decisions with confidence

A SIMPLE AND PRACTICAL METHOD TO ESTIMATE UNDISCOVERED HYDROCARBONS FOR A SPECIFIED TIMEFRAME

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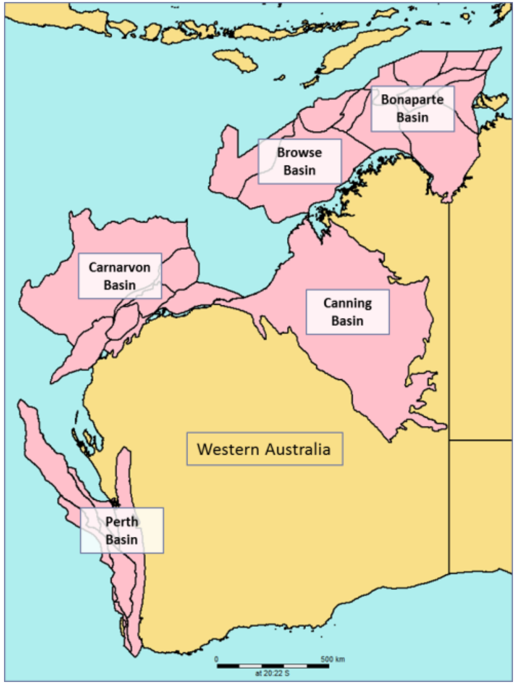
Overview

- Oil companies, utilities, financial institutions and governments need to understand the resources available for future markets *within a defined timeframe*
- RISC has developed a simple approach to estimate the undiscovered resources for basins with a material exploration history for such a timeframe
- Approach uses raw data on exploration wells:
  - number of wells
  - discoveries per year
  - field sizes
- This talk describes this method and gives results for the undiscovered gas resources of the Carnarvon, Browse and Bonaparte Basins

Undiscovered resources

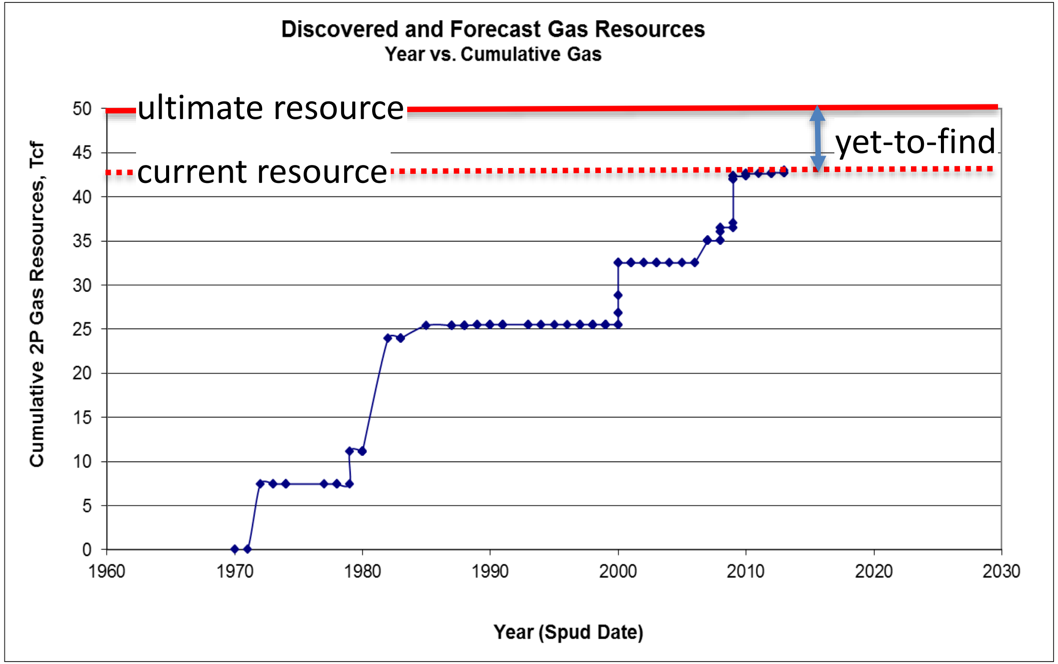
- In basins with some exploration success, experience informs us that additional discoveries will be made; these currently undiscovered resources are the 'yet-to-find'
- There is no probability of success attached to them – there is an implied certainty of discovery
- However, there *is* considerable uncertainty in the total volume to be found; thus estimates of undiscovered volumes must be quoted as a range, e.g. Low - Mid - High

WA basins **NEW MAP NEEDED**



Undiscovered resources

- Exploration tends to discover the largest fields first, and then incrementally smaller fields
- Cumulative discovered resources thus shows progressively smaller increases through time, asymptotically approaching the ultimate resource for the basin
- Difference between the ultimate resource and the current cumulative (original) resource is the yet-to-find



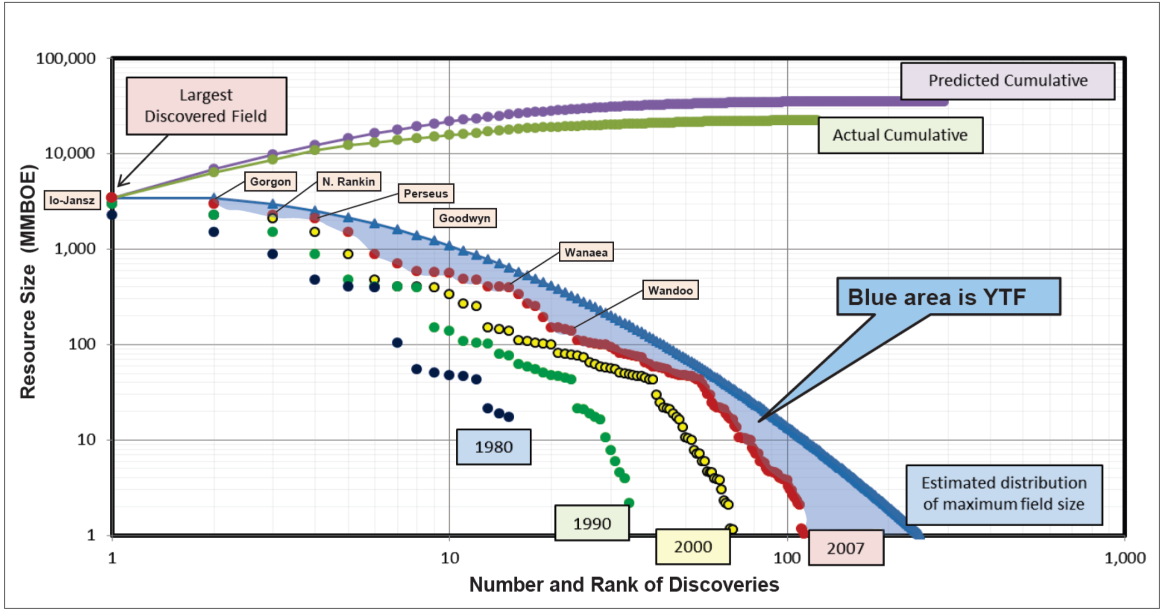
Approaches used to estimate undiscovered resources

- A wide range of techniques can be used to estimate undiscovered resources
- At one end of the spectrum are approaches that require a full geological understanding:
  - Very detailed and data-intensive ground-up petroleum systems and play fairway analyses
  - Charge modelling and migration pathways, depositional environments and reservoir distribution, trap sizes
- At the other are approaches that use extrapolation of discovery rates
  - Also known as discovery-process modelling
  - Requires minimal geological input
- These methods may be combined

Discovery-process modelling of undiscovered resources

- Conventional approaches use the observation that field sizes follow a 'parabolic fractal' trend
- Requires the right choice of 'decay' from the largest discovered field to define *ultimate* resource trend
- Historic 'look-back' is possible, but *forecasts* for specific time periods are difficult

Example for Northern Carnarvon



Barber, P. 2013 Oil exploration potential in the greater northern Australian-New Guinea super gas province, West Australian Basins Symposium, Perth

An alternative approach

- We have developed a method that:
  - uses basic exploration and field data
  - requires minimal understanding of mathematics
  - has inputs and outputs that are readily assessable for reasonableness
  - is related to a forecast period to address specific company requirements
  - produces a range of estimates to capture the uncertainty in the forecast
- Our approach may be considered as a simple variant of discovery-process modelling

How it's done: collect and organise the following data

- Well name
- Spud date
- Well result
- For the discoveries, the mid case ultimate resource (ultimate recoverable [UR] volume) and hydrocarbon phase
  - UR estimates derive from government or company websites or use educated guess for nominal volume
  - by convention, all field resources (including field upgrades and extensions) are attributed to the discovery well
- Order by date and give a well count number (1 = first well)
- Identify discoveries (oil/condensate/gas as appropriate) with a flag
- Calculate cumulative resources
- Plot cumulative resources against year (spud date), exploration well count, discovery count

Calculating the undiscovered resource

- A simple equation is used

number of years	**x**	**number of wells to be drilled per year**	**x**	**average chance of success**	**x**	**average size of discovery**	**=**	**total undiscovered resource**

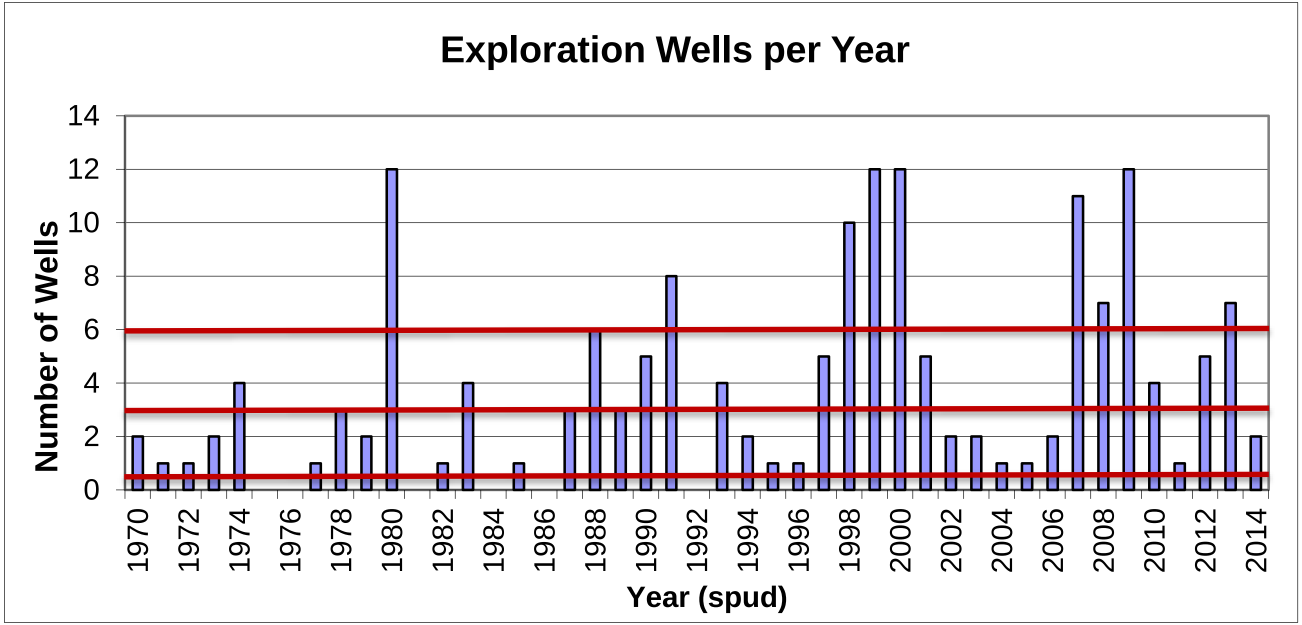
In the following slides we discuss each parameter...

Input 1: Number of years for the forecast period

- Define the number of years that the analysis should cover
- In RISC's experience, a short to medium term forecast of 15 years is often appropriate for company requirements
- This is the only input with a single figure; all other inputs cover a range of outcomes

Input 2: Number of wells to be drilled per year

- Choose minimum, most likely and maximum *average* numbers of *exploration* wells to be drilled per year for the forecast period



Minimum
0.5 wells/yr
Most-likely
3 wells/yr
Maximum
6 wells/yr

Input 3: Chance of discovery

- Choose minimum, most likely and maximum *average* chance of discovery for the forecast period (no implication for commercial volume)
- Refer to historical success rates since (1) start of exploration and (2) a more recent period to define realistic range
- The chance may not have decreased as the basin becomes progressively better understood

Parameter	Since start of exploration	Since 2000
Total wells	170	75
Total discoveries	21	13
Total gas discoveries	19	13
Probability of gas discovery	11%	17%

Minimum
5%
Most-likely
11%
Maximum
23%

Example from Browse Basin

Input 4: Average size of discovery

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- Choose minimum, most likely and maximum *average* size of discovery for the forecast period
- Refer to existing field sizes since start of exploration and for a more recent period to define realistic range
- Average size is likely to be materially smaller than historical averages

Parameter	Since start of exploration	Since 2000
Total discoveries	21	13
Total gas discoveries	19	13
Cum gas discovered, Tcf	45.2	19.7
Average gas discovery size,Tcf	2.4	1.5

Minimum
0.2 Tcf
Most-likely
0.8 Tcf
Maximum
2 Tcf

Example from Browse Basin

Input summary

- The various inputs are defined as a simple triangular distribution

INPUTS				
Case	Forecast period	Wells per year	Average gas success rate	Average size of discovery, Tcf
Minimum	15 yrs	0.5	5%	0.2
Most likely		3	11%	0.8
Maximum		6	23%	2

Example from Browse Basin

Results - example

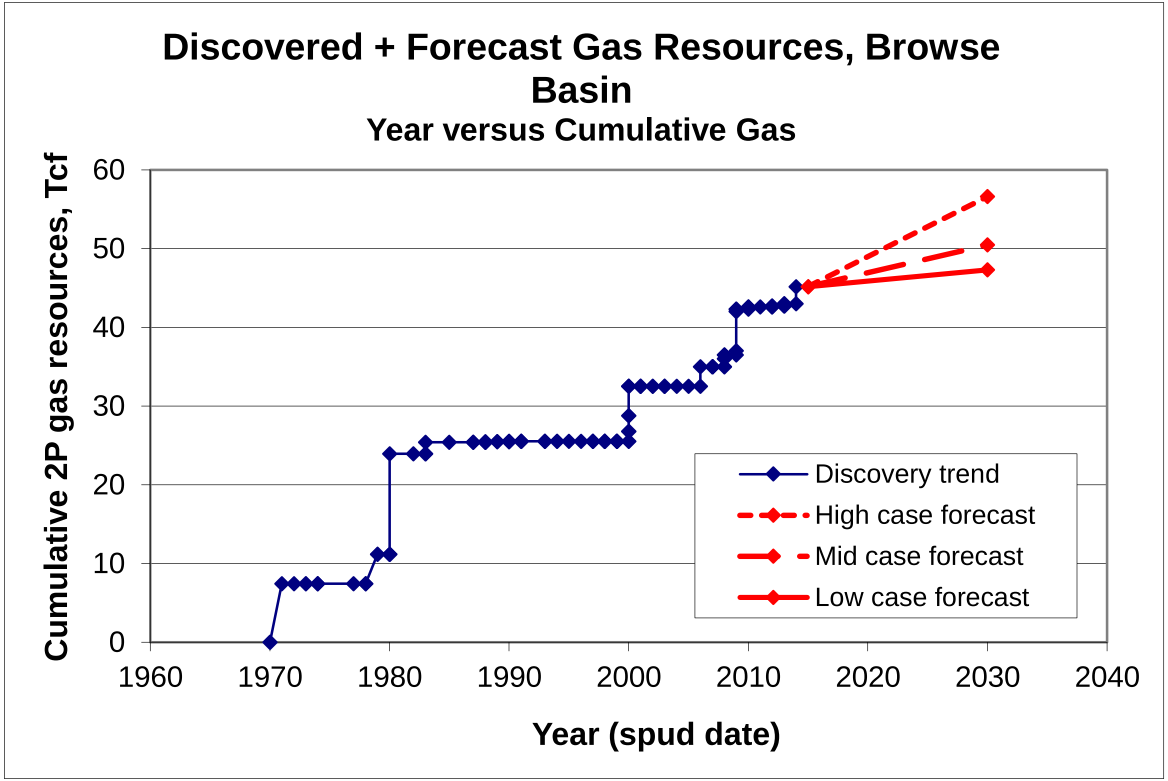
- The various inputs are multiplied probabilistically
- Arithmetic multiplication would give low and high extremes

RESULTS		
Case	**Total new wells to 2030**	**Forecast additional gas, Tcf**
Low Case (P90)	25	2.1
Mid Case (P50)	46	5.3
High Case (P10)	71	11.3

Example from Browse Basin

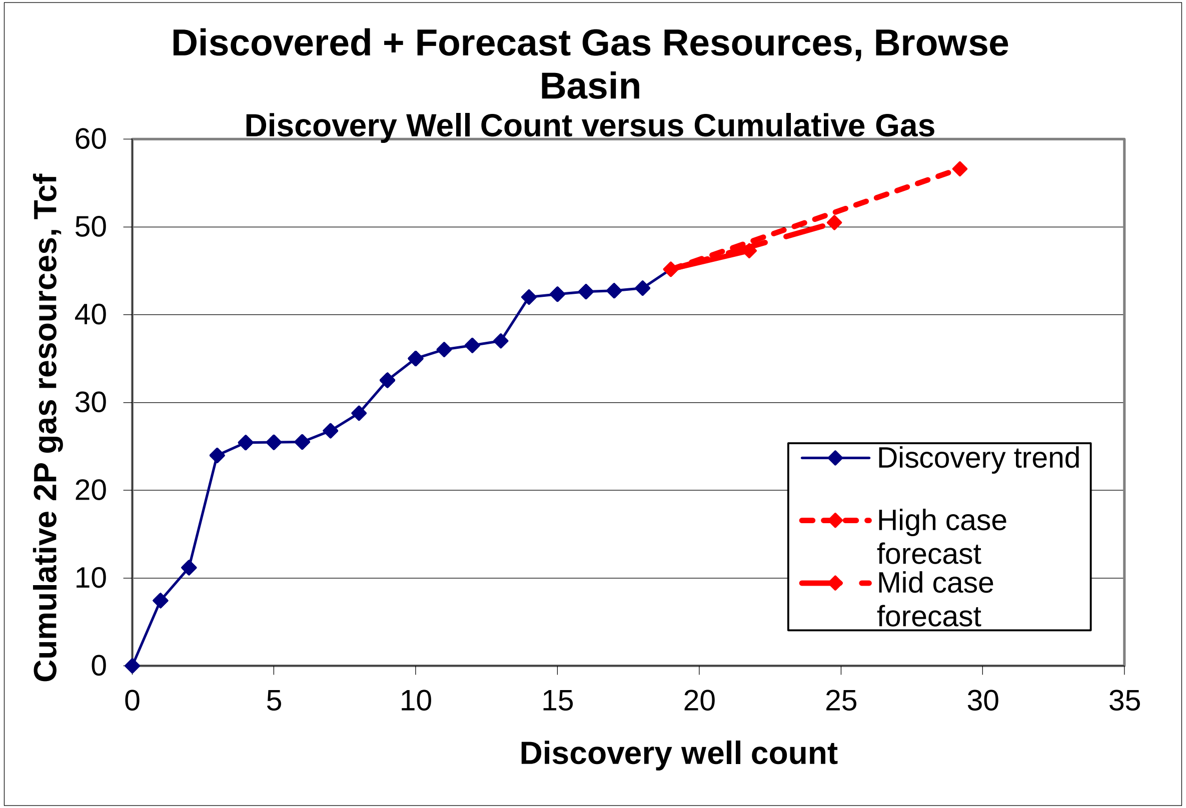
Plot the forecast - (1) Cumulative resources vs. year

- Plot shows the actual progress of exploration and discovery year by year
- Forecast lines are linear; resource only calculated for the end of the period
- Forecast lines have same length, all corresponding to the forecast period
- Check the forecast resources range – is it realistic?



Plot the forecast – (2) Cumulative resources vs. discoveries

- Plot shows the increase of total resource measured against discovery well count
- This is the true 'creaming curve'
- Forecasts are different lengths due to different forecast well numbers



Undiscovered gas resources for main offshore WA basins

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Basin	Area	Undiscovered gas resources for 2015-2030, Tcf		
		Low Estimate (P90)	Mid Estimate (P50)	High Estimate (P10)
Bonaparte Basin	Malita / Sahul / Petrel sub-basins	1.3	3.9	8.2
	Vulcan Graben, Londonderry Shelf, Ashmore Platform	0.0	0.1	0.2
Browse Basin		2.2	5.4	11.3
Northern Carnarvon Basin	Barrow & Dampier sub-basins, Lambert and Peedamullah shelves	0.2	0.5	1.3
	Rankin Platform, Exmouth Plateau-Kangaroo Syncline	4.4	10.6	21.7
	Exmouth Sub-basin	0.0	0.1	0.2
Total (probabilistic, to nearest Tcf)		**16**	**25**	**36**

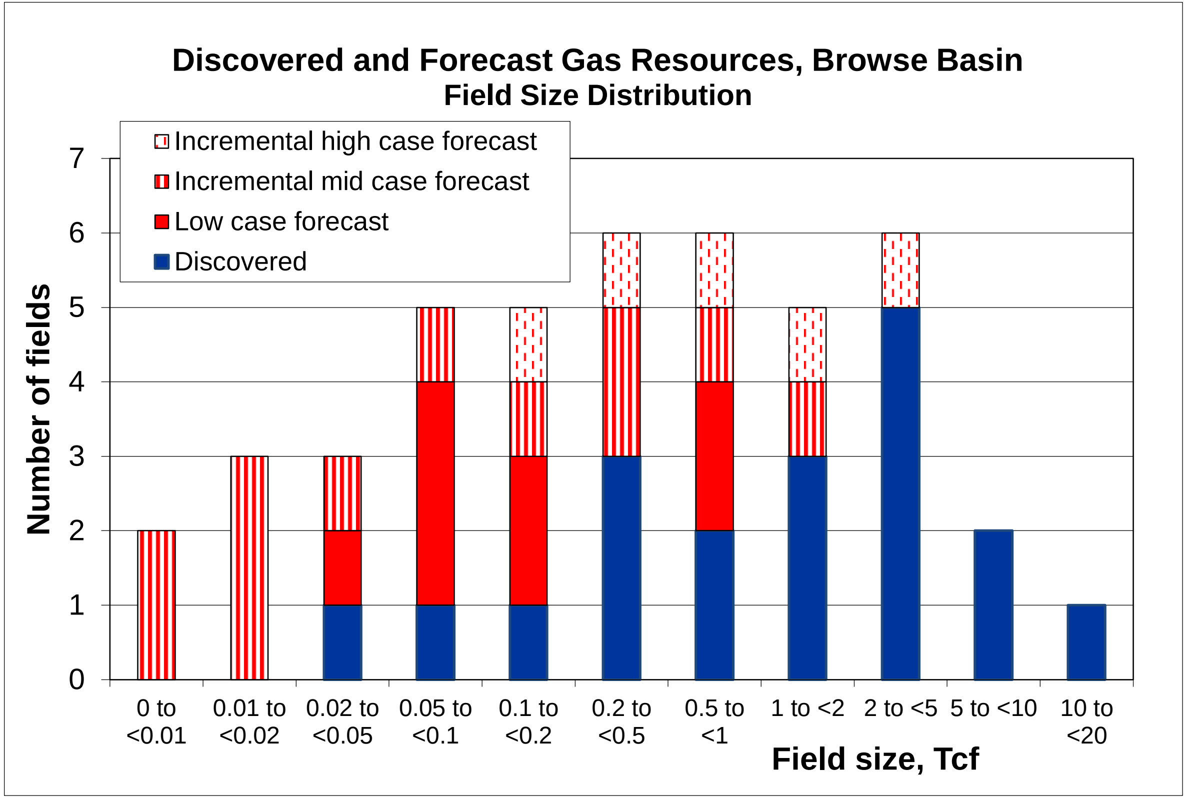
- Largest contributor: outer N Carnarvon – P50 10.6 Tcf

Field size distribution

- As field size is fundamental to commercial viability, companies interested in total undiscovered resources will also be interested in future field sizes.
- The basic input data contains the necessary information to assess the pool size distribution.
- Field size distributions plotted a part of conventional resource estimates tend to use field rank plots. We have used a simpler plot.
- The *discovered* field size data is organised in groups of an approximately logarithmic nature, and plotted against the number of fields.
- The expected increasing number of smaller fields in mature basins is offset in practice as (1) companies drill the largest prospects first, and (2) smaller uneconomic prospects may never be drilled; this gives a skew towards larger field sizes.

Forecast field size distribution

- The estimated total *undiscovered* resource is comprised of pools of various sizes
- Additional pools of varying sizes are added to even out the distribution
- With iteration the totals for each of the Low, Mid and High cases match the calculated forecast resources



Limitations of this technique

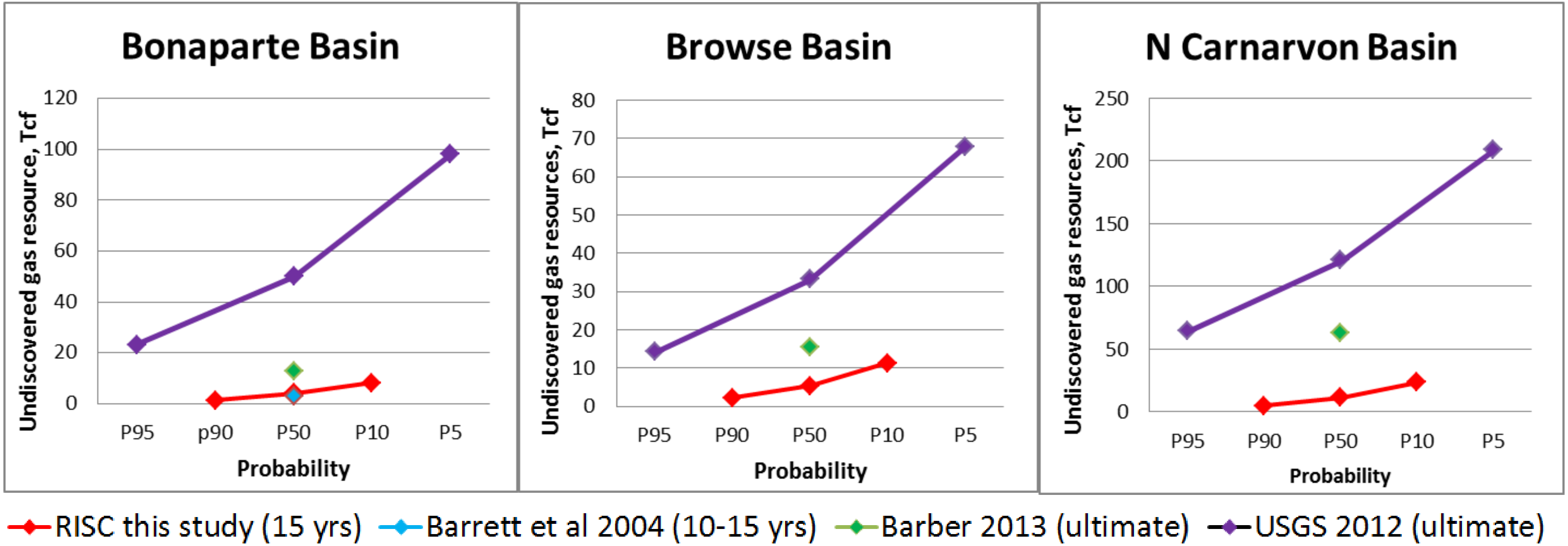
- Needs a material level of exploration within the basin to provide sufficient data for analysis (e.g. assessment of Roebuck Basin/Bedout Sub-basin [Phoenix Field] YTF would not be possible)
- Unexpected success from a new play may not be captured, unless the previously defined high case forecast was particularly optimistic
- These limitations nevertheless also apply to YTF approaches derived from other discovery-process methods
- The analysis refers to whole basins; nominally the area that has been drilled. Consideration of relative prospectivity *within* basins requires geological analysis.

Comparison with previous estimates (1)

- We compare our estimates with those of several previous studies for western Australian basins

Reference	Methodology	Forecast period
Barber, P. 2013	parabolic fractal	ultimate resource
Barrett, AG et al / Geoscience Australia 2004	discovery-process + petroleum systems	10-15 yr ahead
USGS / Pollastro, RM et al 2012	full geological systems analysis	ultimate resource

Comparison with previous estimates (2)



- Current study is roughly consistent with Barrett et al, but ultimate resource YTF for Barber, and especially USGS are much higher, and illustrate difficulties in using such work for a short to medium term outlook

*RISC Low, Mid & High estimates for Bonaparte & Carnarvon basins here are arithmetic sums

Summary

- RISC has developed a simple approach to estimate the undiscovered resources ('yet-to-find') for basins with a material exploration for a specified timeframe
- The method uses simple, understandable and easily auditable parameters (number of exploration wells, probability of success and average field size)
- Using this approach, the total undiscovered gas resources of the Perth, Carnarvon, Browse and Bonaparte Basins are:

Low Estimate	Mid Estimate	High Estimate
16 Tcf	**25 Tcf**	**36 Tcf**

  - The method also allows predictions of field sizes. For the primary gas-bearing basins (outer Carnarvon, Browse, east Bonaparte), these are (Low-Mid-High):

0.5-1 Tcf	1-2 Tcf	2-5 Tcf	5-10 Tcf
3 – 7 – 9 pools	**1 – 3 – 4 pools**	**0 – 1 – 4 pools**	**0 – 0 – 1 pool**

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