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The micro-computer program TENDOWG for estimating undiscovered uranium endowment

by

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INTRODUCTION

The need for a more flexible approach to estimating undiscovered uranium endowment than that which was used during the National Uranium Resource Evaluation (NURE) Program (U.S. Department of Energy, 1980) has resulted in a modification of the standard NURE method which emphasizes greater use of geologic knowledge in the estimating process. The modified method is called the Deposit Size Frequency (DSF) method and has been described in detail in U.S. Geological Survey Circular 994 (Finch and McCammon, 1987).

The purpose of this open-file report is to describe how to run the computer program that was written to estimate undiscovered uranium endowment using the DSF method. The program was modified from the program written to estimate the undiscovered uranium endowment using the standard NURE method (Ford and McLaren, 1980). The modifications that have been made still make it possible to run the program using the standard NURE method.

The standard NURE endowment equation is given by

$$U = A \cdot F \cdot T \cdot G \cdot P$$

where:

U = unconditional uranium endowment in tons U_3O_8 above a cutoff of 0.01 percent U_3O_8,

A = projected surface area of favorable ground in square miles,

F = fraction of A that is underlain by endowment, conditional upon P = 1.0

T = tons of endowed rock per square mile within A · F,

G = average grade of endowment, in decimal fraction form, and

P = probability of occurrence, a factor that expresses the likelihood that one or more deposits actually exist within the favorable area (default: P = 1.0).

The general equation that is used in the DSF method is given by

$$U = A\left(\sum_{i=1}^{k} \left(\frac{n_{ic}}{A_c}\right) T_i\right) G \cdot L$$

where:

U = unconditional uranium endowment in tons of U_3O_8 above a cutoff of 0.01 percent U_3O_8,

A = favorable area in square miles,

k = number of deposit-size classes,

n_{ic}/A_c = spatial density (number of deposits/unit area) of deposits of size T_i (tons of endowed rock) in the ith deposit-size class within a control area A_c,

A_c = control area from which estimates of n_{ic}/A_c are taken,

G = average grade of endowment, in decimal fraction form, and

L = optional scaling factor that expresses the relation between the endowment in the favorable area and that in either the control area (A_c) or some designated subarea (surrogate for A_c) for which estimates of the number of deposits for different size classes have been made.

The procedures for estimating the values of the variables and the underlying assumptions about the variables are described in detail in Circular 994. No attempt is made here to describe these procedures.

RUNNING THE PROGRAM

To run the program for estimating undiscovered uranium endowment using the DSF method, the user types in the following:

tendowg <file.in >file.out

where:

tendowg = name of the program to estimate undiscovered uranium endowment using the DSF method of estimation,

file.in = represents the name of the input file whose specifications will be described below,

file.out = represents the name of the output file where the results of the program will be stored. If >prn is typed instead of >file.out, the output will be directed to the printer. If >file.out is left blank, the output will be directed to the screen. If <file.in is left blank, the program will execute but will expect all input from the terminal.

NOTE: In order for the above command line to execute, DOS Version 2.00 or greater must be installed on the system. For DOS Version 1.10 or less, the user can type in tendowg and enter all input from the terminal.

CREATING file.in

The input file to the program is created as a standard ASCII file using any standard editor. The file consists of a series of lines of input data in which each line with a single character is followed by lines containing the input data that corresponds to the task specified by the character. To preserve the nomenclature used in the standard NURE method, the characters used in the DSF method have remained the same even though the tasks in some cases have changed. This was done in order that, for reporting purposes, the output using the DSF method would be identical to the output using the standard NURE method. For this reason, the characters for designating the tasks have remained, wherever possible, the same as were used for the standard NURE method.

The single characters for designating tasks are as follows:

R -- Accept R, a new region name,

(NOTE: necessary only for multiple regions)

(NOTE: for a specified region, A, F, T, G, P may be specified in any order followed by U and need only be specified if different from previous region)

A -- Accept A, area (square miles),

F -- Accept F, fraction of area underlain by mineralization; or Accept L, optional scaling factor,

T -- Accept T, tons of endowed rock per square mile within A · F, and Accept k, number of deposit-size classes, followed by lower and upper limits for each ith deposit-size class and the spatial density of deposits of size T_i (tons of endowed rock) in the ith deposit-size class within a control area A_c, (NOTE: if k = 0, Accept T only),

G -- Accept G, average grade of endowment, in decimal fraction form,

P -- Accept P, probability of occurrence

(NOTE: necessary only if P not equal to 1.0 for standard NURE method),

U -- Report distribution of endowment

S -- STOP

SAMPLE file.in

The following file called sample.in is an example of a file.in entered as input to tendowg:

```
R
LAKE GILLETTE
49.68,0,0
F
0.1,1,2
T
4
2.5E3,2.5E4
0.04026,.08052,.2013
2.5E4,2.5E5
0.08052,.1610,.3623
2.5E5,2.5E6
```

```
0.06039,.1208,.1812
2.5E6,2.5E7
0,0,.02013
G
0.02,.03,.08
U
R
LAKE MEAD
A
1020,0,0
F
0.01,.1,1
U
S
```

The contents of this file in no particular order are interpreted as follows: There are two regions, LAKE GILLETTE and LAKE MEAD, for which the undiscovered uranium endowment is to be estimated. The undiscovered uranium endowment is to be estimated separately for each region and summed over both regions. LAKE GILLETTE covers an area of 49.68 square miles. LAKE MEAD covers an area of 1,020 square miles. For the control area which lies outside the two regions, there are 4 deposit-size classes of uranium deposits. The first size class ranges from 2,500 to 25,000 tons of endowed rock. The second size class ranges from 25,000 to 250,000 tons and so forth. For the first size class, the modal estimate of the number of deposits per unit area is .08052. The low estimate, corresponding to a 95-percent probability that the spatial density is as least as large, is .04026. The high estimate, corresponding to a 5-percent probability that the spatial density is at least that large, is .2013 and so forth for the other size classes. The modal estimate for the average grade is .03 percent U_3O_8 with a low estimate of .02 and a high estimate of .08, respectively. For LAKE GILLETTE, it is estimated that it is most likely to be as endowed as the control area, a 95-percent probability that it is at least one-tenth as endowed, and a 5-percent probability that it is twice as endowed as the control area. For LAKE MEAD it is estimated that it is most likely to be one-tenth as endowed as the control area, a 95-percent

one-tenth as endowed as the control area, a 95-percent probability that it is at least one-hundredth as endowed, and a 5-percent probability that it is as endowed as the control area.

A SAMPLE RUN

The following command was entered at the terminal:

```
tendowg <sample.in  >sample.out
```

The following is the contents of the output file sample.out:

(NOTE: For illustrative purposes, the responses to the questions are given in the listing below; they do not appear in the output file sample.out).

```
*** URANIUM ENDOWMENT & COST CATEGORY ESTIMATES ***
(FOR INSTRUCTIONS, TYPE CARRIAGE RETURN)
ENTER TASK ? R
ENTER NAME OF REGION  LAKE GILLETTE
ENTER TASK ? A
ENTER X( 5.0), MODE AND X(95.0) FOR AREA     49.68,0,0
AREA      =  4.96800E+01
ENTER TASK ? F
ENTER X( 5.0), MODE AND X(95.0) FOR FRACTION   0.1,1,2
----------------------------FRACTION-----------------------------------
 X( 5.0) : 1.00000E-01  MODE    : 1.00000E+00  X(95.0) : 2.00000E+00
 MEAN    : 6.15054E-01  CO.VAR'N: 4.22387E-01  SKEWNESS:-4.70785E-01
                        KURTOSIS: 2.33852E+00
LOGNORMAL TRUNCATED TO INTERVAL FROM  0.00000E+00 TO  1.00000E+00
ENTER TASK ? T
ENTER NUMBER OF DEPOSIT SIZE CLASSES ? 4
ENTER LOWER AND UPPER LIMIT OF SIZE CLASS  1  2.5E3,2.5E4
ENTER X( 5.0), MODE AND X(95.0) FOR TONNAGE  0.04026,.08052,.2013
----------------------------TONNAGE------------------------------------
 X( 5.0) : 3.18283E+02  MODE    : 6.36566E+02  X(95.0) : 1.59142E+03
 MEAN    : 8.25493E+02  CO.VAR'N: 4.63301E-01  SKEWNESS: 8.93220E-01
                        KURTOSIS: 3.81444E+00
LOGNORMAL TRUNCATED TO INTERVAL FROM  0.00000E+00 TO  2.34334E+03
ENTER LOWER AND UPPER LIMIT OF SIZE CLASS  2  2.5E4,2.5E5
ENTER X( 5.0), MODE AND X(95.0) FOR TONNAGE  0.08052,.1610,.3623
----------------------------TONNAGE------------------------------------
 X( 5.0) : 6.36566E+03  MODE    : 1.27282E+04  X(95.0) : 2.86423E+04
 MEAN    : 1.55734E+04  CO.VAR'N: 4.27564E-01  SKEWNESS: 7.36625E-01
                        KURTOSIS: 3.46890E+00
LOGNORMAL TRUNCATED TO INTERVAL FROM  0.00000E+00 TO  4.04243E+04
ENTER LOWER AND UPPER LIMIT OF SIZE CLASS  3  2.5E5,2.5E6
ENTER X( 5.0), MODE AND X(95.0) FOR TONNAGE  0.06039,.1208,.1812
----------------------------TONNAGE------------------------------------
 X( 5.0) : 4.77425E+04  MODE    : 9.55008E+04  X(95.0) : 1.43251E+05
 MEAN    : 9.55008E+04  CO.VAR'N: 3.03937E-01  SKEWNESS: 0.00000E+00
```

```
                        KURTOSIS: 3.00000E+00
ENTER LOWER AND UPPER LIMIT OF SIZE CLASS  4  2.5E6,2.5E7
ENTER X( 5.0), MODE AND X(95.0) FOR TONNAGE  0,0,.02013
---------------------------TONNAGE-----------------------------------
 X( 5.0) : 0.00000E+00  MODE    : 0.00000E+00  X(95.0) : 1.59142E+05
 MEAN    : 3.52809E+04  CO.VAR'N: 2.02968E+00  SKEWNESS: 4.61136E+00
                        KURTOSIS: 3.02675E+01
LOGNORMAL TRUNCATED TO INTERVAL FROM  0.00000E+00 TO  7.38802E+05
---------------------------TONNAGE-----------------------------------
 X( 5.0) : 3.60625E+03  MODE    : 1.18295E+05  X(95.0) : 3.32088E+05
 MEAN    : 1.55873E+05  CO.VAR'N: 5.91037E-01  SKEWNESS: 6.60505E-01
                        KURTOSIS: 3.11050E+00
LOGNORMAL TRUNCATED TO INTERVAL FROM  0.00000E+00 TO  4.75971E+05
ENTER TASK ? G
ENTER X( 5.0), MODE AND X(95.0) FOR % GRADE  0.02,.03,.08
---------------------------% GRADE-----------------------------------
 X( 5.0) : 2.00000E-02  MODE    : 3.00000E-02  X(95.0) : 8.00000E-02
 MEAN    : 4.16138E-02  CO.VAR'N: 4.41885E-01  SKEWNESS: 1.32520E+00
                        KURTOSIS: 5.11980E+00
LOGNORMAL TRUNCATED TO INTERVAL FROM  7.73463E-03 TO  1.27098E-01
ENTER TASK ? U
----------------------SUMMARY OF INPUT FACTORS-----------------------
             AREA         FRACTION     TONNAGE      % GRADE
LOWER %  :    5.0           5.0          5.0          5.0
LOWER X  :  4.9680E+01   1.0000E-01   3.6062E+03   2.0000E-02
MODE     :  4.9680E+01   1.0000E+00   1.1830E+05   3.0000E-02
UPPER %  :  95.0         95.0         95.0         95.0
UPPER X  :  4.9680E+01   2.0000E+00   3.3209E+05   8.0000E-02
MEAN     :  4.9680E+01   6.1505E-01   1.5587E+05   4.1614E-02
CO.VAR'N :  0.0000E+00   4.2239E-01   5.9104E-01   4.4188E-01
SKEWNESS :  0.0000E+00  -4.7078E-01   6.6050E-01   1.3252E+00
KURTOSIS :  0.0000E+00   2.3385E+00   3.1105E+00   5.1198E+00
---------CONDITIONAL ENDOWMENT : U = A * F * T * G / 100--------------
 MEAN    : 1.98200E+03  CO.VAR'N: 9.48967E-01  SKEWNESS: 2.18585E+00
                        KURTOSIS: 1.09383E+01
-------------UNCONDITIONAL ENDOWMENT : E(P0) = 1.0000----------------
 MEAN    : 1.98200E+03  CO.VAR'N: 9.48967E-01  SKEWNESS: 2.18585E+00
                        KURTOSIS: 1.09383E+01
--------------------PEARSON PERCENTILES FOR ENDOWMENT----------------
            TONS  PROBABILITY              TONS  PROBABILITY
            U308  COND UNCOND              U308  COND UNCOND
      .19715E+03   .05  .0500        .16139E+04   .55  .5500
      .31303E+03   .10  .1000        .18301E+04   .60  .6000
      .43048E+03   .15  .1500        .20726E+04   .65  .6500
      .54792E+03   .20  .2000        .23516E+04   .70  .7000
      .67461E+03   .25  .2500        .26795E+04   .75  .7500
      .80287E+03   .30  .3000        .30892E+04   .80  .8000
      .94375E+03   .35  .3500        .36160E+04   .85  .8500
      .10882E+04   .40  .4000        .43644E+04   .90  .9000
      .12517E+04   .45  .4500        .56688E+04   .95  .9500
      .14244E+04   .50  .5000
ENTER TASK ? R
ENTER NAME OF REGION  LAKE MEAD
ENTER TASK ? A
```

```
ENTER X( 5.0), MODE AND X(95.0) FOR AREA     1020,0,0
AREA      =  1.02000E+03
ENTER TASK ? F
ENTER X( 5.0), MODE AND X(95.0) FOR FRACTION
---------------------------FRACTION-----------------------------------
 X( 5.0) : 1.00000E-02  MODE    : 1.00000E-01  X(95.0) : 1.00000E+00
 MEAN    : 2.89540E-01  CO.VAR'N: 7.71746E-01  SKEWNESS: 1.02556E+00
                        KURTOSIS: 3.44194E+00
LOGNORMAL TRUNCATED TO INTERVAL FROM  0.00000E+00 TO  1.00000E+00
ENTER TASK ? U
----------------------SUMMARY OF INPUT FACTORS-----------------------
            AREA        FRACTION    TONNAGE     % GRADE
LOWER %  :   5.0         5.0         5.0         5.0
LOWER X  :  1.0200E+03  1.0000E-02  3.6062E+03  2.0000E-02
MODE     :  1.0200E+03  1.0000E-01  1.1830E+05  3.0000E-02
UPPER %  :  95.0        95.0        95.0        95.0
UPPER X  :  1.0200E+03  1.0000E+00  3.3209E+05  8.0000E-02
MEAN     :  1.0200E+03  2.8954E-01  1.5587E+05  4.1614E-02
CO.VAR'N :  0.0000E+00  7.7175E-01  5.9104E-01  4.4188E-01
SKEWNESS :  0.0000E+00  1.0256E+00  6.6050E-01  1.3252E+00
KURTOSIS :  0.0000E+00  3.4419E+00  3.1105E+00  5.1198E+00
---------CONDITIONAL ENDOWMENT : U = A * F * T * G / 100--------------
 MEAN    : 1.91566E+04  CO.VAR'N: 1.25434E+00  SKEWNESS: 3.23261E+00
                        KURTOSIS: 2.07052E+01
-------------UNCONDITIONAL ENDOWMENT : E(P0) = 1.0000----------------
 MEAN    : 1.91566E+04  CO.VAR'N: 1.25434E+00  SKEWNESS: 3.23261E+00
                        KURTOSIS: 2.07052E+01
--------------------PEARSON PERCENTILES FOR ENDOWMENT-----------------
           TONS  PROBABILITY             TONS  PROBABILITY
           U3O8  COND UNCOND             U3O8  COND UNCOND
     .28097E+04   .05  .0500       .12787E+05   .55  .5500
     .32223E+04   .10  .1000       .15057E+05   .60  .6000
     .36350E+04   .15  .1500       .17721E+05   .65  .6500
     .40476E+04   .20  .2000       .20979E+05   .70  .7000
     .48170E+04   .25  .2500       .25021E+05   .75  .7500
     .56333E+04   .30  .3000       .30190E+05   .80  .8000
     .66804E+04   .35  .3500       .37189E+05   .85  .8500
     .78545E+04   .40  .4000       .47605E+05   .90  .9000
     .92310E+04   .45  .4500       .66693E+05   .95  .9500
     .10865E+05   .50  .5000
ENTER TASK ? S
---------TOTAL UNCONDITIONAL ENDOWMENT FOR  2 REGIONS----------------
LAKE GILLETTE
LAKE MEAD
-------------UNCONDITIONAL ENDOWMENT : E(P0) = 1.0------------------
 MEAN    : 2.11386E+04  CO.VAR'N: 1.22571E+00  SKEWNESS: 3.14728E+00
                        KURTOSIS: 1.98328E+01
--------------------PEARSON PERCENTILES FOR ENDOWMENT-----------------
           TONS  PROBABILITY             TONS  PROBABILITY
           U3O8  COND UNCOND             U3O8  COND UNCOND
     .29908E+04         .0500       .14343E+05         .5500
     .34675E+04         .1000       .16808E+05         .6000
     .39443E+04         .1500       .19748E+05         .6500
     .44867E+04         .2000       .23281E+05         .7000
```

```
      .53844E+04        .2500       .27642E+05        .7500
      .63158E+04        .3000       .33211E+05        .8000
      .75093E+04        .3500       .40721E+05        .8500
      .88609E+04        .4000       .51863E+05        .9000
      .10416E+05        .4500       .72213E+05        .9500
      .12228E+05        .5000
Stop - Program terminated.
```

The reader is referred to Circular 994 for an explanation of the results. No attempt is made here to elaborate further on the output.

CONTENTS OF DISKETTE

The diskette which accompanies this open-file report contains the following files:

README -- A file containing this report,

SAMPLE.IN -- An example of a file.in input file

SAMPLE.OUT -- An example of a file.out output file

TENDOWG.EXE -- An executable file of the program tendowg,

TENDOWG.FOR -- A file containing the tendowg FORTRAN source program,

LIB4.FOR -- A file containing the FORTRAN subroutine source programs necessary to run tendowg.

The source programs are provided should it be desired or necessary either to modify or recompile tendowg.

REFERENCES

Finch, W. I., and McCammon, R. B., 1987, Uranium resource assessment by the Geological Survey: Methodology and plan to update the national resource base: U.S. Geological Survey Circular 994, 31 p.

Ford, C. E., and McLaren, R. A., 1980, Methods for obtaining distributions of uranium occurrence from estimates of geologic features: U.S. Department of Energy Report GJBX-165(80), 121 p.

U.S. Department of Energy, 1980, An assessment report on uranium in the United States of America: U.S. Department of Energy Report GJO-111(80), 150 p., 6 microfiche.