BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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RECORD 1986/11

FORC2: AN IMPROVED COMPUTER PROGRAM FOR ESTIMATING FUTURE PRODUCTION FROM UNDISCOVERED OIL FIELDS

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ALAN L. HINDE

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SUMMARY

Program FORC2 is an improved version of program FORCT (Hinde, 1982) which was written to estimate annual crude oil production from undiscovered oil resources in a region. FORC2 uses a random sampling method to calculate histograms of annual crude oil production for a period of 20 years, a histogram of the amount of crude oil discovered during part of the period of the estimate (usually 10 years), and a histogram of the amount of crude oil in fields that are brought into production during the same part of the period. It allows the number and sizes of the undiscovered fields, the lead time from discovery to production, and the number of fields discovered per year, to be input as distributions. If required, the number of discoveries per year may be calculated probabilistically using a binomial distribution.

The order of discovery of fields is assumed to be governed by the rule that the probability of discovery of each field is proportional to the square root of the field size. Two production profiles are included in the program, one for onshore fields and one for offshore fields.

The mean, standard deviation, and 20'th and 80'th percentiles, for each of the 22 histograms, are printed. The histograms may also be written into a disk file which can be used either by program LAMPO (Hinde, 1985a), which prints the output, or by program FORAD (Hinde, 1985b), which is used to add probabilistic production profiles.

INTRODUCTION

Program FORCT (Hinde, 1982) was written to calculate amounts of annual oil production from undiscovered fields and to add the amounts together. It required the user to stipulate a discrete size for the undiscovered oil resource in each area. Given the number of fields and an estimate of the size of the largest and smallest field, the program was used to break the undiscovered oil resource up into individual fields, assuming the field sizes are distributed according to an inverse power function. Future rates of discovery and estimates of the lead time between discovery and production could then be input and used in combination with an average field production profile to produce the estimate of future rates of oil production.

Program FORC2 was written to provide probabilistic estimates of annual crude oil production and the amounts discovered and brought into production during a specified period using stochastic distributions for the numbers of fields and the sizes of fields in each area. Most of the other data (the number of discoveries per year, lead time, and the number and sizes of the undiscovered fields (Forman, 1985)) can also be entered in the form of statistical distributions for each region.

The number of discoveries in each region per year may be calculated for a period of x years by a stochastic process using a binomial distribution of n trials with probability of success, p, where the period of x years must be less than or equal to the 20 years of the estimate. The algorithm for this calculation is described in step 5.4 in the next section.

In the program, discovery of fields and subsequent production from the fields is simulated. For each field, a lead time, randomly selected from the input distribution for lead times, is used to determine the year in which production starts. Production for that field is determined by random selection from distributions giving the amount produced in each year. These distributions are built into the program and give the percentage of initial field reserves produced in years one to twenty of production. Separate distributions are given for onshore and offshore fields.

A random sampling process, described in step 5 in the next section, is used to carry out the simulation and produce 20 histograms of total annual crude oil production, a histogram of the amount of crude oil discovered, and a histogram of the amount of crude oil discovered and brought into production. The histograms of annual production, calculated by the program, are printed out in summary as a table of average annual production, standard deviation of the annual production, and the 80'th and 20'th percentiles. A graph of average annual production and the 80'th and 20'th percentiles are plotted adjacent to the table. The amount discovered and the amount discovered and brought into production within a part of the period of the estimate, are stored as histograms and their averages and 20'th and 80'th percentiles are printed. All 22 histograms and relevant output information may be saved in a disk file named by the user.

Program LAMPO (Hinde, 1985a) may be used to read the file containing the saved histograms and to print the FORC2 output. Program FORAD (Hinde, 1985b) may be used to add together a number of distributions from a number of different regions.

DESCRIPTION OF PROGRAM FORC2

The instructions in the program are described, in sequence, below. The program is structured so that many areas, each with completely different data, may be processed. The same number of Monte Carlo iterations is carried out for each area. The program consists of the following instructions carried out by the computer:

1. Read in from the input file: the number of areas to be processed; the number of runs, NRUNS, to be used in the Monte Carlo simulation; and a five digit seed for the random number generator.

2. Read in and print: a title for each area; the first year for the estimate of production; the units of volume; the earliest year in which the first field may be discovered; and the type of distributions to be used for the percentages of initial field reserves produced from fields each year (onshore or offshore). Transfer program control to subroutines CPD and DISWR to read in and print the distributions for the number of discoveries per year and for the lead time between discovery of a field and the start of production.

3. Read in the name of the new disk file into which the estimate of future production is to be written. Call subroutines CPD and and DISWR to read in and print out the distributions for the numbers of fields and for the sizes of fields.

4. Carry out two Monte Carlo simulations in order to determine histograms of the annual oil production. The first time to determine suitable ranges for each of the histograms. The second time for the actual simulation. The Monte Carlo loop consists of the following instructions carried out NRUNS times by the computer:

    4.1 Use subroutine MONTE to simulate discoveries of a set of field sizes using the distributions for the numbers and sizes of fields.

    4.2 Determine the order in which the fields are discovered when the probability of discovery is proportional to the square root of the field size (subroutine FDISC).

    4.3 Determine the lead time for each field by random selection from the distibution.

4.4 The year in which each discovery is made is determined as follows. Firstly, an input binomial distribution with n trials and probability, p, of success is specified and the number of discoveries in the n years period is determined by generating a random binomial variate. Then, each of these discoveries is randomly assigned to one of these n years. The value np is the average number of discoveries for the n years, and p is the average number of discoveries per year. The value for the number of years (n) is usually 10.

4.5 Using the number of discoveries in each year, the year in which the first discovery could be made, the selected lead times, and the distributions for the percentages of initial field reserves produced each year, call subroutine PRODN to calculate the total annual production arising from all fields when discovered in the the simulated order.

5. Write the production profile into the disk file (if specified).

6. Use subroutine PLOUT and function PERC1 to tabulate the 80'th, 50'th, and 20'th percentiles and the average and standard deviation of the estimates of annual production, and to plot the production profiles corresponding to the 80'th and 20'th percentiles and the average.

7 Print the average amount of oil discovered each year and the average amount that is discovered and brought into production within the n-years period of the estimate.

8. Print the mean and the 80'th, 50'th and 20'th percentiles for the totals of the amount discovered and the amount discovered and brought into production within the period of the estimate using function PERC1.

9. Go to 2, until all areas have been processed.

The subprograms mentioned above are described below.

Subroutine FDISC

This subroutine simulates a discovery order so that the probability of discovery of each field is proportional to the square root of its size.

Subroutine PRODN

This subroutine calculates production from each field according to a predetermined set of lead times and a production profile. Two production profiles are available, one for each type of field, and are tabulated below.

Year	percent of total field volume produced onshore wells	offshore wells
1	4.3	5.0
2	8.6	10.0
3	8.6	15.0
4	8.6	15.0
5	8.6	12.0
6	8.6	9.5
7	8.6	7.5
8	8.6	6.0
9	7.8	5.0
10	6.5	4.0
11	4.9	3.0
12	3.9	2.5
13	3.4	2.0
14	2.6	1.5
15	2.0	1.3
16	1.0	0.7
17	1.0	0.0
18	1.0	0.0
19	0.8	0.0
20	0.6	0.0
21	0.0	0.0

Subroutine CPD

This subroutine converts a distribution, as read from the input data file, to a cumulative distribution represented by up to 21 x-value and probability pairs. The type of distribution being read in is represented by a single letter whose meaning is tabulated below.

Letter	Type of distribution	Number of x-value/probability pairs specifying the distribution
K	constant value	1
U	uniform distribution	2 (min, max)
T	triangular distribution	3 (min, most likely, max)
blank	frequency histogram	N (N must be less than 23)
C	cumulative distribution	N (N must be less than 23)
E	truncated exponential	3 (min, average, max)
M	multinomial distribution	2 (no. of trials, probability of success)

Values and corresponding probabilities need to be specified for frequency histograms and cumulative distributions, but for other distribution types only the values have to be specified in the input data (see line 4 of input data). The program calculates the probabilities for these using the x-values (described in parentheses in the above table). Further details on the format for inputting distributions are described in the next chapter.

Subroutine DISWR

This subroutine prints out distributions in their original input format.

Subroutine MONTE

This subroutine is used in the Monte Carlo simulation to select random values using cumulative distributions produced by CPD.

Subroutine PLOUT

Subroutine PLOUT now calculates the 80'th and 20'th percentiles, as well as the mean and standard deviation, of the annual total production and plots the mean and 80'th and 20'th percentiles over the 20 years period.

Function PERC1

This new function returns the p'th percentile of a cumulative probability distribution.

FORMAT OF INPUT DATA

The input for program FORC2 should be typed into a file called 'DATAF2' according to the following format.

Line	Cols	Variable	Description	Format for the entire line
1	1-5	NAREA	Number of areas to be processed.	(3I5)
	6-10	NRUNS	Number of runs in the Monte Carlo loop (if omitted, 1000 is used).	
	11-15	ISEED	See for the random number generator (if omitted, 12345 is used).	

For each area, the following data are required (line 2 onwards).

2	1-80	TITLE	Descriptive title for area.	(40A2)
3	1-5	NSTART	First year of production profile.	(I5,5A2, I5,4A2)
	6-15	IUNIT	Units of volume.	
	16-20	NFDISC	The earliest year during which	

			the first field may be discovered.	
	21-28	IPROD	Type of production profile: ONSHORE or OFFSHORE.	
4	1	TYPE(I)	Type of distribution for number of discoveries per year (K-constant, E-truncated exponential, U-uniform, blank-frequency histogram, C-cumulative, T-triangular). Type B - binomial - may be used for this distribution only.	(A1,I5, (6F10.3))
	2-6	NUM(I)	Number of x-value and probability pairs specifying the distribution for the number of discoveries per year.	
	7-16	VAL(I,1)	X-value of the first pair in the distribution for the number of discoveries per year.	
	17-26	FREQ(I,1)	Corresponding probability or relative frequency of the first pair in the distribution for the number of discoveries per year.	
	27-36	VAL(I,2)	X-value of the second pair.	
	37-46	FREQ(I,2)	Corresponding probability or relative frequency of the second pair.	
	47-56	VAL(I,3)	Parameter value of the third pair.	
	57-66	FREQ(I,3)	Corresponding probability or relative frequency of the third pair.	

If more than 3 pairs are required to specify the distribution, 1 to 4 continuation lines may be added. Up to 3 pairs can be entered per continuation line, 20 columns per pair, starting in column 1 (each number has F10.3 format).

5			Distribution for lead time - specified in the same way as the distribution for line 4 is specified.	
6	1-14	IFILEQ	The name of the new file into	(7A2)

	which the histograms may be written. This file can be used by programs LAMPO and FORAD. It is optional.
7	Distribution for field size - specified in the same way as the distribution for line 4 is specified.
8	Distribution for number of fields - specified in the same way as the distribution for line 4 is specified.

RUNNING THE PROGRAM

The program resides in BMR's Hewlett-Packard computer, and is called FORC2. The input data file 'DATAF2' must be prepared first. If the program has been saved, it can be restored and run with the commands:

```
RP,FORC2
RU,FORC2,1
```

where 1 is the device to which the output is to be sent (1 for the terminal, 16 for the printer).

If the program has not been saved, it is compiled with the command

```
FT,&FORC2,,%FORC2
```

and loaded with the commands

```
RU,LOADR
>EB
>RE,%FORCT
>END
```

then run using the command

```
RU,FORC2,1
```

ACKNOWLEDGEMENTS

The author wishes to thank Dr. D.J. Forman for discussions at the logical design stage of the program and for assistance in preparing the text.

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