BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1986/30

VALAL AND ASSAD: TWO COMPUTER PROGRAMS FOR ESTIMATING AND SUMMING UNDISCOVERED PETROLEUM RESOURCES

by

ALAN L. HINDE

RECORD 1986/30

VALAL AND ASSAD: TWO COMPUTER PROGRAMS FOR ESTIMATING AND SUMMING UNDISCOVERED PETROLEUM RESOURCES

by

ALAN L. HINDE

CONTENTS

SUMMARY

This record describes two computer programs: one for assessing the undiscovered petroleum resources of individual trap types within independent petroleum systems and the other for summing the individual assessments to produce a cumulative probability curve of the total petroleum potential of many independent systems. The procedure is a variation of the creaming method and is called the trap by trap creaming method of assessing undiscovered petroleum resources.

Program VALAL carries out individual assessments of undiscovered oil and gas resources in each trap type. Future closure areas (A) and field sizes (V) are determined using projections of straight lines which relate log A to new-field wildcat number and log V/A to discovery number. Input data are the slope, intercept, standard deviation of residuals, and number of data points for the straight lines and the values of lambda and standard deviation of lambda associated with both of these straight lines. The program prints the cumulative probability distributions of undiscovered potential for each assessment and stores the assessments on a disc file.

Program ASSAD sums the individual assessments by a statistical procedure. It uses two existence probabilities for each assessment: the probability (or one minus the risk) that hydrocarbons have been generated and have migrated within the independent petroleum system and the probability that the given trap type will contain any of the hydrocarbons that migrated. The program prints out the unrisked cumulative probability curve of total undiscovered resources, and an existence risk.

Three other programs are also described: programs VLSRT and ASSRT which sort the VALAL input and output files by basin, sub-basin, sequence level, and trap type; and program VLPNT which prints the VALAL input data file in condensed tabular format.

INTRODUCTION

Program VALAL assesses the undiscovered petroleum resources of individual trap types within each independent petroleum system (IPS; Ulmiskek and Harrison, 1984). The method is outlined by Forman and Hinde (1986) and the program for implementing it has many features in common with program VALAM (Hinde, 1984). The VALAM program, however, was designed to use projections of historical data whereas VALAL is designed to use geological data and analogue data as well as historical data and is intended for the assessment of individual trap types.

Input required for each individual VALAL assessment includes parameters for the straight-line trends of log A vs new-field wildcat number that are believed to represent the undrilled closure areas in expected order of drilling, and parameters for the straight-line trends representing the ratio of V/A plotted on a logarithmic scale against discovery number in the expected order of drilling; the oil and gas success rate; the expected proportion of oil fields and of gas fields; and a distribution for the ratio of oil to oil plus gas in fields containing both oil and gas. The values of lambda for the log A and log V/A trends are also required. Lambda is a measure of the tendency to discover fields with high values of V/A early and to drill the areally large prospects early. These parameters can also be determined by geological methods or by analogy with areas of similar geology.

The individual assessments carried out by program VALAL provide, for each assessment: an unrisked cumulative probability distribution of undiscovered potential; the economic existence probability (arising from the success rate and economic cut-off of field sizes - the economic risk); the two existence probabilities; the percentiles of recoverable potential; and a seriation of average sizes of undiscovered fields.

Once completed, each assessment, risked only with the economic risk, is written onto a disk file for use by program ASSAD, which statistically sums the assessments. The assessments are risked during the summation using the two existence risks - the probability that hydrocarbons have been generated or migrated into the stratigraphic interval and the probability that the hydrocarbons are still retained within the particular trap type (they are input into program VALAL, but are only used in program ASSAD).

A combined oil and gas unit is used so that oil and gas potential may both be assessed from the same data. This unit is named the MOE (MCM(10^6 m^3) of oil equivalents) defined as

$$\text{MOE} = \text{oil (MCM)} + \text{gas (BCM)} \times G$$

where

$$G = \frac{\text{(oil recovery factor)}}{\text{(oil shrinkage factor)} \times \text{(gas expansion factor)} \times \text{gas recovery factor)}}$$

The constant, G, is a factor for converting identified recoverable gas volumes in BCM's to the equivalent volume of recoverable oil in MCM's. The value of G is specified in the input data.

Program VALAL uses the input values for the proportion of oil and gas fields and the proportion of oil and gas within oil and gas fields to convert field sizes in MOE to the respective proportion of oil and gas. The gas component is then divided by G to obtain the amount of gas in BCM's.

DESCRIPTION OF PROGRAM VALAL

Program VALAL carries out many consecutive assessments by Monte Carlo simulation. The instructions given in the program are described below.

Input of general data

The program instructs the computer to read and print the following general data which are common to all the assessments being carried out:-

- title;
- whether onshore or offshore;
- the disk file for storing the assessments for input into program ASSAD;
- a print option telling the program whether to give detailed output for each assessment or to just print the risked average and the two existence probabilities;
- whether the oil or gas component is being assessed;
- the number of iterations for the Monte Carlo simulation;
- values for the standard deviation of lambda to be used if not given in the input data for individual assessments;

Input of data for each assessment

Next, the computer is instructed to read a set of data for the first assessment (that is for a trap type within a specific IPS). The data read are:-

- the basin and sub-basin, sequence level,and trap type;

- the number of future wells to be drilled;

- the triangular distribution for the success rate;

- cut-offs specifying the minimum and maximum field sizes to be accepted in the Monte Carlo simulation. Fields smaller than the minimum cut-off are counted as a discovery , but their resources are considered uneconomic and are not added to the total. When a field larger than the maximum cut-off is generated, another field size is selected to replace it. The maximum field size cut-off may be left blank as cut-offs on closure area and V/A normally achieve the same purpose;

- the proportion of oil, gas, and oil and gas fields and a triangular distribution for the ratio of oil to oil plus gas in the fields containing both oil and gas;

- the range of the cumulative histogram of undiscovered potential. This value is used for the upper limit of the last cell of the histogram. If it is not specified, the program calculates a value. This value may be unsatisfactory. The range should include the entire distribution;

- a cut-off for the closure area, A. This is specified as a maximum value for the next well to be drilled and the values for subsequent wells are determined using the logarithm of this value as the intercept (at the next well) of a line with slope parallel to that of the simulated slope of the log A plot. When values greater than the cut-off are generated, another value is generated to replace it. All values of A are allowed if no cut-off is specified;

- a cut-off for the values of V/A. This is specified as a maximum value for the next field to be discovered and the values for subsequent fields are determined using the logarithm of this value as the intercept (at the next field) of a line with slope parallel to that of the simulated slope of the log V/A versus discovery number plot. When values greater than the cut-off are generated, they are replaced with the cut-off (this results in a truncated lognormal distribution with a spike at the truncation point for V/A). If no cut-off is specified, a default value of 6 is used;

- the probability (one minus the risk) that hydrocarbons have been generated and have migrated to the stratigraphic sequence;

- the probability that traps of the type specified contain hydrocarbons;

- the value of the conversion factor, G, used to convert gas to the equivalent volume of oil;

- the parameters of the straight-line model of log A versus new-field wildcat number (slope, intercept, standard deviation of residuals, lambda, standard deviation of lambda, and the number of new-field wildcats). The intercept is input as the area, in km^2, of the first field, while the slope is the change in log A for a given change in new-field wildcat number. When the slope is zero, the line is horizontal. If the value of lambda is not supplied (and the slope is non-zero) then the computer will calculate and use an average value. This value is the smallest allowed by the model. When no value is given for the standard deviation of lambda then the value of the standard deviation specified in the general data is used;

- the parameters of the straight-line model of log V/A (V/A in metres) versus discovery number.

- a triangular distribution for the intercept of the cut-off line for V/A. If not specified, the single value supplied above is used.

Checking the data

The computer checks the input data for each assessment. If no errors are detected, an assessment is carried out. If an error or inconsistency is detected, it prints out a message, ignores the assessment, and proceeds to the next. (Three logical unit numbers are used by the program. The first specifies where the output for the assessments is to be sent. The second specifies where these error messages are to be sent. The third is used for the histogram of simulated log V/A values.)

Next, subroutine GBMAX, described below, is called to calculate constants used for the extrapolation of simulated straight lines for log A and log V/A. Subroutine GBMAX checks the input value of lambda and if it is below the (minimum) average value allowed by the model, it calculates and substitutes the (minimum) average value.

Monte Carlo simulation of undiscovered potential resources

A Monte Carlo simulation is carried out to produce the assessment. Values of lambda for the log A and log V/A projections are selected independently of each other using a random number generator. Values of slope, intercept, and standard deviation of the residuals for the two straight lines are calculated from the generated values of lambda. These lines are extrapolated and used to select values of log A and log V/A from their distributions about the lines. Values of field size are calculated from the log A and log V/A values and are accumulated into a histogram of undiscovered resources.

The computer carries out the following steps during each Monte Carlo iteration:

- when the slope of log A versus NFW number is zero, the parameters of the straight-line model are determined as follows:

  * a random value of the intercept is selected from a normal distribution with a mean equal to the value of the intercept in the input data and a standard deviation equal to the input standard deviation of residuals divided by the square root of the number of new-field wildcat wells. A random value of the standard deviation of the residuals is selected from a normal distribution with a mean equal to the input standard deviation of residuals and a standard deviation equal to the input standard deviation of residuals divided by the square root of twice the number of new-field wildcat wells;

  otherwise,

  * a positive value of lambda is selected from a normal distribution with a mean equal to the input value of lambda and a standard deviation equal to the input value of the standard deviation of lambda. This value of lambda is used to calculate the corresponding values of slope, intercept, and standard deviation of residuals according to the lambda model (Forman and Hinde, 1985);

- a similar procedure is carried out to determine the parameters of the straight line for the log V/A versus discovery number model;

- a value for the success rate is selected from the triangular distribution of success rates;

- for each simulated future well in the model the program instructs

8

the computer to:

* select a random value of log A using the selected values of the slope, intercept, and standard deviation of residuals for the log A versus new-field wildcat number data. Calculate the cut-off for log A using the input value for the cut-off line at the first simulated well, and the slope calculated above. If log A is greater than the cut-off, repeat the selection of log A;

* select a random value of log V/A using the selected values of the slope, intercept, and standard deviation of residuals. Calculate the cut-off for log V/A using the logarithm of the input value for the cut-off line at the first simulated field, or the triangular distribution for this value if it was supplied, and the slope calculated above. If the value of log V/A is greater than the cut-off, use the cut-off value;

* calculate the log field size using the values of log A and log V/A selected above (log V = log V/A + log A);

* if the value of log V is greater than a limit of SDMAX standard deviations above its average value, return three steps to where a value of log A is selected. (The value of SDMAX is normally set at four standard deviations and the instruction that does this is a data statement at the top of the program);

* calculate the field size V = exp(log V);

* if the field size exceeds the maximum value specified in the input, return five steps to where a value of log A is selected;

* if the field size is less than the minimum economic fields size specified in the input, count this field as an uneconomic discovery which will not be included in the assessment;

otherwise,

* extract the oil or gas component of the field and, if gas, convert from MOE to BCM. Count this field as a potentially economic discovery and add it to the total amount of undiscovered petroleum for this iteration. Separately sum the following quantities: the total amount of potentially economic undiscovered petroleum; the square of the total amount of potentially economic undiscovered petroleum; the new-field wildcat number of the discovery well; and the square of the new-field

wildcat number of the discovery well. These sums are used for the seriation which gives the average size and average new-field wildcat number of future discoveries.

- The value of the total amount of undiscovered oil or gas is stored in one histogram, and the number of potentially economic discoveries is stored in another. These values are also added to the sums required for calculating the moments of total undiscovered oil or gas, and the number of potentially economic discoveries. A histogram of the simulated log V/A values is also produced and this is printed on a separate logical unit;

- The results are printed when all iterations have been carried out;

- The assessment is stored on a disk file, named in the input data, for use by program ASSAD.

Subroutine GBMAX

Subroutine GBMAX takes as input the slope, b, intercept, a, standard deviation of residuals, σ_{res}, and number of data points, n, of a linear regression, as well as the corresponding value of lambda, and calculates the maximum (most negative) slope, B_{max}, (obtained when the data points are ordered in decreasing size), the standard deviation of the y-values, σ_y, and the sum of the y-values, S_y.

The method is based on the equation, developed for the lambda model (Forman and Hinde, 1985) that relates the slope, b, of the fitted line to the value of lambda, λ,

$$b = B_{max}(1 - \exp(-\sigma_y \lambda)) \qquad (1)$$

and uses the two equations for obtaining the least squares estimate of slope and standard deviation of residuals for a linear regression:

$$a = S_y/n - bS_x/n \qquad (2)$$

$$\sigma^2_{res} = n(\sigma^2_y - b^2\sigma^2_x)/(n-2) \qquad (3)$$

S_y is the sum of the y-values and S_x is the the sum of the x-values, σ_x is the standard deviation of the x-values. Because there is a data point at every integer value of x, up to n (there is a log A value for every new-field wildcat well

and a discovery for every discovery number), $S_x = n(n+1)/2$, and $\sigma_x^2 = (n^2-1)/12$.

Rearranging equations (1), (2), and (3) gives three equations that allow B_{max}, σ_y, and S_y to be calculated:

$$S_y = n(a + B(n+1)/2) \quad (4)$$

$$\sigma_y^2 = \sigma_{res}^2(n-2)/n + b^2(n^2-1)/12 \quad (5)$$

$$B_{max} = b/(1 - \exp(-\sigma_y\lambda)) \quad (6)$$

Different values of λ are selected during the simulation. These are used in equations (1), (2), and (3) to get new values for the slope, intercept, and standard deviation of residuals. A problem may arise during the calculation of new values of σ_{res}^2 (equation (3)) if the magnitude of b, as calculated in equation (1), gets too large (as λ gets large): a negative value for σ_{res}^2 may arise. This will occur if the value calculated for B_{max} (equation (6)) is too large and this, in turn, depends on the value calculated for σ_y^2 (equation (5)), and the value of lambda.

Subroutine GBMAX checks for the possible occurrence of this condition and if it can occur for new finite values of λ, it increases the input value of lambda until B_{max} (equation (6)) is small enough so that the condition cannot occur. The subroutine prints out the re-calculated value on the logical unit used for error messages. Trial runs of the program have shown that the assessments are relatively insensitive to the value of lambda.

Format of input data

The format for the input data for program VALAL is tabulated below. It should be typed into a file called 'DATAVL'

Line	Cols	Variable	Description	Format
1	1-60	ITITLE	Title for this run.	(A60)
2	1-3	ONOFF	Whether onshore ('ON'), offshore ('OFF'), or all ('ALL').	(A3)

3	1-14	OFILE	Disc file for storing the assessments.	(A14, I1)
	15	IPRINT	Print option: = 1 print everything = 0 only print initial data and means	
4	1-3	OG	'OIL', 'GAS', or 'BOE'.	(A3,2X, I5,2F10.0)
	6-10	NRUNS	Number of iterations to be used in the simulations.	
	11-20	GSLAMA	If > 0 specifies a global value to be used for the standard deviation of lambda for log A vs NFW number. If < 0 -GSLAMA/DSQRT(NAREA) is used. This is over-ridden by positive values of SDLAMA (below).	
	21-30	GSLAMV	If > 0 specifies a global value to be used for the standard deviation of lambda for log V/A vs discovery number. If < 0 -GSLAMV/DSQRT(NDISC) is used. This is over-ridden by positive values of SDLAMV (below).	
5			- blank -	
6			- blank -	
7			- blank -	

Lines 8 to 12 are repeated for each basin/sub-basin/trap/sequence level combination as required.

8	1-20	BASIN	Basin and sub-basin.	(A20,1X,A4, I5,5F10.0)
	22-25	TRAPH	Trap type and stratigraphic sequence level. (I = lower part of sequence, T = top part of sequence.)	
	26-30	MDRILL	Number of future wells to be drilled.	
	31-40	XTH1	Minimum value of the success rate for the triangular distribution of success rates.	

	41-50	XTH2	Most likely value of the success rate for this distribution.	
	51-60	XTH3	Maximum value of the success rate for this distribution.	
	61-70	FLDMIN	A cut-off specifying the minimum size for future generated fields; if a field is generated smaller than FLDMIN it is ignored and another generated. If not required, leave blank. (Units are MOE).	
	71-80	FLDMAX	A cut-off specifying the maximum size for future generated fields. If a value is generated greater than FLDMAX, another value is generated. If not required, leave blank. (Units are MOE).	
9	1-10	POIL	Proportion of oil fields.	(8F10.0)
	11-20	PGAS	Proportion of gas fields.	
	21-30	OOGMIN	Minimum value for the triangular distribution for the ratio of oil to oil plus gas.	
	31-40	OOGML	Most likely value for this distribution.	
	41-50	OOGMAX	Maximum value for this distribution.	
	51-60	HMAX	Value to be used for the upper limit of the range of the histogram for the assessment. (If zero, the program calculates a value.)	
	61-70	AAMAX	Specifies a decreasing cut-off for maximum values of future generated values of A. Log AAMAX is the intercept of a line (at the next well) whose slope is the generated value of slope for log A vs new-field wildcat number, that gives the cut-offs for future values of log A. If a value is greater than the cut-off, another value is generated. If not specif-	

			ied no cut-off is used. (Units are km^2.)	
	71-80	VAMAX	Specifies a decreasing cut-off for maximum values of future generated values of V/A. Log VAMAX is the intercept of a line (at the next field) whose slope is the generated value of slope for log V/A vs discovery no., that gives the cut-offs for future values of log V/A. If a value is greater than the cut-off, it is replaced with the cut-off. (Default value is 6.) (Units are MOE/sq km = m.)	
10	1-10	RHORIZ	Probability that hydrocarbons have been generated and have migrated in this stratigraphic sequence.	(3F10.0)
	11-20	RTRAP	Probability that hydrocarbons occur within this trap type.	
	21-30	GBOE	A value for the constant that converts gas in BCM's to an equivalent volume of oil in MCM's. If not specified, a default value is used.	
11	1-10	SLOPA	Slope of the line fitted to log A vs NFW number.	(5F10.0,I5)
	11-20	AINTA1	Average actual pre-drill area of closure at the first NFW. (Intercept of the fitted line = AINTA = log AINTA1 - SLOPA).	
	21-30	SDRESA	Standard deviation of the residuals for log A vs NFW number.	
	31-40	ALAMA	Lambda value for log A vs new-field wildcat number. If this value is less than the theoretical minimum value allowed by the model, the theoretical value is used.	
	41-50	SDLAMA	Standard deviation of lambda.	
	51-55	NAREA	Number of NFW's drilled to date.	

12	1-10	SLOPV	Slope of the line fitted to log V/A vs discovery number.	(5F10.0,I5, 3F5.0)
	11-20	AINTV1	Average actual value of V/A at the first discovery. (Intercept of the fitted line = AINTV = log AINTV1 - SLOPV).	
	21-30	SDRESV	Standard deviation of the residuals for log V/A vs discovery number.	
	31-40	ALAMV	Lambda value for log V/A vs discovery number. If this is less than the theoretical minimum value allowed by the model, the theoretical value is used.	
	41-50	SDLAMV	Standard deviation of lambda.	
	51-55	NDISC	Number of discoveries to date.	
	56-60	VAXMIN	Minimum value for the triangular distribution for the intercept, AAMAX, of the cut-off line for V/A.	
	61-66	VAXML	Most likely value for this distribution.	
	67-70	VAXMAX	Maximum value for this distribution. (This distribution, if present, over-rides the value of VAMAX input above.)	

Printing the VALAL input data file

The data in file DATAVL are printed out in compact tabular form by program VLPNT. If a value of lambda is changed by subroutine GBMAX (see above) the new value is printed by VLPNT.

The program is run as follows:

```
>FT,&VLPNT,,-B
>LO
>RU,VLPNT,l
```

where l is the logical unit to which the printout is to be sent. The printout is in condensed type to allow more characters per line than normal.

The value of l specifies one of the following output destinations:

```
1  - the terminal;
6  - a temporary print file which is sent to the
     printer with the command LP,-N;
11 - discard the output;
16 - the printer.
```

Sorting the VALAL input and output files

Program VLSRT sorts the data in DATAVL. The individual assessments are sorted by basin, sub-basin, sequence level, and trap type. This allows program ASSAD to carry out the risking according to the two rules described below.

Program VLSRT is run with the following commands:

```
>FT,&VLSRT,,-B
>LO
>RU,&VLSRT
```

While the program is running, a temporary file is created from DATAVL. The program informs the user when it is creating this file, sorting this file, and copying it back to DATAVL. If the program is aborted while copying from the temporary file back to DATAVL, the data in DATAVL will probably be lost.

If DATAVL was not sorted prior to running VALAL, the output file may be sorted using program ASSRT. This is an alternative way of ensuring that the data for program ASSAD is sorted correctly. The program is run as for VLSRT.

DESCRIPTION OF PROGRAM ASSAD

Program ASSAD reads files created by program VALAL and statistically risks and sums the cumulative probability histograms of resources for each assessment in the VALAL file.

The program can sum all the assessments in the file produced by VALAL, or it can sum the assessments by basin, by sub-basin, or by sequence level. The program firstly asks the user to specify what is required.

The program then asks the user to type, at the terminal, the name of the VALAL file to be read, and the name of an optional output file to store the summed assessments. This latter file is in the same format as the input file. If an output file is specified, the user is asked for a title or identification to be used in the output file. The user is also asked for the number of iterations to be used in the Monte Carlo summation.

The program then reads the following information, for each assessment, stored in the VALAL file,

- the title;
- the basin, sub-basin, trap-type, and sequence level;
- the cumulative probability histogram of undiscovered potential, the range of the histogram, and the number of cells in the histogram (50 at present);
- the units (MCM for oil, BCM for gas);
- the two existence probabilities, one for generation and migration of hydrocarbons within the stratigraphic sequence and the other for the probability that hydrocarbons occur within the specified trap type.

The program sets up an array to handle the risking of each assessment which is carried out according to the following rules: (1) the existence probabilities for each trap type are independent of each other; (2) a dependence is assumed for generation within an independent petroleum system. For example, if hydrocarbons are found to exist in the lower part of a particular independent petroleum system, then they are assumed to occur in the upper part as well, and the existence probability for generation and migration in the upper part is not used. If the lower part does not contain hydrocarbons, the upper sequence is risked independently.

Because of the second rule, the input assessments from VALAL must be sorted by sequence level with the older sequence within the IPS preceeding the younger sequence. This is ensured by ordering the input to VALAL. Program VLSRT (described below) sorts the VALAL input data file (DATAVL).

The computer sums the individual assessments by Monte Carlo simulation. Values of undiscovered potential resources are selected from each input distribution, using random numbers, risked and summed and the sums stored in a histogram. Each time an input assessment is risked successfully it is tallied so that the proportion of times each assessment is risked successfully can be calculated.

The results are printed out at the completion of the iterations. These include: the unrisked histogram and the unrisked moments of the total summed potential resources; the total existence probability (one minus the risk); the percentiles of the unrisked total summed potential; the risked means of each input assessment as obtained from the Monte Carlo simulation (in some cases these means may be less than the means produced by VALAL, multiplied by their risks, because of inaccuracies in representing a distribution by a finite number of histogram cells with a finite range); and the proportion of times each input assessment was risked successfully. These proportions should be the same as the product of the two existence risks except in situations where rule (2) above can affect them.

RUNNING PROGRAMS VALAL AND ASSAD

Program VALAL is run using the commands:

```
FT,&VALAL,,%VALAL
RU,LOADR
>EB
>RE,%VALAL
>END
RU,VALAL,l,m,n
```

where l is the logical unit to which the output results are to be sent, m is the logical unit to which the error messages are to be sent, and n is the logical unit to which the histogram of simulated log V/A values is to be sent.

Program ASSAD is run using the commands:

```
FT,&ASSAD,,%ASSAD
RU,LOADR
>EB
>RE,%ASSAD
>END
RU,ASSAD,l
```

The program asks the user to type in: the option specifying

whether all the assessments in the file are to be summed together, or whether they are to be summed by basin, or sub-basin; the name of the input file containing the assessments produced by VALAL; and the name of the output file for storing the total summed assessment. If the latter is not required, press <RETURN>; if a name is typed in the program asks for a title to be entered into the first two lines of the file. If the option to sum the entire file has been specified, the program asks for a subtitle for the output file.

If the file already exists, an error mesage is printed and the program stops.

The number of iterations is requested next. If this is omitted (by just pressing <RETURN>), the number of iterations in the input file is used.

ACKNOWLEDGEMENTS

The author sincerely thanks David Forman for creating the framework of the trap by trap creaming method of assessment upon which the programs were constructed and for critical help in preparing the text.

REFERENCES

FORMAN, D.J., and HINDE, A.L., 1985 - An improved statistical method for assessment of undiscovered petroleum resources. Bulletin of the American Association of Petroleum Geologists, v69, pp106-118.

FORMAN, D.J., and HINDE, A.L., 1986 - Examination of the creaming methods of assessment applied to the Gippsland Basin, offshore Australia. In Rice, D.R., Ed. Oil and gas assessment: methods and applications. The American Association of Petroleum Geologists. Studies in geology no. 21.

HINDE, A.L., 1984 - VALAM and ARLAM: two computer programs for estimating hypothetical petroleum resources using prospect areas and field sizes. Bureau of Mineral Resources, Australia, Record 1984/29.

ULMISKEK, G., and HARRISON, W., 1984 - Quantitative methods for assessment of petroleum resources of poorly known basins. In Masters, C.D., Ed. Petroleum Resource Assessment. International Union of Geological Sciences Publication 17, 80-94.