.3)                                                    SML 081
      Q=RISK(1)+RISK(2) $ RISK(1)=RISK(1)/Q $ RISK(2)=RISK(2)/Q             82
      ORISK(KK)=RISK(1)  $  GRISK(KK)=RISK(2)                           SML 083
      IF(NRISK.LT.3) GO TO 34                                           SML 084
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      DO 33  I=3,NRISK                                                  SML 085
      ORISK(KK)=ORISK(KK)*RISK(I)                                       SML 086
   33 GRISK(KK)=GRISK(KK)*RISK(I)                                       SML 087
   34 PRINT 5,(TITLE(I),I=9,16)                                         SML 088
      PRINT 35,((LABEL(J,I+11),J=1,2),RISK(I),I=1,NRISK)                SML 089
   35 FORMAT(5X,2A10,F10.3)                                             SML 090
      OILMN=XOM*ORISK(KK)   $  GASMN=XGM*GRISK(KK)                      SML 091
      PRINT 36 ,ORISK(KK),GRISK(KK)                                     SML 092
   36 FORMAT(10X,21HOIL EXISTENCE RISK IS,F10.4,/,                      SML 093
     1       10X,21HGAS EXISTENCE RISK IS,F10.4)                        SML 094
      PRINT  37                                                         SML 095
   37 FORMAT(10X,27HRISKED MEAN RESOURCE VALUES)                        SML 096
      FOILMN=OILMN*6.2898  $  FGASMN=GASMN*.035315                      SML 097
      PRINT 25,OILMN,FOILMN,GASMN,FGASMN                                SML 098
      SMOMN=SMOMN+OILMN $ SMGMN=SMGMN+GASMN                             SML 099
      SXOM=SXOM+XOM  $ SXGM=SXGM+XGM                                    SML 100
  200 CONTINUE                                                          SML 101
      CALL QUIPLOT(F,GAS,21,NPLAYS,11H*CUM.PROB.*,23H*GAS RES.-MILL. CU. SML 102
     1 M.*)                                                             SML 103
      CALL QUIPLOT(F,OIL,21,NPLAYS,11H*CUM.PROB.*,23H*OIL RES.-MILL. CU. SML 104
     1 M.*)                                                             SML 105
C
      PRINT 205                                                         SML 106
  205 FORMAT(10X,33HTOTAL RISKED MEAN RESOURCE VALUES)                  SML 107
      FSMOMN=SMOMN*6.2898 $FSMGMN=SMGMN*.035315                         SML 108
      PRINT 25,SMOMN,FSMOMN,SMGMN,FSMGMN                                SML 109
C
C  RESOURCES FROM INDIVIDUAL PROSPECTS ARE SUMMED
C
      DO 210 I=1,3000                                                   SML 110
  210  XN(I)=0                                                          SML 111
C
C  MONTE CARLO SIMULATION PREFORMED
C
      DO 230 I=1,LIM                                                    SML 112
      OILSUM=0.       $    SORISK=0.                                    SML 113
      DO 220 J=1,NPLAYS                                                 SML 114
      SORISK=SORISK+ORISK(J)                                            SML 115
      CHANCE=RANF(D)                                                    SML 116
      IF(CHANCE.GT.ORISK(J)) GO TO 220                                  SML 117
      N=RANF(D)*20 .+1.5                                                SML 118
      OILSUM=OILSUM+OIL(N,J)                                            SML 119
  220 CONTINUE                                                          SML 120
      IF(SORISK.LT.0.01) GO TO 236                                      SML 121
      IJ=OILSUM*200./SXOM +1                                            SML 122
      IF(IJ.GT.3000) 230,225                                            SML 123
  225 XN(IJ)=XN(IJ)+1                                                   SML 124
  230 CONTINUE                                                          SML 125
      CALL RANGE(LIM,100)                                               SML 126
      OSRES(1)=OSRES(2)*2.-OSRES(3) $ FOSRES(1)=OSRES(1)*6.2896         SML 127
      OSRES(101)=SMAXO $ FOSRES(101)=SMAXO*6.2898                       SML 128
      DO 235 I=2,100                                                    SML 129
      OSRES(I)=R(I-1)*SXOM /2.                                          SML 130
  235 FOSRES(I)=OSRES(I)*6.2898                                         SML 131
  236 DO 240 I=1,3000                                                   SML 132
  240 XN(I)=0.                                                          SML 133
      DO 260 I=1,LIM                                                    SML 134
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      GASSUM=0.     $  SGRISK=0.                                        SML 135
      DO 250 J=1,NPLAYS                                                 SML 136
      SGRISK=SGRISK+GRISK(J)                                            SML 137
      CHANCE=RANF(D)                                                    SML 138
      IF(CHANCE.GT.GRISK(J)) GO TO 250                                  SML 139
      N=RANF(D)*20  .+1.5                                               SML 140
      GASSUM=GASSUM+GAS(N,J)                                            SML 141
  250 CONTINUE                                                          SML 142
      IF(SGRISK.LT.0.01) GO TO 268                                      SML 143
      IJ=GASSUM*200./SXGM   +1                                          SML 144
      IF(IJ.GT.3000)260,255                                             SML 145
  255 XN(IJ)=XN(IJ)+1                                                   SML 146
  260 CONTINUE                                                          SML 147
      CALL RANGE(LIM,100)                                               SML 148
      GSRES=GSRES(2)*2.-GSRES(3) $ FGSRES(1)=GSRES(1)*.035315           SML 149
      GSRES(101)=SMAXG $ FGSRES(101)=SMAXG*.035315                      SML 150
      DO 265 I=2,100                                                    SML 151
      GSRES(I)=R(I-1)*SXGM/2.                                           SML 152
  265 FGSRES(I)= GSRES(I)*.035315                                       SML 153
  268 PRINT 270                                                         SML 154
  270 FORMAT(30X,35H*** RISKED AND SUMMED RESOURCES ***)                SML 155
      PRINT 275                                                         SML 156
  275 FORMAT(15X,10HCUM. PROB.,2X,10HRISKED OIL,2X,10HRISKED GAS,22X,   SML 157
     110HCUM. PROB.,2X,10HRISKED OIL,2X,10HRISKED GAS)                  SML 158
      PRINT 276                                                         SML 159
  276 FORMAT(30X,16HMILL. CU. METRES,40X,16HMILL. CU. METRES)           SML 160
      DO280 I=1,101                                                     SML 161
  280 F(I)=1.-(I-1)/100.                                                SML 162
      PRINT 285,(F(I),OSRES(I),GSRES(I),F(I+50),OSRES(I+50),GSRES(I+50), SML 163
     1I=1,50)                                                           SML 164
  285 FORMAT(10X,F12.2,2F12.0,20X,F12.2,2F12.0)                         SML 165
      PRINT 270                                                         SML 166
      PRINT 286                                                         SML 167
  286 FORMAT(30X,10HMILL. BBL.,4X,8HB. C. F.,32X,10HMILL. BBL.,4X,8HB. C SML 168
     1. F.)                                                             SML 169
      PRINT285,(F(I),FOSRES(I),FGSRES(I),F(I+50),FOSRES(I+50),FGSRES(I+ SML 170
     150),I=1,50)                                                       SML 171
      PRINT 290                                                         SML 172
  290 FORMAT(1H1)                                                       SML 173
      CALL QUIPLOT(OSRES,F, 99,1,23H*OIL.RES.-MILL. CU. M.*,11H*CUM.PROB SML 174
     1.*)                                                               SML 175
      CALL QUIPLOT(GSRES,F, 99,1,23H*GAS.RES.-MILL. CU. M.*,11H*CUM.PROB SML 176
     1.*)                                                               SML 177
      CALL QUIPLOT(FOSRES,F,99,1,23H*OIL.RES.-MILL. B.B.L.*,11H*CUM.PROB SML 178
     1.*)                                                               SML 179
      CALL QUIPLOT(FGSRES,F,99,1,17H*GAS.RES.-B.C.F.*,11H*CUM.PROB.*)   SML 180
      IF(NPUNCH.EQ.1) 294,999                                           SML 181
  294 PUNCH 295,(OSRES(I),GSRES(I),I=1,100)                             SML 182
  295 FORMAT(10G8.2)                                                    SML 183
  999 CONTINUE                                                          SML 184
      STOP                                                              SML 285
      END                                                               SML 286
```

```
      SUBROUTINE CUMPROB
C
C THIS SUBROUTINE READS IN STRINGS OF PROB.WEIGHTED VARIABLES AND OUTPUTS A
C 20 VALUE CUM.PROB.DISTRIBUTION FOR EACH STRING.
C
      DIMENSION D1(20,20),D2(20,20),A(20),B(20),Z(20 ,200)              CMP 002
      COMMON LABEL(2,20),CPROB(20,21),XN(3000),XCUM(3000),R(101)        CMP 003
      DO100 I=1,11                                                      CMP 004
      READ10,L,(D1(I,J),D2(I,J),J=1,L)                                  CMP 005
   10 FORMAT(I10,7F10.2,/,(8F10.2))                                     CMP 006
      PRINT 11,(LABEL(J,I),J=1,2),(D1(I,J),J=1,L)                       CMP 007
   11 FORMAT (5X,2A10,(10F10.3))                                        CMP 008
C
C  IF FACTOR SINGLE VALUED ALGORITHM IS BYPASSED
C
      IF(L.EQ.1) 15,17                                                  CMP 009
   15 DO 16 M=1,21                                                      CMP 010
   16 CPROB(I,M)=D1(I,1)                                                CMP 011
      GO TO 100                                                         CMP 012
   17 PRINT 18,(D2(I,J),J=1,L)                                          CMP 013
   18 FORMAT(19X,6HWEIGHT,10F10.3)                                      CMP 014
C
C NORMALIZE THE FREQUENCY DISTRIBUTION
C
      AREA=0.      $  L1=L-1                                            CMP 015
      DO 20 J=1,L1                                                      CMP 016
   20 AREA=AREA+(D1(I,J+1)-D1(I,J))*(D2(I,J+1)+D2(I,J))/2               CMP 017
      DO 25 J=1,L                                                       CMP 018
   25 D2(I,J)=D2(I,J)/AREA                                              CMP 019
C
C  FREQUENCY DISTRIBUTION OF 200  VALUES IS NOW GENERATED
C
      DO 30 J=1,L1                                                      CMP 020
      A(J)=(D2(I,J)-D2(I,J+1))/(D1(I,J)-D1(I,J+1))                      CMP 021
   30 B(J)=D2(I,J)-A(J)*D1(I,J)                                         CMP 022
      DO 35 J=1,200                                                     CMP 023
   35 Z(I,J)=D1(I,1)+(J-1)*(D1(I,L)-D1(I,1))/199.                       CMP 024
C
C  DISTRIBUTION IS SPLIT INTO 20 PORTIONS OF EQUAL AREA
C
      AREA=0.  $  M=1  $  N=1                                           CMP 025
      DO 60 J=1,199                                                     CMP 026
      IF(Z(I,J+1).GE.D1(I,N+1)) 40,50                                   CMP 027
   40 DELTA=A(N)*(D1(I,N+1)+Z(I,J))*(D1(I,N+1)-Z(I,J))/2.+              CMP 028
     1    A(N+1)*(Z(I,J+1)+D1(I,J+1))*(Z(I,J+1)-D1(I,N+1))/2.+          CMP 029
     2    B(N)*(D1(I,N+1)-Z(I,J))+B(N+1)*(Z(I,J+1)-D1(I,N+1))           CMP 030
      N=N+1 $ AREA=AREA+DELTA                                           CMP 031
      IF(AREA.GE.M/20.) 41,60                                           CMP 032
   41 AREA1=AREA-DELTA+.5*A(N-1)*(D1(I,N)**2-Z(I,J)**2)                 CMP 033
     1 +B(N-1)*(D1(I,N)-Z(I,J))    $ M=M+1                              CMP 034
      IF(AREA1.GE.M/20.-.05) 42,43                                      CMP 035
   42 CPROB(I,M)=Z(I,J)+(D1(I,N)-Z(I,J))*(M/20.-.05-AREA+DELTA)/        CMP 036
     1 (AREA1-AREA+DELTA)        $ GO TO 60                             CMP 037
   43 CPROB(I,M)=D1(I,N)+(Z(I,J+1)-D1(I,N))*(M/20.-.05-AREA1)/(AREA-AREA CMP 038
     11)    $ GO TO 60                                                  CMP 039
   50 DELTA=A(N)*(Z(I,J+1)+Z(I,J))*(Z(I,J+1)-Z(I,J))/2. +               CMP 040
     2 B(N)*(Z(I,J+1)-Z(I,J))          $ AREA=AREA+DELTA                CMP 041
```

```
      IF(AREA.GE.M/20.) 55,60                                          CMP 042
   55 M=M+1                                                            CMP 043
      CPROB(I,M)=Z(I,J)+(M/20.+DELTA-AREA)/DELTA*(Z(I,J+1)-Z(I,J))     CMP 044
   60 CONTINUE                                                         CMP 045
      CPROB(I,1)=D1(1,1)  $  CPROB(I,21)=D1(1,L)                       CMP 046
  100 CONTINUE                                                         CMP 047
C          15,50 & 85 % CUM. PROB. DATA OUTPUT TO CHECK INPUT DATA
      PRINT 105                                                        CMP 048
  105 FORMAT(20X,48H15,50,&85% CUM. PROB. OUTPUT TO CHECK INPUT DATA,/, CMP 049
     16X,10HCUM. PROB.,20X,3H85%,17X,3H50%,17X,3H15%)                  CMP 050
      PRINT 110,((LABEL(J,I),J=1,2),CPROB(I,4),CPROB(I,11),CPROB(I,18),I CMP 051
     1=1,11)                                                           CMP 052
  110 FORMAT(1X,2A10,10X,F10.3,10X,F10.3,10X,F10.3)                    CMP 053
      RETURN                                                           CMP 054
      END                                                              CMP 055
```

```
      SUBROUTINE RANGE(LIM,NN)                                          RGE 001
C
C  THIS SUBROUTINE CONSTRUCTS A CUMULATIVE PROB DIST. OF NN POINTS
C  FROM A FREQUENCY DISTRIBUTION OF 3000 POINTS
      COMMON LABEL(2,20),CPROB(20,21),XN(3000),XCUM(3000),R(101)        RGE 002
C
      XCUM(1)=XN(1)                                                     RGE 003
      DO  5 I=2,3000                                                    RGE 004
    5 XCUM(I)=XCUM(I-1)+XN(I)                                           RGE 005
      DO 6 I=1,NN                                                       RGE 006
    6 R(I)=0.                                                           RGE 007
      DO 10 I=1,3000                                                    RGE 008
      M=XCUM(I)*NN/LIM+1                                                RGE 009
   10 R(M)=I/100.-NN*.00001                                             RGE 010
       R(NN+1)=30.                                                      RGE 011
      DO 15 I=1,NN                                                      RGE 012
      IF(R(I).EQ.0.)15,20                                               RGE 013
   15 CONTINUE                                                          RGE 014
   20 K=I+1                                                             RGE 015
      DO 40 I=K,NN                                                      RGE 016
      IF(R(I).EQ.0.)  25,40                                             RGE 017
   25 N=1                                                               RGE 018
   27 IF(R(I+N).EQ.0.) 30,32                                            RGE 019
   30 N=N+1                                                             RGE 020
      GO TO 27                                                          RGE 021
   32 DO 35 J=1,N                                                       RGE 022
   35 R(I+J-1)=R(I-1)+(R(I+N)-R(I-1))*J/(N+1)                           RGE 023
   40 CONTINUE                                                          RGE 024
      RETURN                                                            RGE 025
      END                                                               RGE 026
```

```
§ EOS
Ø1
Ø2
RESERVOIR VOLUME
PAY THICKNESS
FRACTION TRAP FILL
POROSITY
WATER SATURATION
OIL RECOVERY FACTOR
GAS REC. FACTOR
PRESSURE
TEMPERATURE
GAS DEVIATION FACTOR
FORMATION VOLUME FACTOR
OIL V. GAS
GAS V. OIL
RESERVOIR
SOURCE
THERMAL HISTORY
TRAP & SEAL
TIMING
FLUSHING
BLANK CARD
BLACKKNIFE
          3   3Ø.        Ø.       12Ø.     1.       23Ø.     Ø.
          3   .1         Ø.       .25      1.       .5       Ø.
          4   .2         Ø.       .35      .5       .5       1.       .7
     Ø.
          3   .1Ø        Ø.       .15      1.       .23      Ø.
          3   .1Ø        Ø.       .25      1.       .4       Ø.
          1   .2Ø
          1   .75
          1   45ØØ.
          1   69Ø.
          1   .9
          1   1.5
EXISTENCE  RISK
Ø8
 .5          .5          1.         1.         .5        .7        .7        1.
TURTLEDOVE



          3   1ØØ.       Ø.       2ØØ.     1.       3ØØ.     Ø.
          3   .1         Ø.       .25      1.       .5       Ø.
          3   .15        Ø.       .5       1.       1.       Ø.
          4   .1Ø        Ø.       .15      .8       .2Ø      1.       .25
     Ø.
          1   .25
          1   .2
          1   .75
          1   44ØØ.
          1   67Ø.
          1   .9
          1   1.5
EXISTENCE RISK
Ø8
 .3          .7          1.         .8         .8        .7        .5        .3
§ END OF INFORMATION
```

APPENDIX 2

SAMPLE PRINTOUT

APPENDIX 2 - SAMPLE PRINTOUT

```
DOC . CPDMRXVA,  SIML40,,,,,,,,,,1842,,02/03/77,,,,LPCP

** 7000 SCOPE 2.1.3-205 MOD 01/03/77  12.43.54 ** 02/03/77       77061

        SYSTEM BULLETIN 23 ---  1/ 6/76. USE -SYSBULL,LFN. OR -SYSBULL.  3333333

HH.MM.SS CPU SECOND ORIGIN
          18.39.44 DAD.        DIOS  VERSION 10/02/77.
          18.39.44 DAD.        DAD DOCUMENT NAME -      SIML.
          18.39.44 DAD.          389 RECORDS READ.
18.39.46 00000.008 CYB.       -SIML(T10)
18.39.46 00000.011 JOB.       -COMMENT.*********************E.J.RIESZ*****************EXT352*******************
18.39.46 00000.011 JOB.       -LIMIT(0)
18.39.46 00000.012 LOD.       -FTN(SL)
18.39.55 00000.860 USR.            .845 CP SECONDS COMPILATION TIME
18.39.55 00000.861 LOD.       -LGO.
18.39.57 00000.983 CYB.          LD610 - FLS REQUIRED TO LOAD - 0011670 OU.COG
18.39.57 00000.985 CYB.          LD603 - EXECUTION INITIATED OS.EXP
18.39.57 00000.985 USR.         FORTRAN LIBRARY 401              18/12/75
18.40.00 00002.595 USR.            STOP
18.40.00 00002.595 USR.             1.610 CP SECONDS EXECUTION TIME
18.40.00 00002.596 CYB.
18.40.00 00002.597 CYB.          LDMRXVA                  5.725  BLOCKS
18.40.00 00002.597 CYB.          DFILEVA                  0.264  BLOCKS
18.40.00 00002.597 CYB.          OUTPUT                  18.641  BLOCKS
18.40.00 00002.598 CYB.          SC050 - 000045 SC/LC SWAPS
18.40.00 00002.598 CYB.
18.40.00 00002.598 CYB.          JOB                      2.599  SEC                1.083  $
18.40.00 00002.598 CYB.          USR                      1.982  SEC
18.40.00 00002.598 CYB.          URC                      1.740  SS                 0.725  $
18.40.00 00002.599 CYB.          SCM                     43.821  KWSEC              0.365  $
18.40.00 00002.599 CYB.          RMS                      0.018  MWSEC              0.001  $
18.40.00 00002.599 CYB.          I/O                      0.030  MW                 0.050  $
18.40.00 00002.599 CYB.          TOTAL                    5.337  SS                 2.223  $
18.40.00 00002.600 CYB.          PRI                      2.000  K
18.40.00 00002.600 CYB.          RATE                     0.417  $/SEC
18.40.00 00002.600 CYB.          CHARGE                                             2.22   $
```

```
      PROGRAM SIMULAT (INPUT,OUTPUT,PUNCH,TAPE61=OUTPUT)                SIM 001
C
C  SIMULAT CONVERTS STRINGS OF WEIGHTED VALUES FOR FACTORS IN REC. OIL & GAS
C  VOLUME FORMULAE INTO CUM. PROB. DISTRIBUTIONS FOR RESOURCES IN INDIVIDIAL
C  PROSPECTS, EXISTENCE RISKS, AND ADDS DISTRIB'S USING MONTE CARLO SIMULATION
C  TO PRODUCE CUM. PROB. DISTRIB'S OF RESOURCES FOR A GROUP OF PROSPECTS.
C  EXISTENCE RISK FACTORS ARE ASSUMED INDEPENDENT. PROGRAM PROSADD MUST BE USED
C  IN CONJUNCTION WITH SIMULAT TO ADD RESOURCES FROM A GROUP OF PROSPECTS WHEN
C  SOME EXISTENCE RISK FACTORS ARE TAKEN AS DEPENDENT FROM PROSPECT TO PROSPECT.
C
      DIMENSION TITLE(20),F(101),OIL(21,23),GAS(21,23),RISK(23),ORISK(23 SIM 002
     1),GRISK(23),OSRES(101),FOSRES(101),GSRES(101),FGSRES(101),        SIM 003
     2MAXO(23),MINO(23),MAXG(23),MING(23)                               SIM 004
      COMMON LABEL(2,20),CPROB(20,20),XN(500),XCUM(500),R(101)          SIM 005
C
C  IF NPUNCH = 1, CARD DECK OF SUMMED CUM. PROB. DISTRIB. IS PRODUCED.
C
      READ 1,NPUNCH                                                     SIM 006
    1 FORMAT(I2)                                                        SIM 007
C
C  NPLAYS IS NO. OF PROSPECTS TO BE SUMMED.
C
      READ 1,NPLAYS                                                     SIM 008
      READ 2,((LABEL(J,I),J=1,2),I=1,20)                                SIM 009
    2 FORMAT(2A10)                                                      SIM 010
      SMOMN=0. $  SMGMN=0.       $   LIM=2000. $ SXOM=0. $ SXGM=0.      SIM 011
C
C     LIM CONTROLS MAXIMUM NO. OF COMPUTATIONS IN SIMULATION
C
      DO 200 KK=1,NPLAYS                                                SIM 012
      READ 4,(TITLE(I),I=1,8)                                           SIM 013
    4 FORMAT(8A10)                                                      SIM 014
      PRINT 5,(TITLE(I),I=1,8)                                          SIM 015
    5 FORMAT(30X,8A10)                                                  SIM 016
      CALL CUMPROB(IND)                                                 SIM 017
C
C MAX. & MIN. RESOURCE VALUES ARE COMPUTED SEPARATELY
C
      MING(KK)=CPROB(1,1)*CPROB(2,1)*CPROB(3,1)*CPROB(4,1)*(1-CPROB(5,20 SIM 018
     1))*CPROB(7,1)*35.3*(14.73+CPROB(8,1))/CPROB(9,20)/CPROB(10,20)    SIM 019
      MAXG(KK)=CPROB(1,20)*CPROB(2,20)*CPROB(3,20)*CPROB(4,20)*(1-CPROB( SIM 020
     15,1 ))*CPROB(7,20)*520.*(14.73+CPROB(8,20))/14.73/CPROB(9,1 )/CPRO SIM 021
     2B(10,1)                                                           SIM 022
      MAXO(KK)=CPROB(1,20)*CPROB(2,20)*CPROB(3,20)*CPROB(4,20)*(1-CPROB( SIM 023
     15,1 ))*CPROB(6,20)/CPROB(11,1 )                                   SIM 024
      MINO(KK)=CPROB(1,1)*CPROB(2,1)*CPROB(3,1)*CPROB(4,1)*(1-CPROB(5,20 SIM 025
     1))*CPROB(6,1)/CPROB(11,20)                                        SIM 026
      OIL(1,KK)=MINO(KK) $ OIL(21,KK)=MAXO(KK)                          SIM 027
      GAS(1,KK)=MING(KK) $ GAS(21,KK)=MAXG(KK)                          SIM 028
      MAXSO=MAXSO+MAXO(KK) $ MINSO=MINSO+MINO(KK)                       SIM 029
      MAXSG=MAXSG+MAXG(KK) $ MINSG=MINSG+MING(KK)                       SIM 030
      DO 10 I=1,500                                                     SIM 031
   10 XN(I)=0.                                                          SIM 032
      GM=0.   $   OILMN=0.  $  GASMN=0.    $  XOM=0. $  XGM=0.          SIM 033
C
C SCALING IS USED TO GIVE A RANGE OF 500 VALUES WHICH SHOULD COVER MOST VALUES
C  OUTPUT FROM SIMULATION.
```

```
      C
            SCALE1=CPROB(1,18)*CPROB(2,18)*CPROB(3,18)*CPROB(4,18)*(1-CPROB(5,  SIM 034
           118))*CPROB(6,18)/CPROB(11,18)                                       SIM 035
            IF(SCALE1.EQ.0.)GO TO 17                                            SIM 036
      C
      C  MONTE CARLO SIMULATION PREFORMED
      C
            DO 14 I=1,LIM                                                       SIM 037
            DO 12 J=1,11                                                        SIM 038
            II=RANF(D)*20+1                                                     SIM 039
            IF(II.GT.20) II=20                                                  SIM 040
         12 F(J)=CPROB(J,II)                                                    SIM 041
            IQ=F(1)*F(2)*F(3)*F(4)*(1-F(5))*F(6)/F(11)/SCALE1*200               SIM 042
            QM=QM+IQ                                                            SIM 043
            IF(IQ.LT.1) IQ=1                                                    SIM 044
            IF(IQ.GT.500) 14,13                                                 SIM 045
         13 XN(IQ)=XN(IQ)+1                                                     SIM 046
         14 XOM=QM*SCALE1/200./LIM     $  FXOM=XOM*6.2898                       SIM 047
            CALL RANGE(LIM,20)                                                  SIM 048
            DO 15 I=1,19                                                        SIM 049
         15 OIL(I+1,KK)=R(I)*SCALE1*.5                                          SIM 050
            QM=0.                                                               SIM 051
            DO  16 I=1,500                                                      SIM 052
         16 XN(I)=0.                                                            SIM 053
         17 SCALE2=CPROB(1,18)*CPROB(2,18)*CPROB(3,18)*CPROB(4,18)*(1-CPROB(5,  SIM 054
           118))*CPROB(7,18)*520.*(14.73+CPROB(8,18))/14.73/CPROB(9,18)/        SIM 055
           2CPROB(10,18)                                                        SIM 056
            IF(SCALE2.EQ.0.) 23,18                                              SIM 057
         18 DO 21 I=1,LIM                                                       SIM 058
            DO 19 J=1,10                                                        SIM 059
            II=RANF(D)*20+1                                                     SIM 060
            IF(II.GT.20) II=20                                                  SIM 061
         19 F(J)=CPROB(J,II)                                                    SIM 062
            IQ=F(1)*F(2)*F(3)*F(4)*(1-F(5))*F(7)*520.*(14.73+F(8))/14.73/F(9)/  SIM 063
           1F(10)/SCALE2*200                                                    SIM 064
            QM=QM+IQ                                                            SIM 065
            IF(IQ.LT.1) IQ=1                                                    SIM 066
            IF(IQ.GT.500) 21,20                                                 SIM 067
         20 XN(IQ)=XN(IQ)+1                                                     SIM 068
         21 XGM=QM*SCALE2/200./LIM     $  FXGM=XGM*.035315                      SIM 069
            CALL RANGE(LIM,20)                                                  SIM 070
            DO 22 I=1,19                                                        SIM 071
         22 GAS(I+1,KK)=R(I)*SCALE2*.5                                          SIM 072
         23 PRINT 24                                                            SIM 073
         24 FORMAT(10X,29HUNRISKED MEAN RESOURCE VALUES)                        SIM 074
            PRINT 25, XOM,FXOM,XGM,FXGM                                         SIM 075
         25 FORMAT(10X,45HMEAN REC.OIL RES.-MILL.CU.METRES.-MILLION BBL,/,      SIM 076
           130X,F10.3,5X,F10.3,/,                                               SIM 077
           210X,47HMEAN REC.GAS RES.-MILL.CU.METRES.  -BILLION  CF,/,           SIM 078
           330X,F10.3,5X,F10.3)                                                 SIM 079
            DO 26  I=1,21                                                       SIM 080
         26 F(I)=1.05-I/20.                                                     SIM 081
            PRINT 27 ,(F(I  ),OIL(I,KK),GAS(I,KK),I=1,21)                       SIM 082
         27 FORMAT (1X,9HCUM.PROB., 2X,17HUNRISKED RESOURCE,/,12X,3HOIL,7X,     SIM 083
           13HGAS.          20(/,3F10.3,20X))                                   SIM 084
      C
      C  THE EXISTENCE RISK FACTORS FOR A PROSPECT ARE INPUT AND COMPOUNDED
```

```
      C
            READ 4,(TITLE(I),I=9,16)                                  SIM 085
            READ 1,NRISK                                              SIM 086
            READ 32 ,(RISK(I),I=1,NRISK)                              SIM 087
         32 FORMAT(8F10.3)                                            SIM 088
            ORISK(KK)=RISK(1)  $  GRISK(KK)=RISK(2)                   SIM 089
            IF(NRISK.LT.3) GO TO 34                                   SIM 090
            DO 33  I=3,NRISK                                          SIM 091
            ORISK(KK)=ORISK(KK)*RISK(I)                               SIM 092
         33 GRISK(KK)=GRISK(KK)*RISK(I)                               SIM 093
         34 PRINT 5,(TITLE(I),I=9,16)                                 SIM 094
            PRINT 35,((LABEL(J,I+11),J=1,2),RISK(I),I=1,NRISK)        SIM 095
         35 FORMAT(5X,2A10,F10.3)                                     SIM 096
            OILMN=XOM*ORISK(KK)  $  GASMN=XGM*GRISK(KK)               SIM 097
            PRINT 36 ,ORISK(KK),GRISK(KK)                             SIM 098
         36 FORMAT(10X,21HOIL EXISTENCE RISK IS,F10.4,/,              SIM 099
           1       10X,21HGAS EXISTENCE RISK IS,F10.4)                SIM 100
            PRINT  37                                                 SIM 101
         37 FORMAT(10X,27HRISKED MEAN RESOURCE VALUES)                SIM 102
            FOILMN=OILMN*6.2898  $  FGASMN=GASMN*.035315              SIM 103
            PRINT 25,OILMN,FOILMN,GASMN,FGASMN                        SIM 104
            SMOMN=SMOMN+OILMN $ SMGMN=SMGMN+GASMN                     SIM 105
            SXOM=SXOM+XOM  $ SXGM=SXGM+XGM                            SIM 106
            DO 45 I=1,20                                              SIM 107
         45 OIL(I,KK)=(OIL(I,KK)+OIL(I+1,KK))*.5                      SIM 108
            DO 55 I=1,20                                              SIM 109
         55 GAS(I,KK)=(GAS(I,KK)+GAS(I+1,KK))*.5                      SIM 110
        200 CONTINUE                                                  SIM 111
      C
      C CARDS WITH A IN COL. MM ARE OPTIONAL AND ARE USED IF LINE PRINTER PLOTS REQD.
            CALL QUIPLOT(F,GAS,21,NPLAYS,11H*CUM.PROB.*,23H*GAS RES.-MILL. CU. SMLA 10
           1 M.*)                                                     SMLA 11
            CALL QUIPLOT(F,OIL,21,NPLAYS,11H*CUM.PROB.*,23H*OIL RES.-MILL. CU. SMLA 20
           1 M.*)                                                     SMLA 21
      C
            PRINT 205                                                 SIM 112
        205 FORMAT(10X,33HTOTAL RISKED MEAN RESOURCE VALUES)          SIM 113
            FSMOMN=SMOMN*6.2898 $FSMGMN=SMGMN*.035315                 SIM 114
            PRINT 25,SMOMN,FSMOMN,SMGMN,FSMGMN                        SIM 115
      C
      C  RESOURCES FROM INDIVIDUAL PROSPECTS ARE SUMMED
      C
            DO 210 I=1,500                                            SIM 116
        210  XN(I)=0                                                  SIM 117
      C
      C  MONTE CARLO SIMULATION PREFORMED
      C
            DO 230 I=1,LIM                                            SIM 118
            OILSUM=0.      $    SORISK=0.                             SIM 119
            DO 220 J=1,NPLAYS                                         SIM 120
            SORISK=SORISK+ORISK(J)                                    SIM 121
            CHANCE=RANF(D)                                            SIM 122
            IF(CHANCE.GT.ORISK(J)) GO TO 220                          SIM 123
             N= RANF(D)*20 .+1                                        SIM 124
            IF(N.GT.20 ) N=20                                         SIM 125
            OILSUM=OILSUM+OIL(N,J)                                    SIM 126
        220 CONTINUE                                                  SIM 127
```

```
      IF(SORISK.LT.0.01) GO TO 236                                      SIM 128
      IJ=OILSUM*100./SXOM +1                                            SIM 129
      IF(IJ.GT.500 ) 230,225                                            SIM 130
  225 XN(IJ)=XN(IJ)+1                                                   SIM 131
  230 CONTINUE                                                          SIM 132
      CALL RANGE(LIM,100)                                               SIM 133
      OSRES(1)=MINSO $ OSRES(101)=MAXSO                                 SIM 134
      DO 235 I=2,100                                                    SIM 135
      OSRES(I)=R(I-1)*SXOM                                              SIM 136
  235 FOSRES(I)=OSRES(I)*6.2898                                         SIM 137
  236 DO 240 I=1,500                                                    SIM 138
  240 XN(I)=0.                                                          SIM 139
      DO 260 I=1,LIM                                                    SIM 140
      GASSUM=0.      $  SGRISK=0.                                       SIM 141
      DO 250 J=1,NPLAYS                                                 SIM 142
      SGRISK=SGRISK+GRISK(J)                                            SIM 143
      CHANCE=RANF(D)                                                    SIM 144
      IF(CHANCE.GT.GRISK(J)) GO TO 250                                  SIM 145
       N= RANF(D)*20 .+1                                                SIM 146
      IF(N.GT.20 ) N=20                                                 SIM 147
      GASSUM=GASSUM+GAS(N,J)                                            SIM 148
  250 CONTINUE                                                          SIM 149
      IF(SGRISK.LT.0.01) GO TO 268                                      SIM 150
      IJ=GASSUM*100./SXGM  +1                                           SIM 151
      IF(IJ.GT.500) 260,255                                             SIM 152
  255 XN(IJ)=XN(IJ)+1                                                   SIM 153
  260 CONTINUE                                                          SIM 154
      CALL RANGE(LIM,100)                                               SIM 155
      GSRES(1)=MINSG $ GSRES(101)=MAXSG                                 SIM 156
      DO 265 I=2,100                                                    SIM 157
      GSRES(I)=R(I-1)*SXGM                                              SIM 158
  265 FGSRES(I)= GSRES(I)*.035315                                       SIM 159
  268 PRINT 270                                                         SIM 160
  270 FORMAT(10X,16HSUMMED RESOURCES)                                   SIM 161
      PRINT 275                                                         SIM 162
  275 FORMAT(10X,10HCUM. PROB.,2X,10HRISKED OIL,2X,10HRISKED GAS,22X,   SIM 163
     110HCUM. PROB.,2X,10HRISKED OIL,2X,10HRISKED GAS,2X,14HMILL.CU.METR SIM 164
     1ES)                                                               SIM 165
      DO280 I=1,101                                                     SIM 166
  280 F(I)=1.-(I-1)/100.                                                SIM 167
      PRINT 285,(F(I),OSRES(I),GSRES(I),F(I+50),OSRES(I+50),GSRES(I+50), SIM 168
     1I=1,50)                                                           SIM 169
  285 FORMAT(10X,3F12.2,20X,3F12.2)                                     SIM 170
      PRINT 290                                                         SIM 171
  290 FORMAT(1H1)                                                       SIM 172
C
C CARDS WITH A IN COL. 77 ARE OPTIONAL AND ARE USED IF LINE PRINTER PLOTS REQD.
      CALL QUIPLOT(OSRES,F, 99,1,23H*OIL.RES.-MILL. CU. M.*,11H*CUM.PROB SMLA30
     1.*)                                                               SMLA 31
      CALL QUIPLOT(GSRES,F, 99,1,23H*GAS.RES.-MILL. CU. M.*,11H*CUM.PROB SMLA 40
     1.*)                                                               SMLA 41
      CALL QUIPLOT(FOSRES,F,99,1,23H*OIL.RES.-MILL. B.B.L.*,11H*CUM.PROB SMLA 50
     1.*)                                                               SMLA 51
      CALL QUIPLOT(FGSRES,F,99,1,17H*GAS.RES.-B.C.F.*,11H*CUM.PROB.*)   SMLA 60
C
      IF(NPUNCH.EQ.1) 294,999                                           SIM 173
  294 PUNCH 295,(OSRES(I),GSRES(I),I=1,100)                             SIM 174
```

```
      295 FORMAT(10G8.2)                                         SIM 175
230   999 CONTINUE                                               SIM 176
          STOP                                                   SIM 177
          END                                                    SIM 178
```

```
            SUBROUTINE CUMPROB(IND)                                                CMP 001
      C
      C THIS SUBROUTINE READS IN STRINGS OF PROB.WEIGHTED VARIABLES AND OUTPUTS A
      C 20 VALUE CUM.PROB.DISTRIBUTION FOR EACH STRING.
      C
            DIMENSION D1(20,20),D2(20,20),A(20),B(20),Z(20 ,200),APROB(21)        CMP 002
            COMMON LABEL(2,20),CPROB(20,20),XN(500),XCUM(500),R(101)              CMP 003
            IND=0                                                                  CMP 004
            DO100 I=1,11                                                           CMP 005
            READ10,L,(D1(I,J),D2(I,J),J=1,L)                                       CMP 006
         10 FORMAT(I10,7F10.2,/,(8F10.2))                                          CMP 007
            PRINT 11,(LABEL(J,I),J=1,2),(D1(I,J),J=1,L)                            CMP 008
         11 FORMAT (5X,2A10,(10F10.3))                                             CMP 009
      C
      C  IF FACTOR SINGLE VALUED ALGORITHM IS BYPASSED
      C
            IF(L.EQ.1) 15,17                                                       CMP 010
         15 DO 16 M=1,20                                                           CMP 011
         16 CPROB(I,M)=D1(I,1)                                                     CMP 012
            GO TO 100                                                              CMP 013
         17 IND=1                                                                  CMP 014
            PRINT12,(D2(I,J),J=1,L)                                                CMP 015
         12 FORMAT(19X,6HWEIGHT,10F10.3)                                           CMP 016
      C
      C NORMALIZE THE FREQUENCY DISTRIBUTION
      C
            AREA=0.        $  L1=L-1                                               CMP 017
            DO 20 J=1,L1                                                           CMP 018
         20 AREA=AREA+(D1(I,J+1)-D1(I,J))*(D2(I,J+1)+D2(I,J))/2                    CMP 019
            DO 25 J=1,L                                                            CMP 020
         25 D2(I,J)=D2(I,J)/AREA                                                   CMP 021
      C
      C  FREQUENCY DISTRIBUTION OF 200  VALUES IS NOW GENERATED
      C
            DO 30 J=1,L1                                                           CMP 022
            A(J)=(D2(I,J)-D2(I,J+1))/(D1(I,J)-D1(I,J+1))                           CMP 023
         30 B(J)=D2(I,J)-A(J)*D1(I,J)                                              CMP 024
            DO 35 J=1,200                                                          CMP 025
         35 Z(I,J)=D1(I,1)+(J-1)*(D1(I,L)-D1(I,1))/199.                            CMP 026
      C
      C  DISTRIBUTION IS SPLIT INTO 20 PORTIONS OF EQUAL AREA
      C
            AREA=0  $  CPROB(I,1) =D1(I,1)    $M=1       $ J1=1                    CMP 027
            DO 60J=2,199                                                           CMP 028
         40 IF(Z(I,J).GE.D1(I,J1+1)) 45,50                                         CMP 029
         45 J1=J1+1          $  GO TO 40                                           CMP 030
         50 AREA=AREA+A(J1)*(Z(I,J+1)+Z(I,J))*(Z(I,J+1)-Z(I,J))/2.                 CMP 031
           1+B(J1)*(Z(I,J+1)-Z(I,J))                                               CMP 032
            IF(AREA.GE.M/20.) 55,60                                                CMP 033
         55 M=M+1           $  CPROB(I,M)= Z(I,J)                                  CMP 034
         60 CONTINUE                                                               CMP 035
         90 CONTINUE                                                               CMP 036
        100 CONTINUE                                                               CMP 037
            PRINT 105                                                              CMP 038
        105 FORMAT(6X,10HCUM. PROB.,20X,3H15%,17X,3H50%,17X,3H85%)                 CMP 039
            PRINT 110,((LABEL(J,I),J=1,2),CPROB(I,4),CPROB(I,11),CPROB(I,18),I CMP 040
           1=1,11)                                                                 CMP 041
```

```
  110 FORMAT(1X,2A10,10X,F10.3,10X,F10.3,10X,F10.3)              CMP 042
      DO 120 I=1,11                                              CMP 043
      APROB(1)=D1(I,1)                                           CMP 044
      DO 112 J=2,21                                              CMP 045
  112 APROB(J)=CPROB(I,J-1)                                      CMP 046
      DO 120 J=1,20                                              CMP 047
  120 CPROB(I,J)=(APROB(J)+APROB(J+1))*.5                        CMP 048
      RETURN                                                     CMP 049
      END                                                        CMP 050
```

```
      SUBROUTINE RANGE(LIM,NN)                                          RGE 001
C
C  THIS SUBROUTINE CONSTRUCTS A CUMULATIVE PROB DIST. OF NN POINTS
C  FROM A FREQUENCY DISTRIBUTION OF 500 POINTS
C
      COMMON LABEL(2,20),CPROB(20,20),XN(500),XCUM(500),R(101)          RGE 002
      XCUM(1)=XN(1)                                                     RGE 003
      DO  5 I=2,500                                                     RGE 004
    5 XCUM(I)=XCUM(I-1)+XN(I)                                           RGE 005
      DO 6 I=1,NN                                                       RGE 006
    6 R(I)=0.                                                           RGE 007
      DO 10 I=1,500                                                     RGE 008
      M=XCUM(I)*NN/LIM+1                                                RGE 009
   10 R(M)=I/100.-NN*.00001                                             RGE 010
       R(NN+1)=5.                                                       RGE 011
      DO 15 I=1,NN                                                      RGE 012
      IF(R(I).EQ.0.)15,20                                               RGE 013
   15 CONTINUE                                                          RGE 014
   20 K=I+1                                                             RGE 015
      DO 40 I=K,NN                                                      RGE 016
      IF(R(I).EQ.0.)  25,40                                             RGE 017
   25 N=1                                                               RGE 018
   27 IF(R(I+N).EQ.0.) 30,32                                            RGE 019
   30 N=N+1                                                             RGE 020
      GO TO 27                                                          RGE 021
   32 DO 35 J=1,N                                                       RGE 022
   35 R(I+J-1)=R(I-1)+(R(I+N)-R(I-1))*J/(N+1)                           RGE 023
   40 CONTINUE                                                          RGE 024
      RETURN                                                            RGE 025
      END                                                               RGE 026
```

BLACKKNIFE

RESERVOIR AREA	30.000	120.000	230.000	
WEIGHT	0.000	1.000	0.000	
PAY THICKNESS	.100	.250	.500	
WEIGHT	0.000	1.000	0.000	
FRACTION TRAP FILL	.200	.350	.500	.700
WEIGHT	0.000	.500	1.000	0.000
POROSITY	.100	.150	.230	
WEIGHT	0.000	1.000	0.000	
WATER SATURATION	.100	.250	.400	
WEIGHT	0.000	1.000	0.000	
OIL RECOVERY FACTOR	.200			
GAS REC. FACTOR	.750			
PRESSURE	4500.000			
TEMPERATURE	690.000			
GAS DEVIATION FACTOR	.900			
FORMATION VOLUME FAC	1.500			

CUM. PROB.	15%	50%	85%
RESERVOIR AREA	81.256	124.472	171.709
PAY THICKNESS	.194	.275	.377
FRACTION TRAP FILL	.348	.474	.577
POROSITY	.131	.157	.190
WATER SATURATION	.181	.249	.317
OIL RECOVERY FACTOR	.200	.200	.200
GAS REC. FACTOR	.750	.750	.750
PRESSURE	4500.000	4500.000	4500.000
TEMPERATURE	690.000	690.000	690.000
GAS DEVIATION FACTOR	.900	.900	.900
FORMATION VOLUME FAC	1.500	1.500	1.500

UNRISKED MEAN RESOURCE VALUES

MEAN REC.OIL RES.-MILL.CU.METRES.-MILLION BBL

.213 1.342

MEAN REC.GAS RES.-MILL.CU.METRES. -BILLION CF

303.023 10.701

CUM.PROB.	UNRISKED RESOURCE OIL	GAS
1.000	0.000	7.000
.950	.045	64.927
.900	.066	90.932
.850	.084	112.603
.800	.096	138.608
.750	.114	155.945
.700	.129	173.282
.650	.141	194.953
.600	.156	212.290
.550	.171	238.296
.500	.186	264.301
.450	.201	285.972
.400	.219	307.643
.350	.234	337.983
.300	.255	368.322
.250	.282	402.996
.200	.306	437.670
.150	.342	489.681
.100	.390	559.028
.050	.459	667.384
0.000	1.000	1686.000

	EXISTENCE RISK
OIL V. GAS	.500
GAS V. OIL	.500
SOURCE	1.000
THERMAL HISTORY	1.000
RESERVOIR	.500
TRAP & SEAL	.700
TIMING	.700
FLUSHING	1.000

OIL EXISTENCE RISK IS .1225

GAS EXISTENCE RISK IS .1225

RISKED MEAN RESOURCE VALUES

MEAN REC.OIL RES.-MILL.CU.METRES.-MILLION BBL

.026 .164

MEAN REC.GAS RES.-MILL.CU.METRES. -BILLION CF

37.120 1.311

	TURTLEDOVE			
RESERVOIR AREA	100.000	200.000	300.000	
WEIGHT	0.000	1.000	0.000	
PAY THICKNESS	.100	.250	.500	
WEIGHT	0.000	1.000	0.000	
FRACTION TRAP FILL	.150	.500	1.000	
WEIGHT	0.000	1.000	0.000	
POROSITY	.100	.150	.200	.250
WEIGHT	0.000	.800	1.000	0.000
WATER SATURATION	.250			
OIL RECOVERY FACTOR	.200			
GAS REC. FACTOR	.750			
PRESSURE	4400.000			
TEMPERATURE	670.000			
GAS DEVIATION FACTOR	.900			
FORMATION VOLUME FAC	1.500			

CUM. PROB.	15%	50%	85%
RESERVOIR AREA	154.271	199.497	244.724
PAY THICKNESS	.194	.275	.377
FRACTION TRAP FILL	.359	.539	.744
POROSITY	.141	.178	.213
WATER SATURATION	.250	.250	.250
OIL RECOVERY FACTOR	.200	.200	.200
GAS REC. FACTOR	.750	.750	.750
PRESSURE	4400.000	4400.000	4400.000
TEMPERATURE	670.000	670.000	670.000
GAS DEVIATION FACTOR	.900	.900	.900
FORMATION VOLUME FAC	1.500	1.500	1.500

UNRISKED MEAN RESOURCE VALUES

MEAN REC.OIL RES.-MILL.CU.METRES.-MILLION BBL

.431 2.708

MEAN REC.GAS RES.-MILL.CU.METRES. -BILLION CF

642.974 22.707

CUM.PROB.	UNRISKED RESOURCE OIL	GAS
1.000	0.000	21.000
.950	.108	166.083
.900	.141	214.988
.850	.175	273.675
.800	.202	312.799
.750	.229	351.923
.700	.262	400.829
.650	.289	439.953
.600	.323	479.077
.550	.350	518.202
.500	.383	567.107
.450	.410	616.012
.400	.444	664.918
.350	.471	713.823
.300	.504	772.510
.250	.558	831.196
.200	.619	909.445
.150	.679	997.474
.100	.774	1134.410
.050	.935	1339.812
0.000	1.000	2887.000

	EXISTENCE RISK
OIL V. GAS	.300
GAS V. OIL	.700
SOURCE	1.000
THERMAL HISTORY	.800
RESERVOIR	.800
TRAP & SEAL	.700
TIMING	.500
FLUSHING	.300

OIL EXISTENCE RISK IS .0202

GAS EXISTENCE RISK IS .0470

RISKED MEAN RESOURCE VALUES

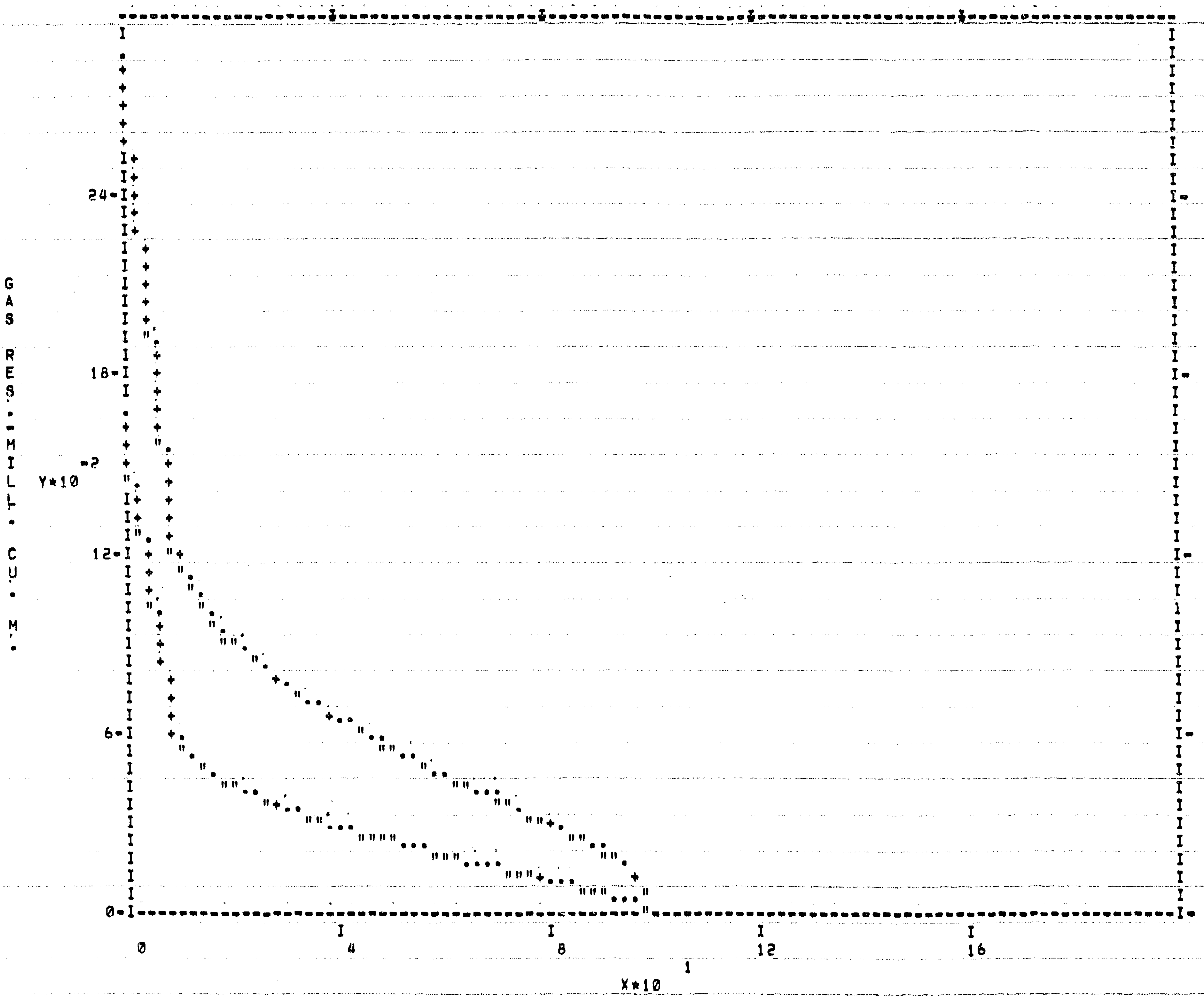
MEAN REC.OIL RES.-MILL.CU.METRES.-MILLION BBL

.009 .055

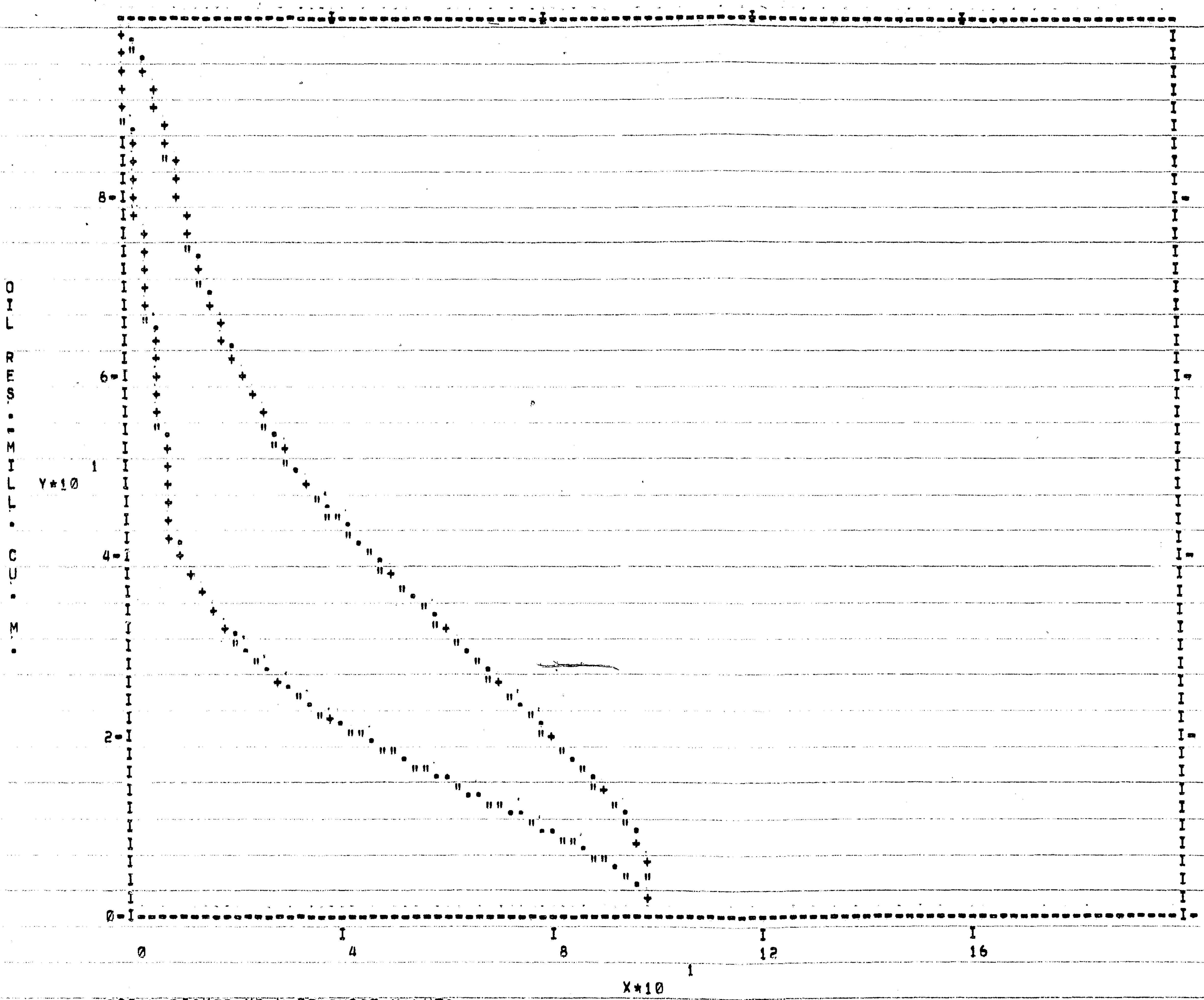
MEAN REC.GAS RES.-MILL.CU.METRES. -BILLION CF

30.245 1.068

CUM.PROB.



CUM.PROB.



TOTAL RISKED MEAN RESOURCE VALUES
MEAN REC.OIL RES.-MILL.CU.METRES.-MILLION BBL
.035 .219
MEAN REC.GAS RES.-MILL.CU.METRES. -BILLION CF

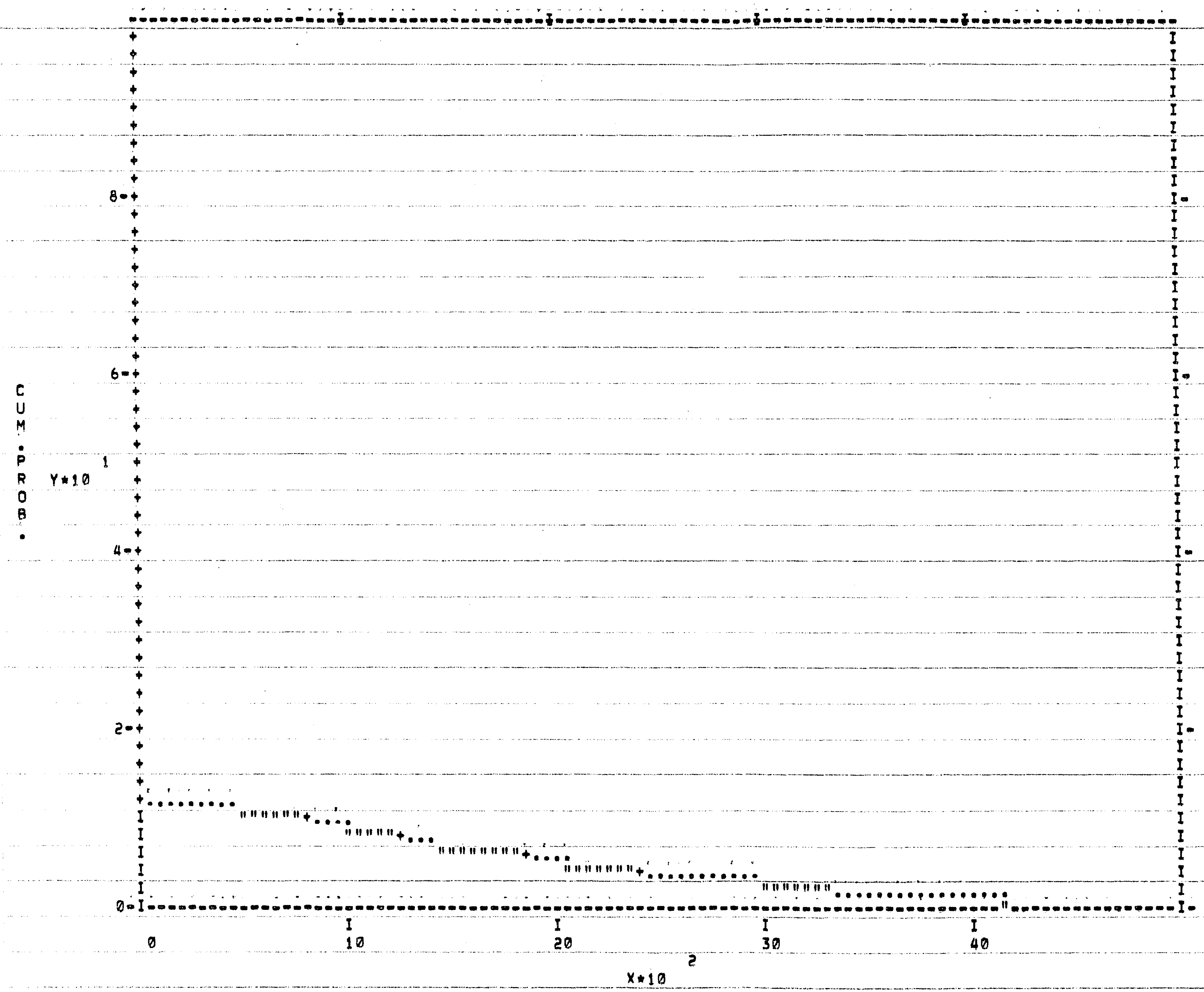
67.366 2.379

SUMMED RESOURCES

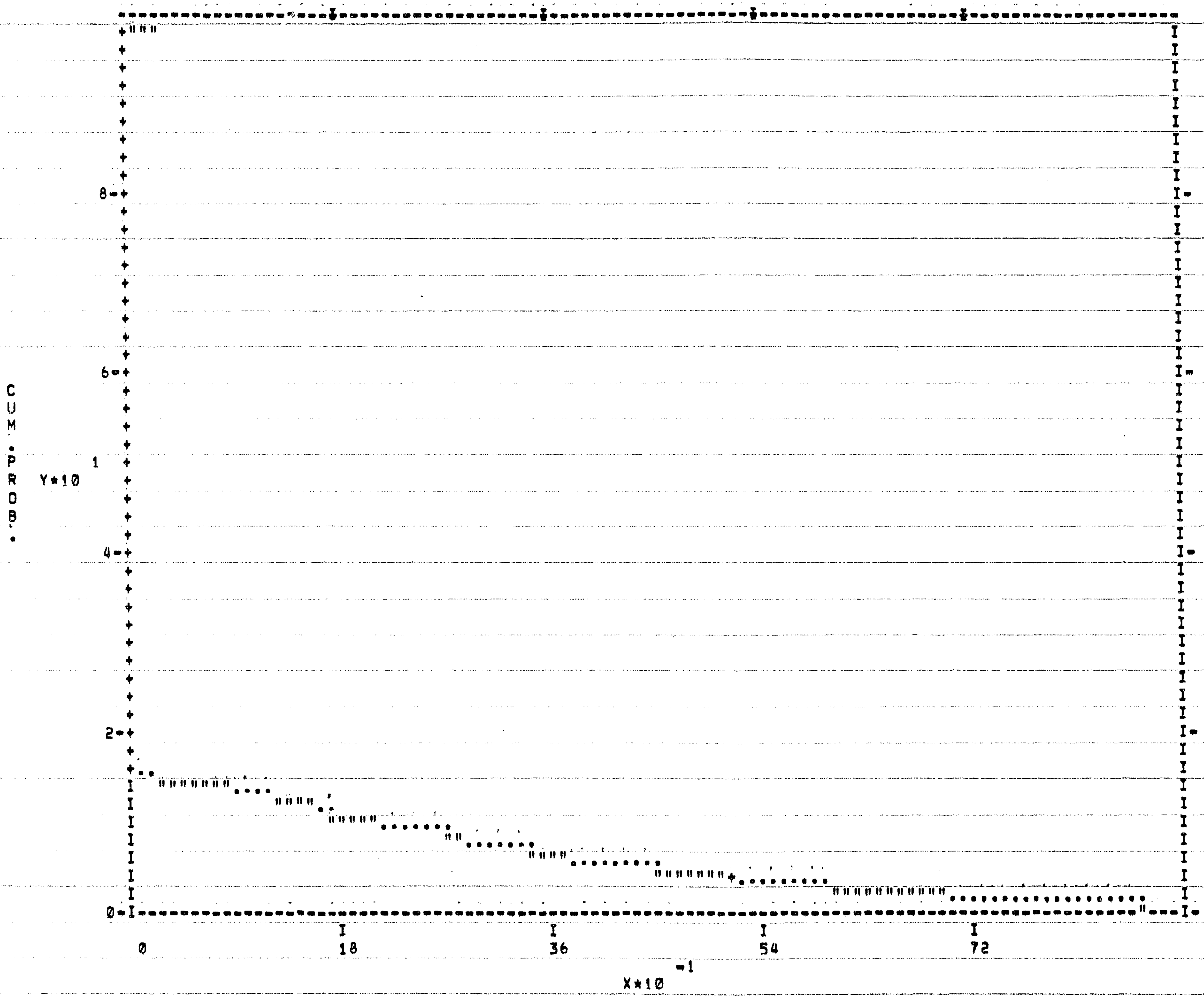
CUM. PROB.	RISKED OIL	RISKED GAS
1.00	0.00	28.00
.99	0.00	0.00
.98	0.00	0.00
.97	0.00	0.00
.96	0.00	0.00
.95	0.00	0.00
.94	0.00	0.00
.93	0.00	0.00
.92	0.00	0.00
.91	0.00	0.00
.90	0.00	0.00
.89	0.00	0.00
.88	0.00	0.00
.87	0.00	0.00
.86	0.00	0.00
.85	0.00	0.00
.84	0.00	0.00
.83	0.00	0.00
.82	0.00	0.00
.81	0.00	0.00
.80	0.00	0.00
.79	0.00	0.00
.78	0.00	0.00
.77	0.00	0.00
.76	0.00	0.00
.75	0.00	0.00
.74	0.00	0.00
.73	0.00	0.00
.72	0.00	0.00
.71	0.00	0.00
.70	0.00	0.00
.69	0.00	0.00
.68	0.00	0.00
.67	0.00	0.00
.66	0.00	0.00
.65	0.00	0.00
.64	0.00	0.00
.63	0.00	0.00
.62	0.00	0.00
.61	0.00	0.00
.60	0.00	0.00
.59	0.00	0.00
.58	0.00	0.00
.57	0.00	0.00
.56	0.00	0.00
.55	0.00	0.00
.54	0.00	0.00
.53	0.00	0.00
.52	0.00	0.00
.51	0.00	0.00

CUM. PROB.	RISKED OIL	RISKED GAS MILL.CU.METRES
.50	0.00	0.00
.49	0.00	0.00
.48	0.00	0.00
.47	0.00	0.00
.46	0.00	0.00
.45	0.00	0.00
.44	0.00	0.00
.43	0.00	0.00
.42	0.00	0.00
.41	0.00	0.00
.40	0.00	0.00
.39	0.00	0.00
.38	0.00	0.00
.37	0.00	0.00
.36	0.00	0.00
.35	0.00	0.00
.34	0.00	0.00
.33	0.00	0.00
.32	0.00	0.00
.31	0.00	0.00
.30	0.00	0.00
.29	0.00	0.00
.28	0.00	0.00
.27	0.00	0.00
.26	0.00	0.00
.25	0.00	0.00
.24	0.00	0.00
.23	0.00	0.00
.22	0.00	0.00
.21	0.00	0.00
.20	0.00	0.00
.19	0.00	0.00
.18	0.00	0.00
.17	0.00	0.00
.16	0.00	27.43
.15	0.00	93.65
.14	0.00	122.03
.13	0.00	159.87
.12	.05	178.79
.11	.08	216.63
.10	.10	273.39
.09	.13	292.31
.08	.15	349.07
.07	.19	377.45
.06	.21	453.13
.05	.24	519.35
.04	.30	604.49
.03	.33	699.09
.02	.42	869.37
.01	.64	1172.09

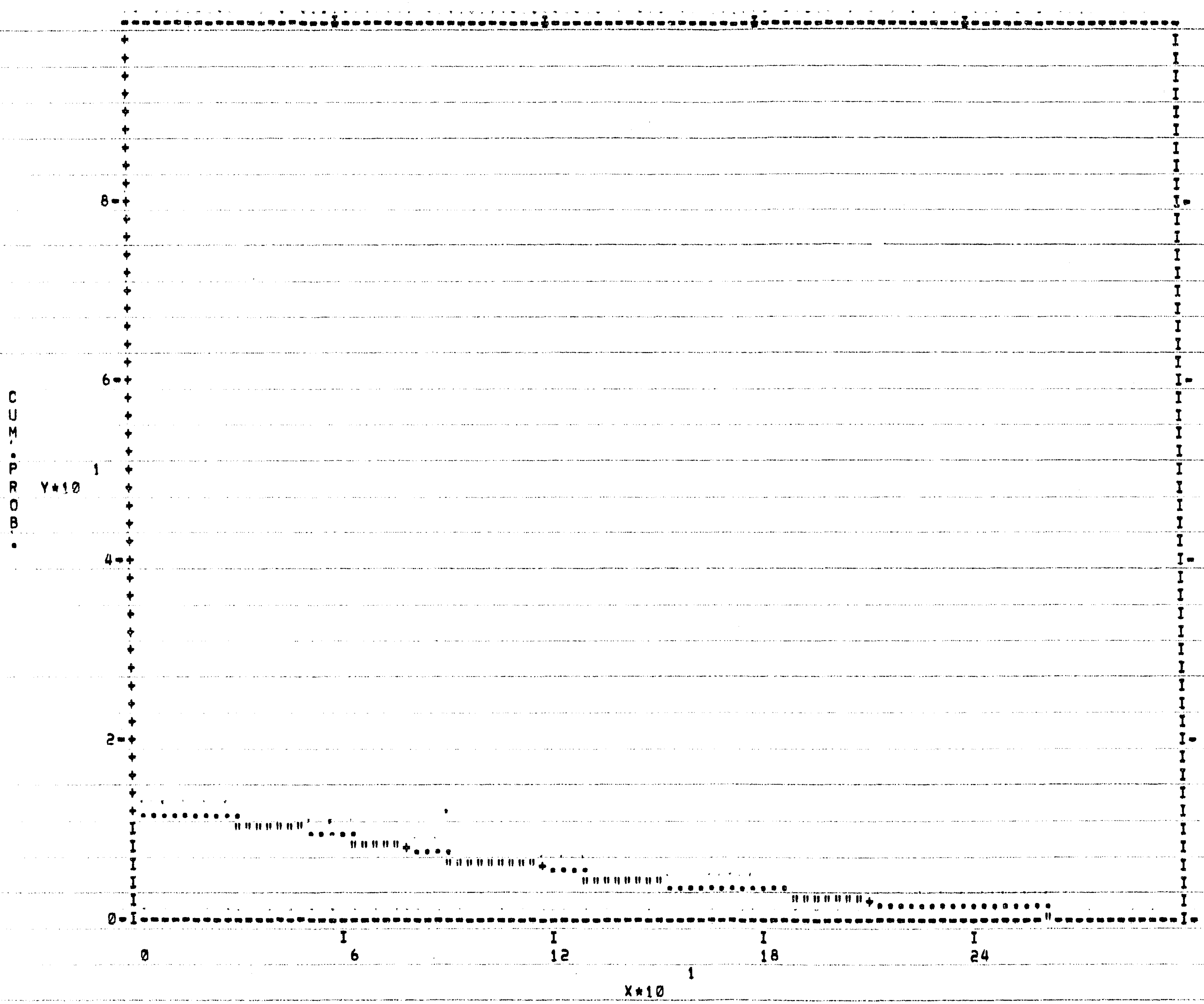
OIL.RES.-MILL. CU. M.

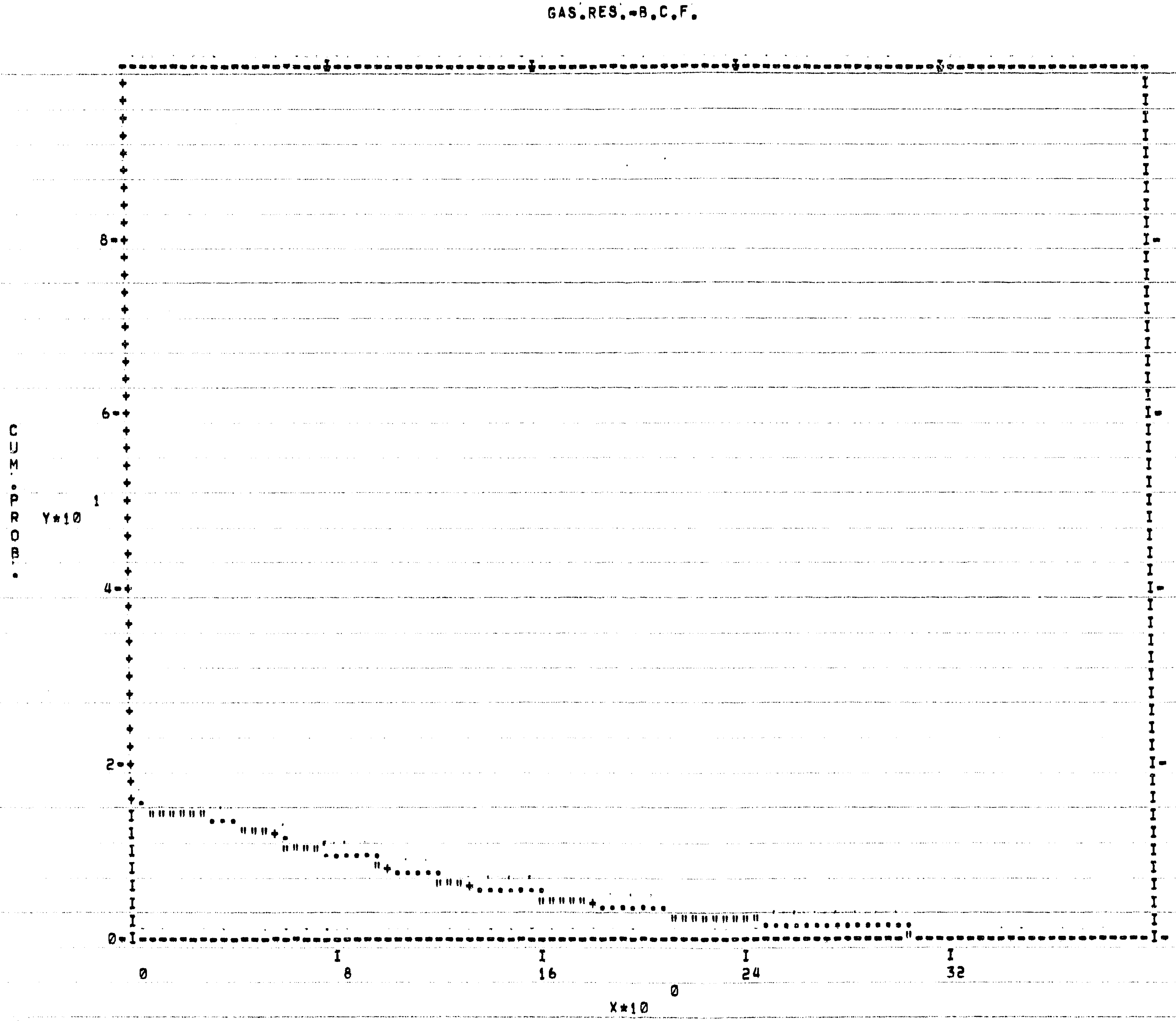


GAS.RES.-MILL. CU. M.



OIL.RES.-MILL. B.B.L.




GAS.RES.-B.C.F.
CUM.PROB.
Y*10
1
8
6
4
2
0
8
16
24
32
0
X*10
0