OMV AUSTRALIA PTY LTD
ACN 082 932 027

SOLE DEVELOPMENT
(Patricia Baleen Extension)

GIP and Reserves Estimate

SD-01-RE-0012
Part A

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Table of Contents

Appendices

Figures

Tables

1 INTRODUCTION

The Sole field GIP and reserves were assessed at both deterministic and probabilistic levels. This part (Part A) covers the probabilistic methodology employed and the rationale for the uncertainty range in the reserves parameters. It also covers a comparison of the deterministic and probabilistic GIP and reserves results.

The GIP and Reserves are primarily based on results from detailed 2D seismic data and two wells drilled on structure. The Sole-2 appraisal well was drilled and tested in 2002 and an infill 2D seismic was acquired in 2003.

2 PROBABILISTIC VOLUME METHODOLOGY

Three deterministic structural isochron maps representing different probabilities (e.g. P90, most likely and P10) were created (Part C). The GRV represented by these probability maps were combined statistically with the uncertainty distribution of both the 'gas sand interval velocity' factor and the GWC to yield the GRV distribution.

The uncertainty distribution on the other parameters of net-to-gross, porosity, hydrocarbon saturation and expansion factor were combined probabilistically with the GRV range to give the range in GIP. The GIP range was combined probabilistically with the range in recovery factors to yield the reserves distribution.

3 PARAMETER VALUE AND UNCERTAINTY RANGES

The uncertainty range in the input parameter values used for the probabilistic estimate of GIP and reserves are discussed below. Graphical representation of the parameter distribution functions is given in Appendix AA.

3.1 GRV

The GRV determination from the 2-D seismic data is detailed in Part C of the report.

A log normal distribution was applied to the low and high case GRV maps (see Part C). It was assumed that the low and high case GRV maps were at the P90 and P10 levels respectively. This gave a P50 GRV of 509.6 MMm3 (Table A1).

Table A1 Sole Field: GRV range from P90 and P10 deterministic maps

P10	536.7
P90	483.9

For the probabilistic estimate of the volumes the gas sand interval velocity and the GWC uncertainty were included. Both uncertainties were assumed to be normal distribution.

- The variation of the most likely gas sand interval velocity of 2100m/sec is assumed to be +-2.5% at an 80% confidence level.
- The variation of the field GWC is +-0.4m at an 80% confidence level (see Appendix CC of Part C).

The above uncertainties were included in the probabilistic estimate of the GRV yielding a slight increase in the range of the GRV, as expected (see Table A2).

Table A2 Sole Field: Probabilistic GRV range (includes uncertainty in gas sand velocity and GWC)

Max	596.3
P10	538.9
P50	508.9
P90	481.7
Min	428.7

3.2 Net-to-Gross

Sole-1 and Sole-2 wells are interpreted with a net-to-gross of 100% and 97%[1] respectively for the gas bearing rock (see Part B).

The high net-to-gross seen on the Sole structure is also seen in the water and oil bearing Latrobe of correlatable regional wells (Hammerhead-1, Leatherjacket-1 and Dart-1). The amplitude response from the 2-D seismic data does not show any degradation in the quality of the gas-bearing reservoir across the field.

Shale nodules and clasts have been observed on the Sole-2 core. However they are below the vertical resolution of the wireline logs and are not considered to be laterally extensive.

From the geological model 8% shale volume in the field is estimated to be at the high end of the average amount of shale in the Sole field (ref. Part D).

For the probabilistic volumes a normal distribution is assumed with 95% taken as the mean for the average net-to-gross in the Sole field and 90% taken as the P99 case with the maximum truncated at 100% net-to-gross. This gives a P90 of 93% and a P10 of 97% for the average net-to-gross in the field.

3.3 Porosity

The average porosity of the field was determined from the two wells on structure (Sole-1 and Sole-2) along with the directly correlatable Dart-1 well some 6-7km off structure (Table A3). The full sequence of the Latrobe and its sub-groups are correlatable between Sole-1, Sole-2 and Dart-1.

The average porosities seen in the gas sand of Sole-2 and the top 70 metres (approximate Sole field crestal thickness) of the Latrobe in Sole-1 and Dart-1 have been averaged to give a field average porosity of 31.3 p.u. with a standard deviation of 2.3 p.u. A normal distribution was assumed for the probabilistic volumetric estimate.

This gives a P90 of 28 p.u. and a P10 of 34 p.u. for the field average porosity.

Table A3 Summary of Well Average Porosities (Sole-1, Sole-2 and Dart-1)

Well	**Unit**	**From (mss)**	**To (mss)**	**Gross**	**Net**	**N/G**	**phit** (ave)	**phit** (st dev)
Sole-2 Logs	Gas-Bearing Latrobe	745.0	816.6	71.6	69.3	0.97	0.303	0.032
Sole-1		800.2	870.2	70.0	70.0	1.00	0.317	0.038
Dart-1	Latrobe	911.2	981.2	70.0	69.2	0.99	0.319	0.042

[1] *There is an argument that some non-net interpreted from the wireline logs in Sole-2 is in fact tight streaks of a pyritic nature and should be included in a higher net-to-gross as this can be expected to have storage volume.*

The robustness in the field average porosity range has been tested against the porosities seen in equivalent Latrobe formations in regional wells, some 15km distance west of the field. Hammerehad-1 and Leatherjacket-1 have average porosities of 27.7 p.u. and 29.8 p.u. respectively. From the distribution assumed for the field average porosity there is a 7% chance that the average field porosity is less than 27.7p.u. It is noted that Hammerhead-1, at a depth of 1300 metres, can be expected to have a lower average porosity than the Sole field wells at 800 metres. Moreover the Hammerhead-1 wireline log porosity maybe underestimated given the pyritic nature of the formation.

For completeness other intervals of averaged core and log data for Sole-1, Sole-2 and Dart-1 is given in Table A4.

Table A4 Summary of Well Average Petrophysics Data (Sole-1, Sole-2 and Dart-1)

Well	Unit	From (mss)	To (mss)	Gross	Net	N/G	phit	phit (st dev)	perm (mD)	Sh	Comment
Sole-2 Logs	Gas-Bearing Latrobe	745.0	816.6	71.6	69.3	0.97	0.303	0.032	3939.4	0.850	Mobile gas.
Sole-2 Logs	Water-Bearing Latrobe	816.6	846.5	29.9	29.9	1.00	0.317	0.024	2416.9	0.066	Mobile water.
Sole-2 Logs	All Latrobe	745.0	846.5	101.5	99.2	0.98	0.307	0.031	3400.6	0.606	All Latrobe.
Sole-2 Logs	Cored Interval	748.7	784.8	36.0			0.313	0.024			
Sole-2 Core Amb	Cored Interval						0.334	0.042			94 plugs (Horiz and Vertical)
Sole-2 Core Amb	Cored Interval						0.328	0.040			68 plugs (Horiz)
Sole-2 Core in-situ (conv)							0.319	0.040			68 plugs (Horiz) Amb to NOBP (0.97)
Sole-2 Core 1000NOBP	Cored Interval						0.321	0.042			19 plugs (All horiz/No vert. measured)
Sole-1	Gas-Bearing Latrobe	800.2	818.2	18.0	18.0	1.00	0.326	0.037	3978.0	0.663	Mobile gas.
Sole-1	Water-Bearing Latrobe	818.2	880.2	62.0	62.0	1.00	0.312	0.038	2812.7	0.013	Mobile water.
Sole-1	All Latrobe	800.2	880.2	80.0	80.0	1.00	0.315	0.038	3040.6	0.164	All Latrobe.
Sole-1		800.2	870.2	70.0	70.0	1.00	0.317	0.038			70m Thickness
Dart-1	Latrobe	911.2	981.2	70.0	69.2	0.99	0.319	0.042	4268.2	0.001	Mobile water.
Dart-1	Latrobe	981.2	1113.2	132.0	130.0	0.99	0.255	0.052	396.3	0.018	Mobile water.
Dart-1	Golden Beach	1113.2	1202.2	89.0	2.0	0.02	0.302		2872.0	0.000	Mobile water.

3.4 Saturation

The average gas saturation for the Sole field was estimated at 80% from an average of the saturation height profile per reservoir facies weighted with the most likely GRV-depth relationship.

This corresponds favourably with the 82% average gas saturation calculated from the attribute populated base case Roxar Geological model with the most likely structural map (see Part D).

The range in the average gas saturation (68% to 88%) for the Sole field was determined by weighting the range in the saturation height profile from the Sole-2 capillary pressure core plugs with the range in the GRV-depth relationship. This takes account the volume of rock covering the gas saturation transition zone.

The end points of the plug permeability range have been used to estimate the range in average field hydrocarbon saturation values of 68% and 88%. It is assumed that these values correspond to P99 and P1 respectively with a triangular distribution around a most likely value of 80% for the probabilistic volumetric estimate.

This gives a P90 of 72% and a P10 of 85% for the field average hydrocarbon saturation.

3.5 Gas Expansion Factor

The analysis of the six separator gas samples and two downhole gas samples are consistent and provide a high degree of certainty in the gas composition. There is also high confidence in the pressure data as a result of the Sole-2 DST and MDT measurements. It is expected that the estimated range in Eg is small.

The range in the Eg value of 81.9 to 83.3 scf/rcf was determined from different methodologies, software programmes and correlations used. The 81.9 to 83.3 scf/fcf were assumed at the P90 and P10 level values of the field average gas expansion factor (Eg) with a normal distribution for the probabilistic estimate of GIP. This relates to a Bg of 0.0122 and 0.0120 rcf/scf respectively.

3.6 Recovery Factor (RF)

The recovery factor has been reviewed against the base case development scenario that has two development wells in the main field accumulation. A range of sensitivities was carried out on the base case model. The biggest impacts on the recovery factor are the residual gas saturation and the connectivity of the northern lobe and Sole-1 lobe to the main field accumulation (ref. Part E).

The uncertainty in the residual gas saturation (see section B2.12 of Part B) for an average initial gas saturation of 80% is considered to be 24%, 15% and 8% at the P90, P50 and P10 level respectively. On the base case simulation model these residual gas saturations correspond to a RF of 60.5%, 71% and 76% respectively.

For the probabilistic reserves a residual gas saturation of 20% is taken as the most likely. This is a conservative approach corresponding to a most likely recovery factor of 66%.

The high side recovery factor was taken to represent 100% volumetric sweep efficiency with a low residual gas saturation of 10% giving a RF of 78%. This was assumed to be at the P1 level.

The low side recovery factor was taken to represent a high residual gas saturation of 25% with both the northern lobe and Sole-1 lobe not connected to the main field accumulation. This gives a RF of 55% and is assumed to be at the P99 level.

A normal distribution was assumed giving a P90 of 59% and a P10 of 72% for the field average recovery factor.

It is noted that there is further potential upside in the RF should a development well be drilled in both the main field and the northern lobe. This coupled with a low residual gas saturation of 10% could result in a recovery factor as high as 86%. This upside has not been included in the probabilistic range of the recovery factor.

Variation to the base case locations for the two development wells will be reviewed as part of the development optimisation of well location and well redundancy against gas contractual arrangements. This will be part of the final Sole Field Development Plan.

4 PROBABILISTIC MODEL RESULTS

On a P50 basis the estimate of GIP and reserves in the Sole field are 346 Bscf and 227 Bscf respectively (Table A5 and Figure A3). The P90 estimate of GIP and reserves are 300 Bscf and 191 Bscf respectively.

The P90 to the P10 probability (i.e. 80% confidence range) for the GIP and reserves estimates is covered by 98 Bscf and 80 Bscf respectively.

Table A5 Overview of 2003 GIP and Reserves

Sole Field	**OMV-2003**			
	Mean	P90	P50	P10
GIP (Bscf)	**349**	300	346	398
Reserves (Bscf)	**230**	191	227	271

Figure A1 Sole Field GIP & Reserves Distribution

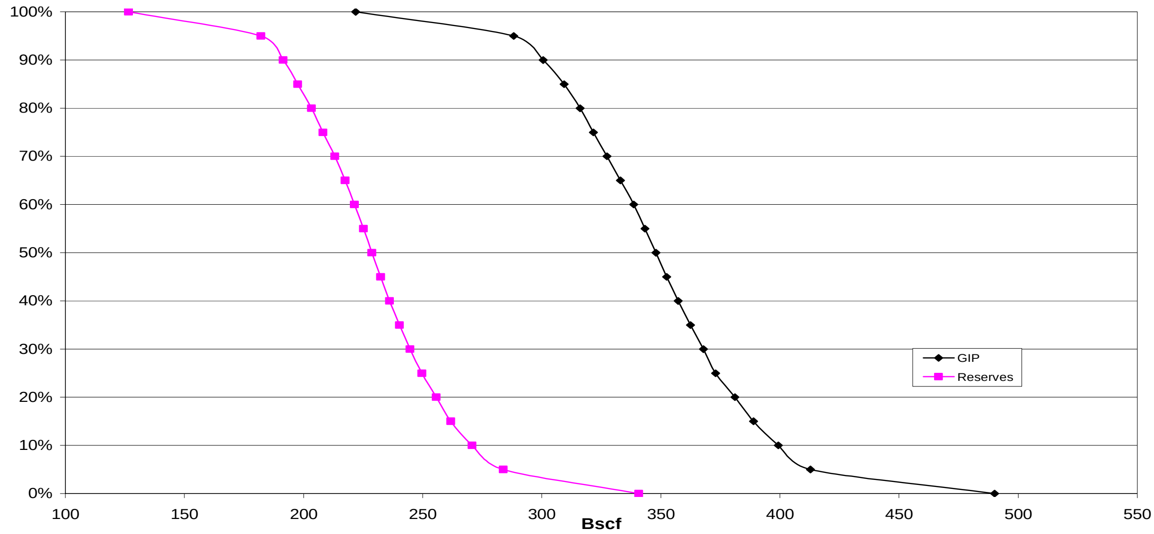
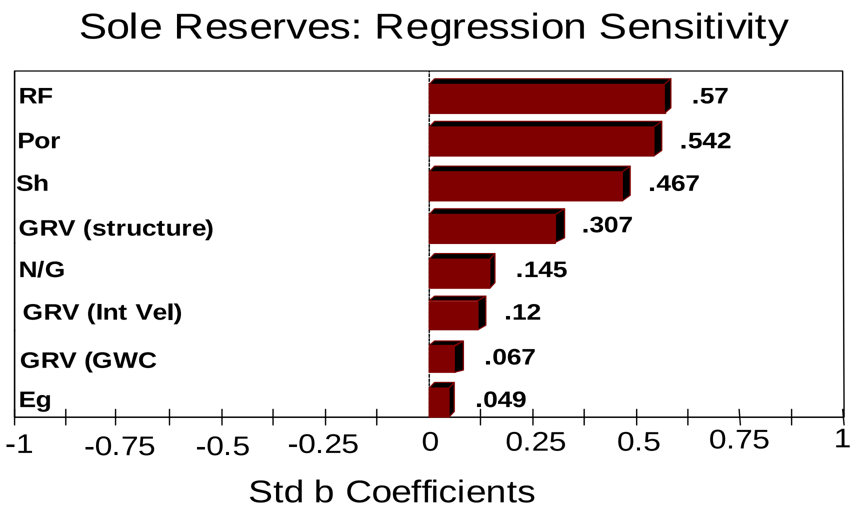


Figure A2 Sole Reserves: Regression Sensitivity[2]



The uncertainty of the Recovery factor ("RF") is identified as the most significant parameter on the reserves uncertainty (Figure A2) followed by Porosity, Sh and the mapped GRV range etc., The uncertainty on the RF is primarily a function of the uncertainty in the residual gas saturation.

There is limited scope for reserves uncertainty reduction through further engineering studies. Moreover it is considered that there is no scope for reserves uncertainty reduction by way of further data acquisition on a value of information to cost basis in advance of a potential field development. However further simulation modelling will help in the optimisation of well placement for field development.

Differences between the pre-Sole-2 (2001) and post Sole-2 (2003) volumes are given in Appendix AB.

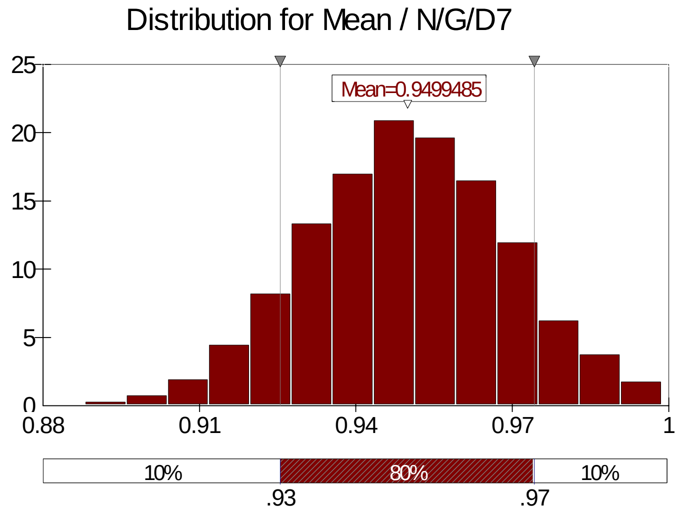
5 PROBABILISTIC AND DETERMINISTIC MODEL COMPARISON

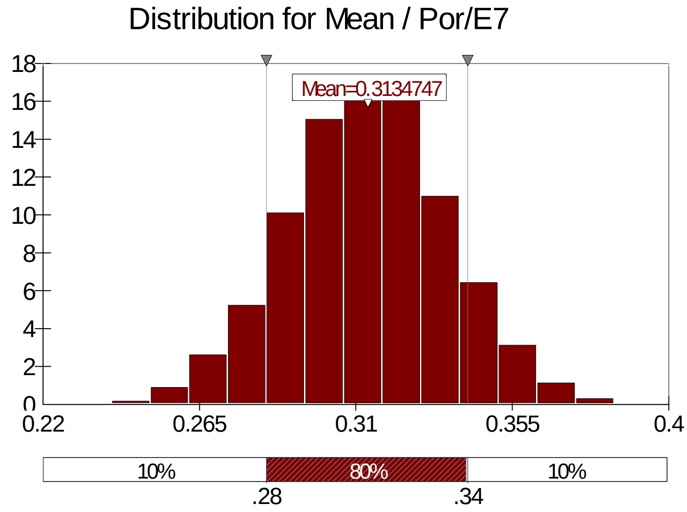
- The most likely case structural map GRV of 494.5Mm3 (Part C) corresponds to a P75 on the GRV probabilistic distribution function.
- The base case 3D geological model, created from the most likely structural map and the base case facies model, with a net-to-gross of 100% has a mean GIP of 358.7Bscf (Part D). This corresponds to a P72 on the GIP probabilistic distribution function in line with the probability of the most likely mapped GRV (P75).
- The conservative 3D geological model, created from the most likely structural map and the base case facies model with 8% volume of non-reservoir has a mean GIP of 327.2Bscf (Part D). This corresponds to a P75 on the GIP probabilistic distribution function in line with the probability of the most likely mapped GRV (P75).
- The optimistic 3D geological model, created from the P10 structural map and the base case facies model has a mean GIP of 379.5Bscf (Part D). This corresponds to a P25 on the GIP probabilistic distribution function.

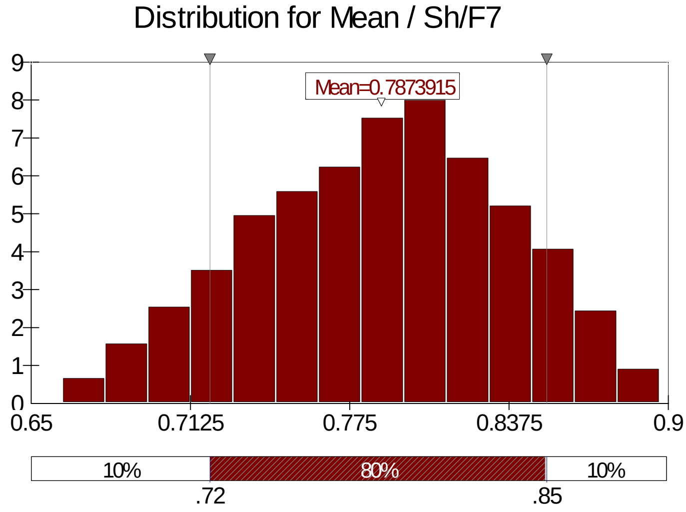
[2] The stb b coefficient values correspond to the fraction change in the standard deviation of the output parameter (Reserves) from a 1 standard deviation change in the input parameter. This sensitivity analysis identifies the "driving variables" that merit additional scrutiny and, by contrast helps reduce effort wasted on worrying about the wrong things. Unlike the traditional tornado chart or spider diagrams obtained by tracking the changes in an output caused by allowing exactly one model input to vary while holding the others fixed, this sensitivity analysis from Monte Carlo simulation is far more versatile because it permits functional or correlation-type relationships among the inputs.

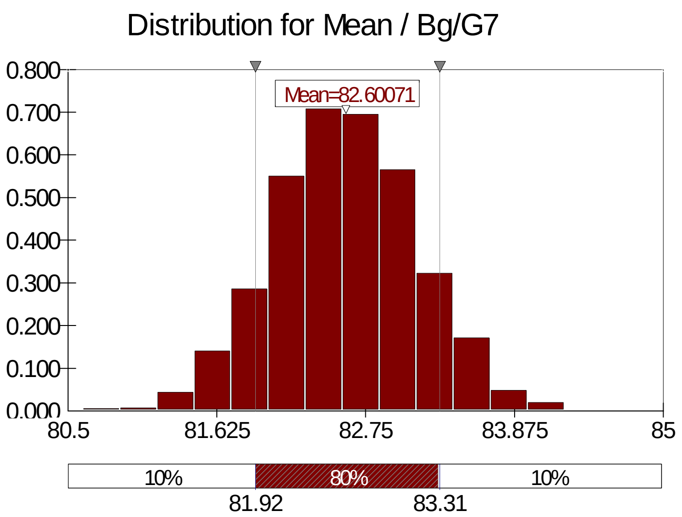
- The GIP range from the 10 geological realisations on the base case 3D model (Part D) corresponds to the P82.5 to P65 on the GIP probabilistic distribution function.
- The smallest GIP from the 3D geological model realisations is 318.3Bscf. This corresponds to a P78 on the GIP probabilistic distribution.
- The largest GIP from the 3D geological model realisations is 389.8Bscf. This corresponds to a P15 on the GIP probabilistic distribution.
- The extremities on the GIP from the 3D geological model realisations are within the 80% confidence range of the probabilistic GIP range.
- The probabilistic GIP range is wider that the 3D geological model GIP range. The prime reason for this is the uncertainties on some parameters (porosity and saturation) used in the probabilistic estimate are wider taking account of possible variations across the field. The 3D geological model porosity and saturation ranges are limited to the variations observed in the Sole-1 and Sole-2 well logs.

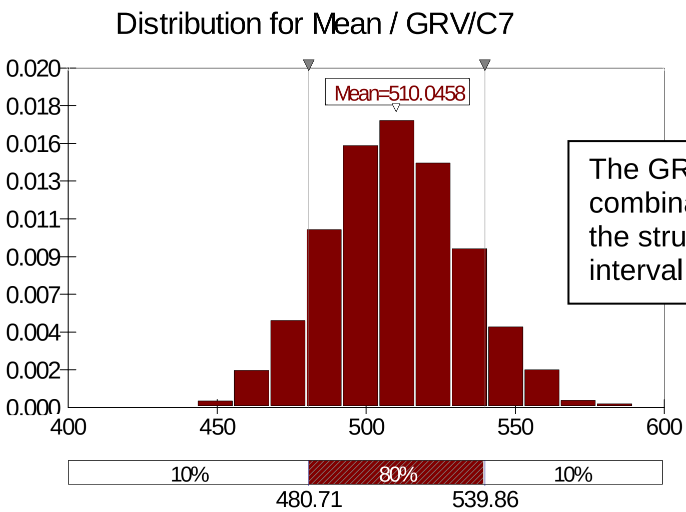
APPENDIX AA SOLE FIELD GIP AND RESERVES: 2003 PARAMETER DISTRIBUTION FUNCTIONS



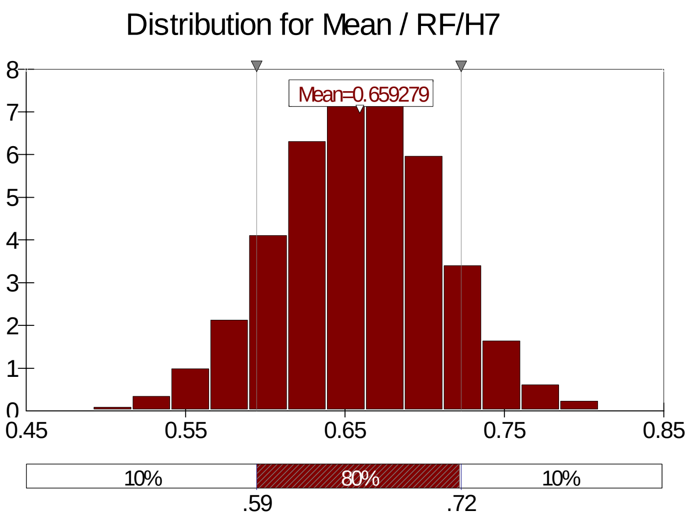








The GRV distribution is a combination of the uncertainties in the structural maps, the gas sand interval velocity and the GWC.



APPENDIX AB DIFFERENCES IN THE 2001 AND 2003 VOLUMES

TABLE OF CONTENTS

This appendix highlights some of the differences in the results, the methodology and the available data employed in the determination of probabilistic volumetrics for the Sole field pre Sole-2 (2001) and post Sole-2 (2003).

1 RESULTS

The following is a comparison between Pre Sole-2 (2001) and Post Sole-2 (2003) GIP and Reserves estimates:

GIP (Table AB1 and Figure AB2)

- A 19% increase on the 2001 GIP at the Mean level
- A 23% increase on the 2001 GIP at the P50 level
- A 38% increase on the 2001 GIP at the P90 level
- A 7% increase on the 2001 GIP at the P10 level
- An uncertainty range of -13%/+15% on 346Bscf (P50) at the 80% confidence level

Reserves (Table AB1 and Figure AB3)

- A 15% increase on the 2001 Reserves at the Mean level
- A 19% increase on the 2001 Reserves at the P50 level
- A 36% increase on the 2001 Reserves at the P90 level
- A 5% increase on the 2001 Reserves at the P10 level
- An uncertainty range of -16%/+19% on 227scf (P50) at the 80% confidence level

Table AB1 GIP and Reserves estimates from Pre and Post Sole-2 (2001 vs 2003)

Sole Field	**GIP (Bscf)**			
	Mean	P90	P50	P10
OMV-2001	**292**	217	282	372
OMV-2003	**349**	300	346	398

Sole Field	**Reserves (Bscf)**			
	Mean	P90	P50	P10
OMV-2001	**200**	142	191	257
OMV-2003	**230**	191	227	271

Figure AB1 GIP Distribution (Sole Field): Pre and Post Sole-2 (2001 vs 2003)

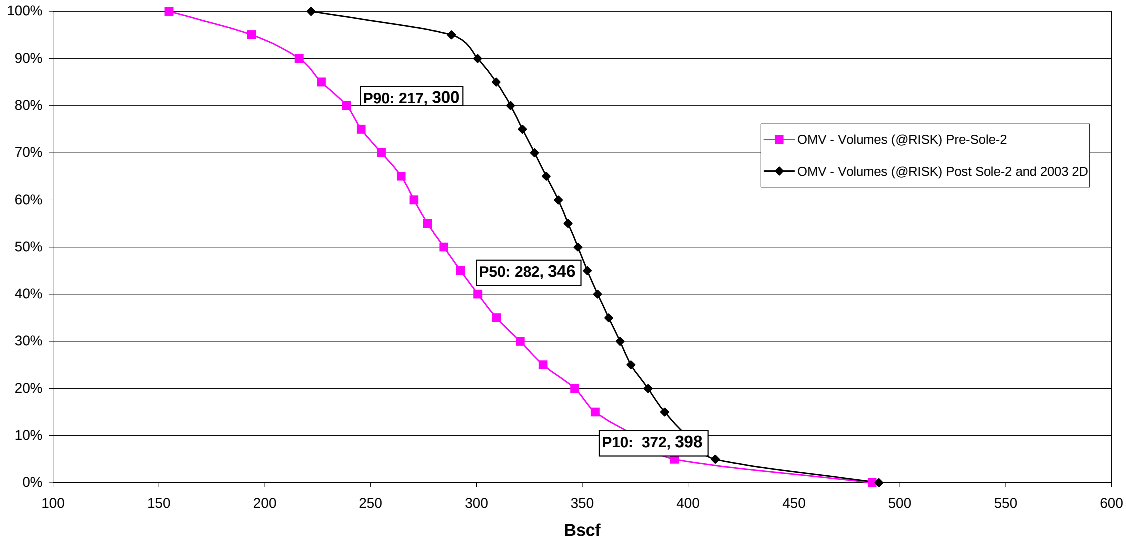
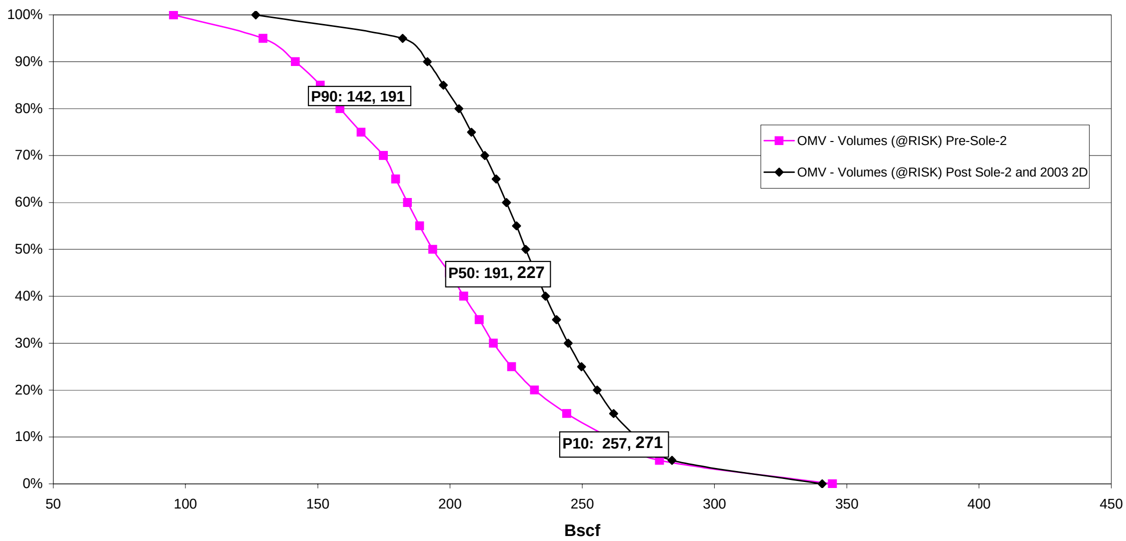


Figure AB2 Reserves Distribution (Sole Field): Pre and Post Sole-2 (2001 vs 2003)



2 DATA

The 2003 probabilistic volumetric estimate utilised the 2003 2-D seismic data, the results from a petrophysical evaluation of regional wells (Part B), Sole-2 (2002) well data, test results and reservoir simulation.

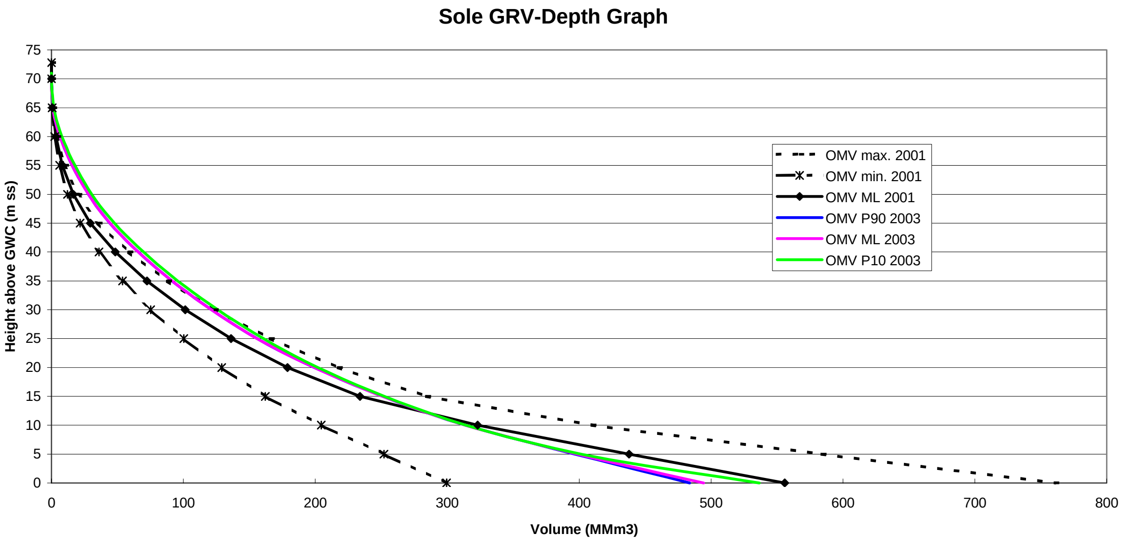
3 GRV

A GRV-depth graph is given in Figure AB3 presenting the range in OMV's GRV between 2001 and 2003.

At the mean level the 2003 GRV (510 MMm3) is 6% lower than the 2001 estimate (542 MMm3).

In 2001 the uncertainties in the GRV reflected the large uncertainties that were carried for the interval gas velocity and seismic resolution (see Part C). These uncertainties were reduced from drilling of Sole-2 and the results of the 2D seismic data. The gas sand interval velocity uncertainty range was reduced from 1600/2118/2600 m/s to 2050/2100/2150 m/s at 80% confidence level.

Figure AB3 Sole GRV-Depth Ranges (OMV–2001 and 2003)



4 NET-TO-GROSS

At the mean level the 2003 net-to-gross of 95% is 8% higher than the 2001 estimate of 87.5%.

In 2001 a uniform distribution was assumed with end points of 75% and 100%. This gave a P90 of 77% and a P10 of 98%.

The 2003 distribution is normal with a P90 of 93% and a P10 of 97%. The significant increase in the average net-to-gross value for the field at the P90 level is primarily attributed to the high net-to-gross seen in the crestal Sole-2 well along with the regional wells and supported by the 3D geological modelling.

5 POROSITY

In 2003 a petrophysical evaluation of the Sole field wells was carried out. This included Sole-2 calibrated against core analysis along with correlatable wells Dart-1, Leatherjacket-1 and Hammerehad-1 (Part B).

The results of this study gave greater confidence for higher porosities within the field. The 2003 evaluation gave an average field porosity for the field at P90 of 28 p.u. and at P10 of 34 p.u. This compares with a P90 of 27 p.u. and at P10 of 31 p.u in 2001.

Moreover the range in average field porosities for the field was increased at the 80% confidence level from 4p.u. to 6 p.u.

At the mean level the 2003 Porosity (31.3 p.u.) is 8% higher than the 2001 estimate (28.8 p.u.).

6 HYDROCARBON SATURATION

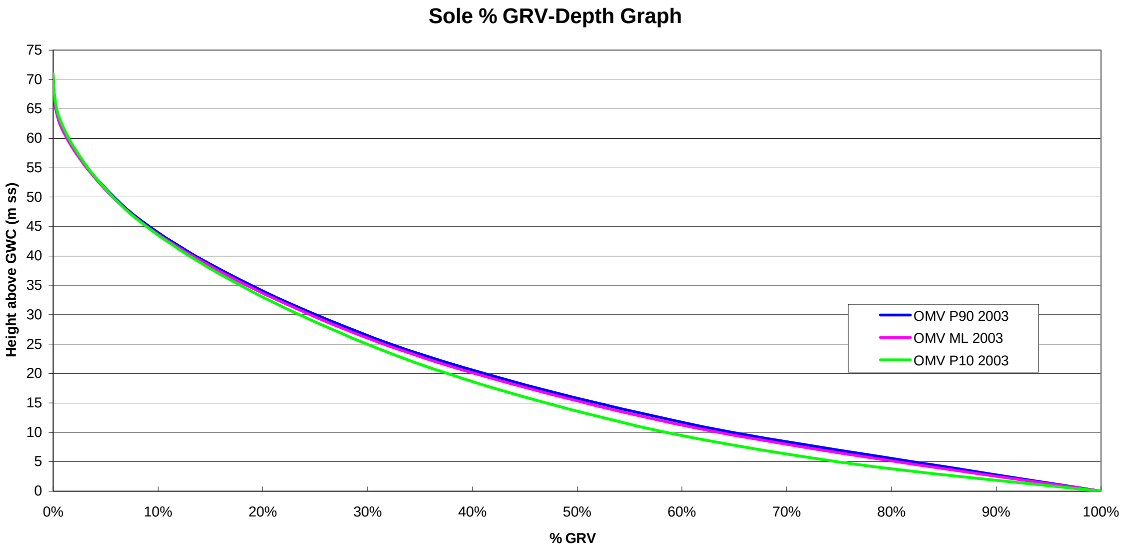
The average gas saturation and its range for the Sole field were estimated by weighting the saturation profile corresponding to the appropriate rock facies with the GRV. This suitably takes account of the volume of rock covering the gas saturation transition zone. It is noted that for the range in the 2003 maps some 50% of the GRV is covered in the first 16 metres above the GWC (Figure AB4).

The 2003 evaluation has an average field hydrocarbon saturation for the field at P90 of 72% and at P10 of 85%. This compares with a P90 of 64% and at P10 of 75% in 2001.

At the mean level the 2003 Hydrocarbon Saturation (80%) is 15% higher than the 2001 estimate (69.5%).

The primary change in the average hydrocarbon saturation for the field is the greater confidence on the existence of a significantly smaller transition zone than previously carried (2001). This confidence is a result of the saturation profiles determined from both the Sole-2 capillary pressure curve measurements and the calibration with the wireline logs (Part B).

Figure AB4 Sole % GRV versus Depth (OMV 2003)



7 EXPANSION FACTOR

At the mean level the 2003 average reservoir Eg of 83.2 scf/rcf is 3.5% lower than the 2001 estimate of 86 scf/rcf. An Eg of 86 scf/rcf was based on the Sole-1 1973 reservoir pressure of 1223 psia and temperature of 110F.

The 2003 average reservoir Eg for the field at P90 is 81.9 scf/rcf and at P10 is 83.3 scf/rcf. This compares with a P90 of 84.7 scf/rcf and a P10 of 87.3 scf/rcf in 2001.

The primary change in the average expansion factor for the field is the greater confidence in the gas composition and certainty on some depletion in the reservoir pressure.

8 RECOVERY FACTOR

The average Recovery Factor and its range for the Sole field were estimated by reservoir simulation of the Sole field GIP range and its uncertainties in 2003.

The 2003 evaluation has an average Recovery Factor for the field at P90 of 59% and at P10 of 72%. This compares with a P90 of 60% and a P10 of 76% in 2001.

At the mean level the 2003 Recovery Factor (66%) is 3% lower than the 2001 estimate (68%).

The primary change in the average Recovery Factor for the field is due to the greater confidence brought from the 2003 simulation modelling.