

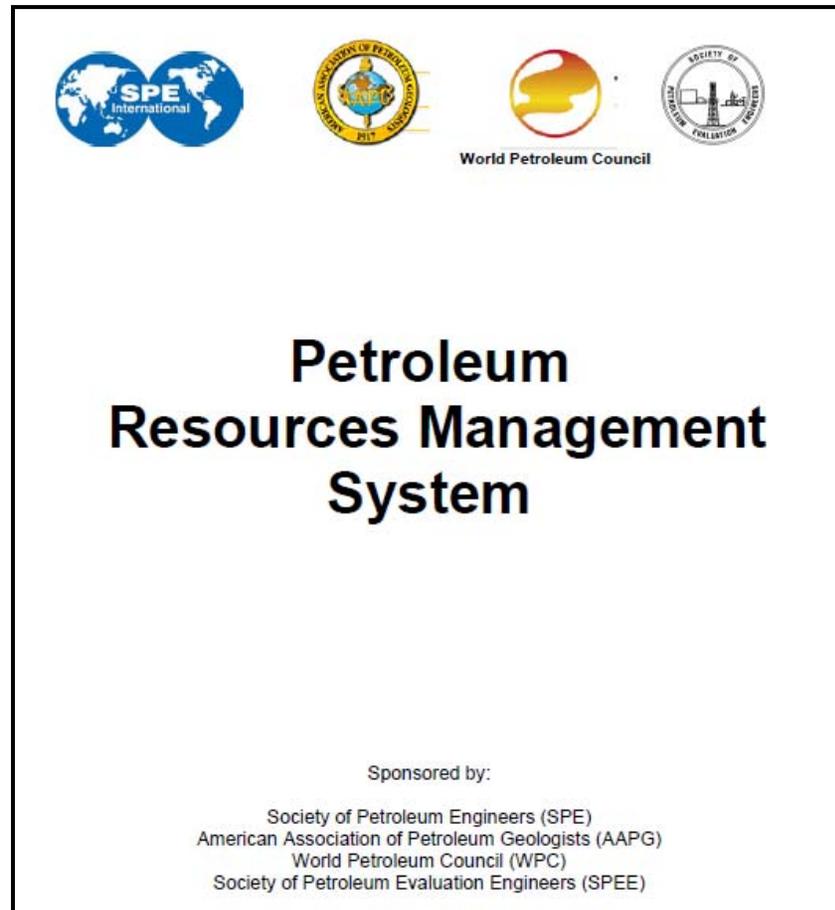
Progress Towards a Common Language for Unconventional Resources and Reserves

Roadmap for Unconventional Gas Projects in South Australia

**Jim Weaver and Creties Jenkins
DeGolyer and MacNaughton
July 27, 2012**

The Petroleum Resources Mgmt. System

- PRMS was created by the SPE Oil and Gas Reserves Committee and released in March, 2007
- Approved by other professional societies
- Was a key component of the 2009 SEC rules revisions
- Commonly called the “Definitions” document

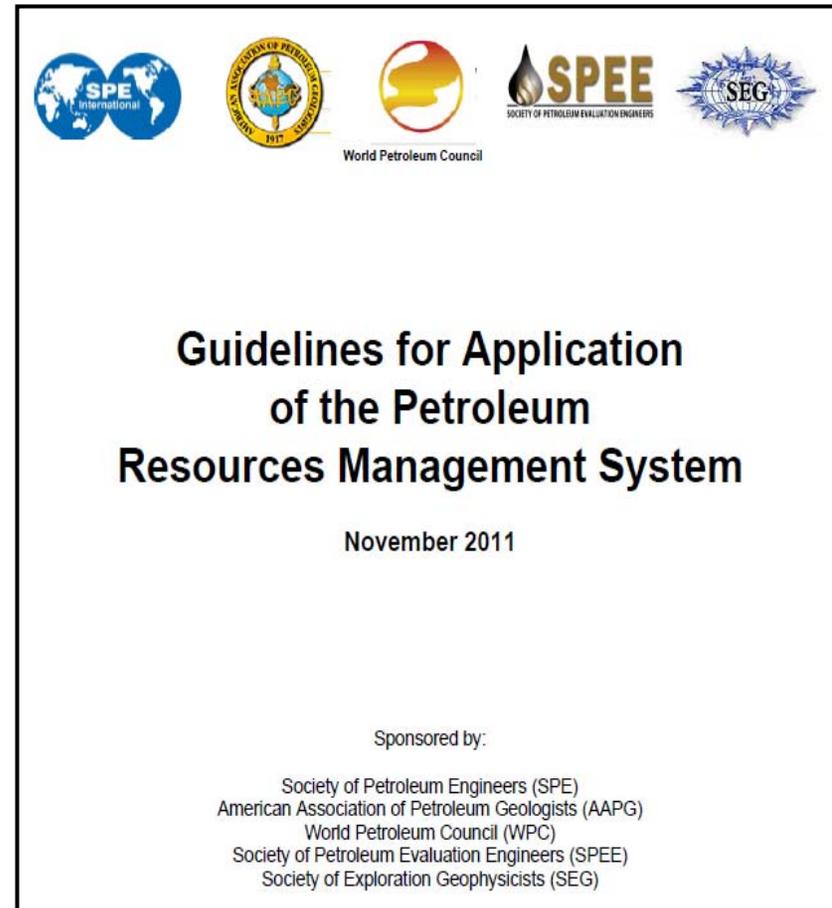


What PRMS Says about Unconventionals

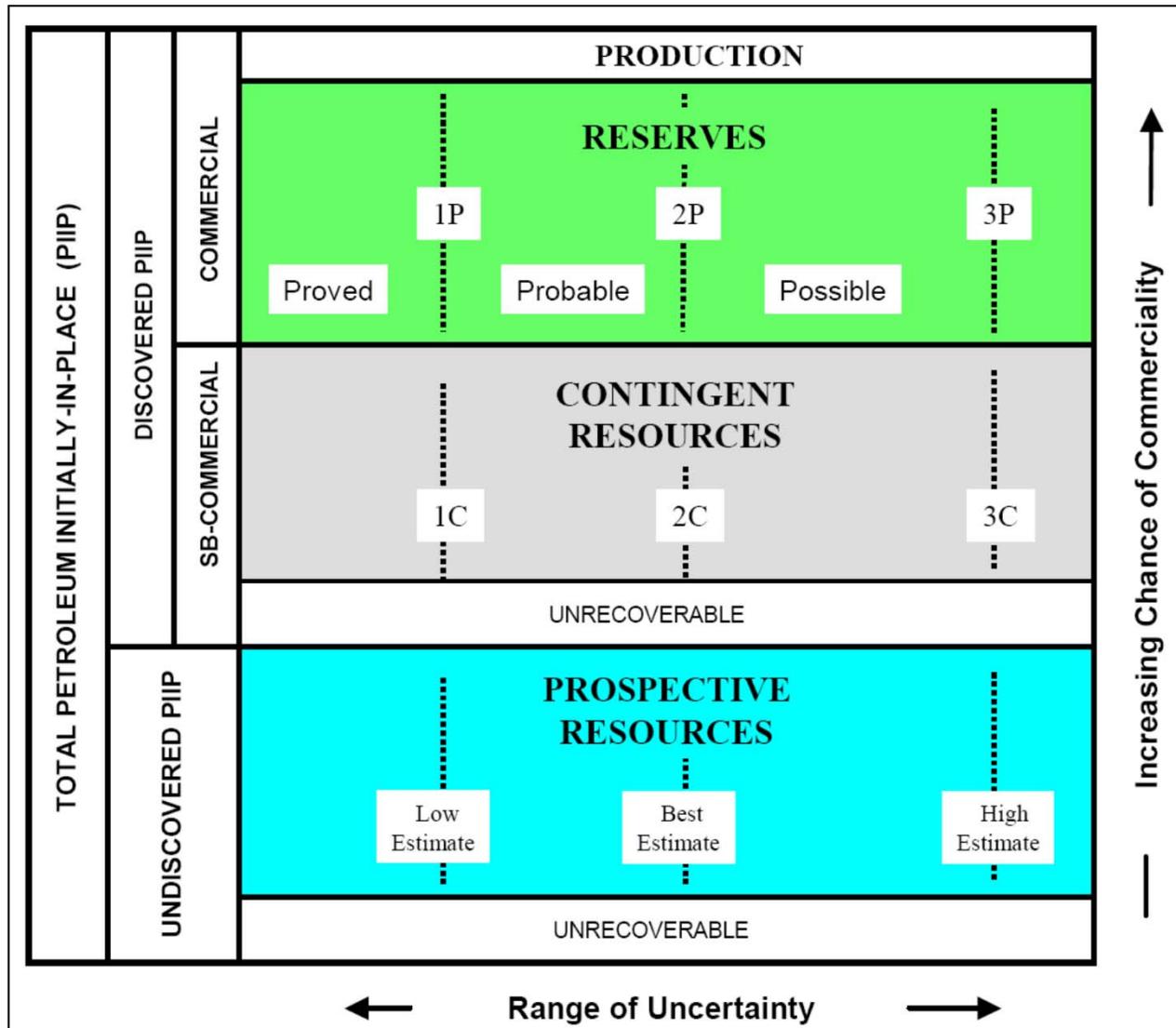
- Exist in petroleum accumulations that are pervasive throughout a large area
- Are not significantly affected by hydrodynamic influences (also called “continuous-type deposits”)
- Typically need increased sampling density to define uncertainty of in-place volumes, variations in reservoir and hydrocarbon quality, and their detailed spatial distribution
- May require successful pilots or operating projects in the subject reservoir or successful projects in analogous reservoirs to establish a distribution of recovery efficiencies

The PRMS Applications Document

- Released in November 2011
- Provides additional guidance for the application of PRMS
 - Emphasizes that the discovery test needs to be satisfied prior to making any estimates of discovered resources
 - Clarifies the criteria for a good analog and, in the absence of this, requires a planned and budgeted pilot project
 - Restricts the areal extent to which discovered resources can be assigned around a discovery well

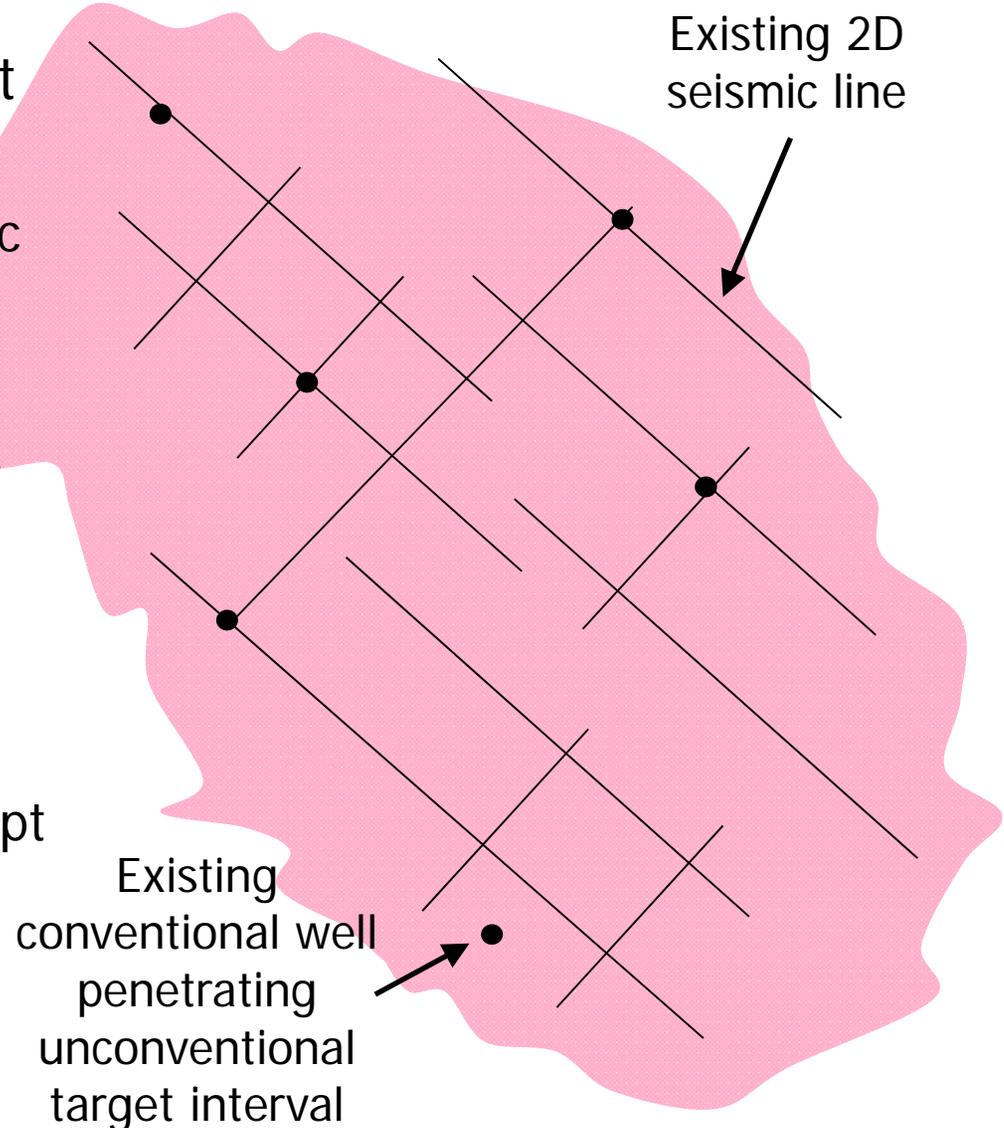


The PRMS Classification Framework

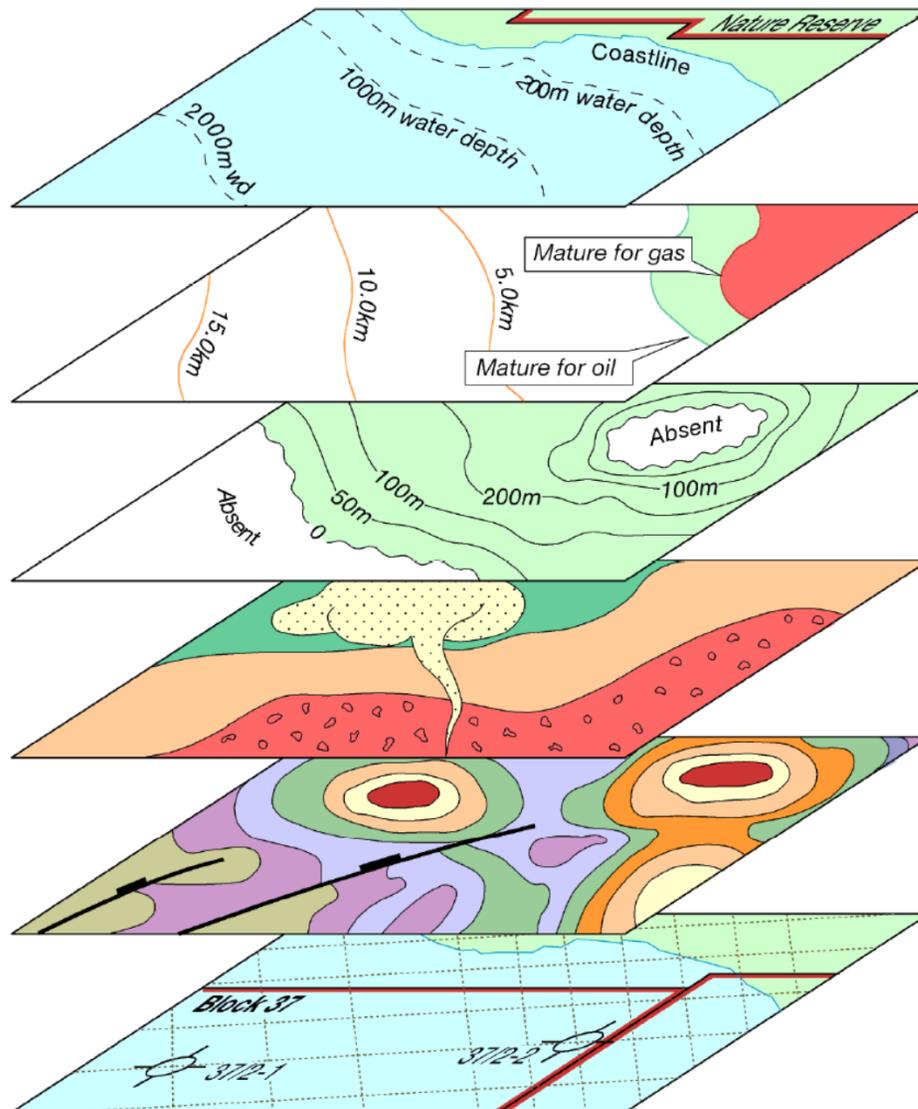


Estimating Prospective Resources

- Requires a minimum amount of data to make an estimate
 - Base map of wells and seismic lines
 - Stratigraphic column/type log
 - Structure and thickness maps
 - List of target zones and their potential property ranges
 - Strike and dip seismic X-sections
 - Exploration model/play concept
 - Development plan, economic model, net interest



Maps for Characterizing Prospects and Inputs



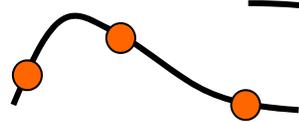
- Organic richness (TOC)
- Thermal maturity (%Ro)
- Structure/tectonics
- Gross/net thickness
- Lithofacies/mineralogy
- Geomechanical properties
- Seeps/slicks/surface geochem.
- Porosity/Permeability
- Fluid saturations (Sg, So, Sw)
- Evidence of overpressure
- Overburden thickness
- Seal thickness/rheology
- Reservoir temperature
- Paleogeography
- Key wells
- Restricted/inaccessible areas
- Pipelines, other infrastructure

Example Shale Inputs for Monte Carlo Simulation

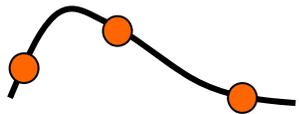
Parameter	Low	Best	High
Area, acres	1,600	16,000	160,000
Net thickness, feet	50	200	600
Sorbed gas storage capacity, scf/ton	30	50	80
Shale density, g/cc	2.5	2.7	2.9
Matrix porosity, decimal	0.03	0.05	0.07
Matrix Sg, decimal	0.30	0.50	0.70
Gas FVF, scf/rcf	150	225	300
Rec. efficiency, %	10	30	50

Fitting and Sampling the Distributions

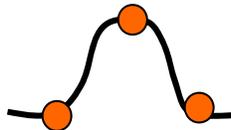
Area



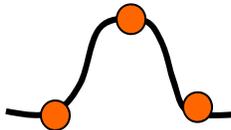
Net thickness



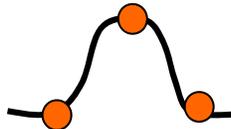
Sorbed gas



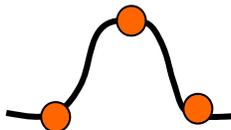
Shale density



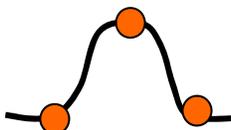
Matrix porosity



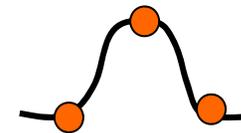
Matrix Sg



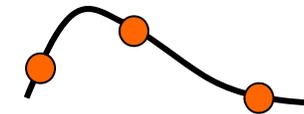
Gas FVF



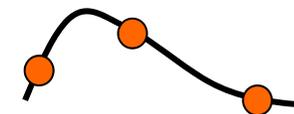
Rec. efficiency



GIIP



Prospective Resources



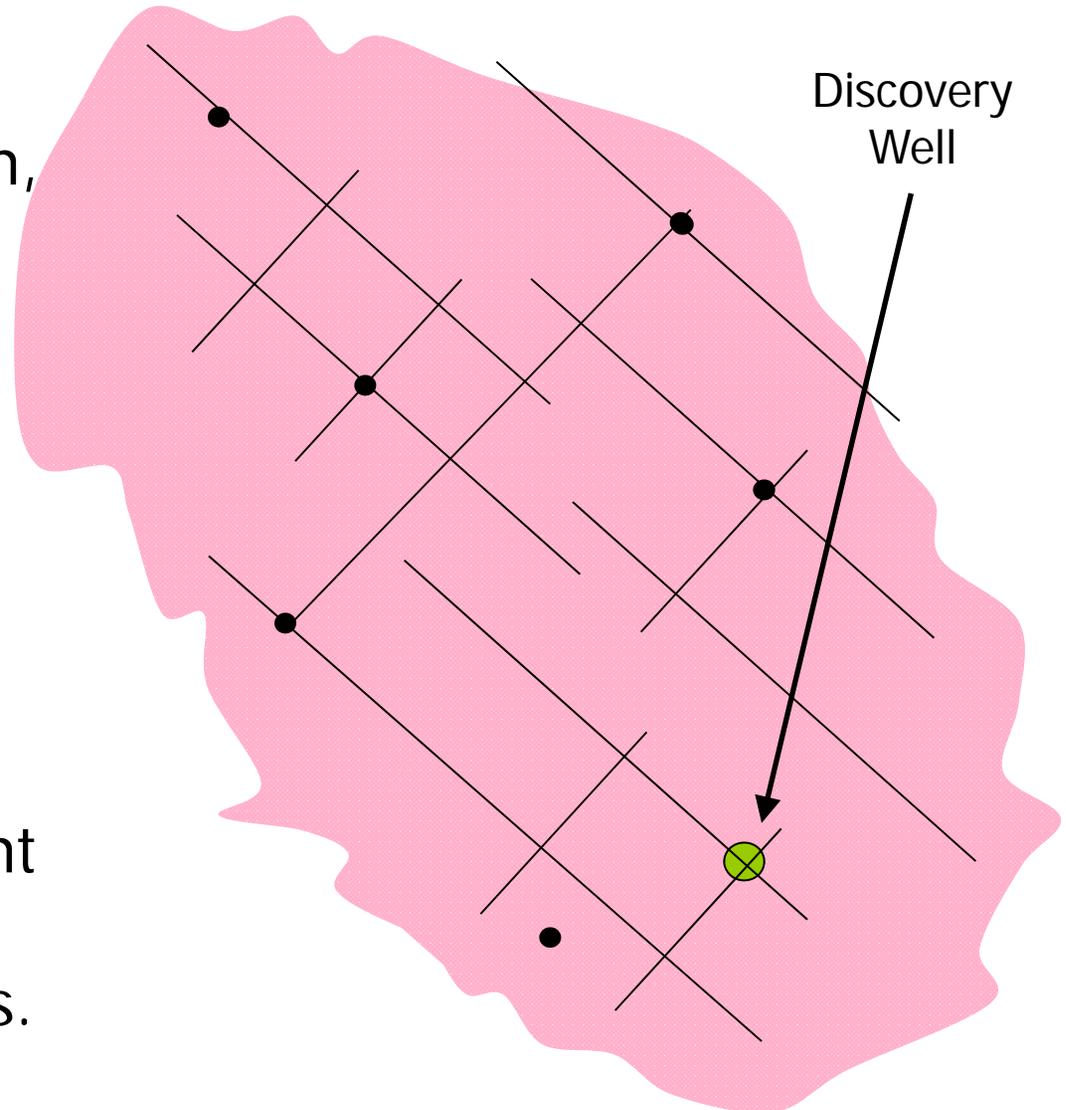
Example of a Prospective Resources Assessment

<u>Parameter</u>	<u>Low</u>	<u>Best</u>	<u>High</u>	<u>Mean</u>
OGIP, Bscf	6,158	10,168	16,563	12,247
Prospective Resources, Bscf	1,161	2,814	5,983	3,456

***Prospective Resources are commonly risked by
the chance of geologic success
and the chance of commercial success***

The Discovery Well

- A discovery is one petroleum accumulation, or several petroleum accumulations collectively, for which one or several exploratory wells have established through testing, sampling, and/or logging the existence of a significant quantity of potentially moveable hydrocarbons.



The Discovery Test Worksheet

Category	Importance	Data	Score	Supporting Comments
Natural or stimulated flow of hydrocarbons to surface	5	5	25	Most definitive criteria; flow must come from the reservoir interval. Data score can range from 1 (flow too small to measure) to 5 (greater than 100 MCFD)
Significant thickness from log and core data	4	5	20	Need to have some idea what the lithology is (mudlog) and some type of core data (sidewall core, whole core) for calibration. For a data score of 5, need at least 100 feet of pay for shale or 25 feet of pay for coal
Analog (commercial, nearby, geologically comparable)	3	0	0	Difficult to collect enough evidence in the discovery well to achieve this unless the target interval is being developed in an offset area
Core desorption (gas content)	3	0	0	Data score of 5 would be hundreds of scf/ton, desorb quickly, and come from an interval that is gas-saturated (or nearly so) with respect to the isotherm
Well test (DFIT, MDT) indicating permeability	2	0	0	Very important in CBM if coals have not yet been dewatered
Mudlog shows, gas kicks, composition of gas	2	0	0	Must be gas moving through matrix into wellbore - not from a few open fractures, or by destruction of wellbore rock by drilling
Favorable core properties (perm, porosity, Sw)	1	5	5	Measurements are difficult to make in these tight rocks and there is significant variability from well to well
			50	TOTAL SCORE of 42 required to pass the Discovery Test

- The "Importance" column ranks the relative importance of a given category from 1 to 5
- The "Data" column (user input) ranks the strength of the well data on a scale of 0 to 5
- The example input above assumes a strong flow of HCs to surface + significant thickness

Passing the Discovery Test

- The simplest way to pass the discovery test is with a significant flow of hydrocarbons to the surface from a thick accumulation
 - Natural or stimulated flow of hydrocarbons to surface
 - Significant thickness from log and core data
- In the absence of flow to surface, other less definitive data can be used to demonstrate that moveable hydrocarbons are present
 - The desorption of cores at the surface
 - Gas kicks and mudlog shows during drilling
- For coalseam gas reservoirs that are not dewatered, a well test (to show permeability), core desorption, and a good analog are needed to satisfy the discovery criteria
- Significant thickness, an analog, and favorable core properties alone will be insufficient for a discovery because this dataset lacks sufficient indications of potentially moveable hydrocarbons.

Assigning Contingent Resources

- Once an accumulation is declared “discovered”, contingent resources may be assigned if the technology that will be used to produce the hydrocarbons has been demonstrated to be commercially viable in **analogous** reservoirs, and a development plan is provided
- If the technology has been demonstrated to be commercially viable in other reservoirs that are not analogous, then a **pilot project** will be necessary to demonstrate commerciality for the subject reservoir
- If a pilot project is planned and budgeted, discovered recoverable quantities may be classified as Contingent Resources.
- If no pilot project is planned and budgeted, all quantities should be classified as Discovered Unrecoverable Resources.

What's An Analogous Reservoir?

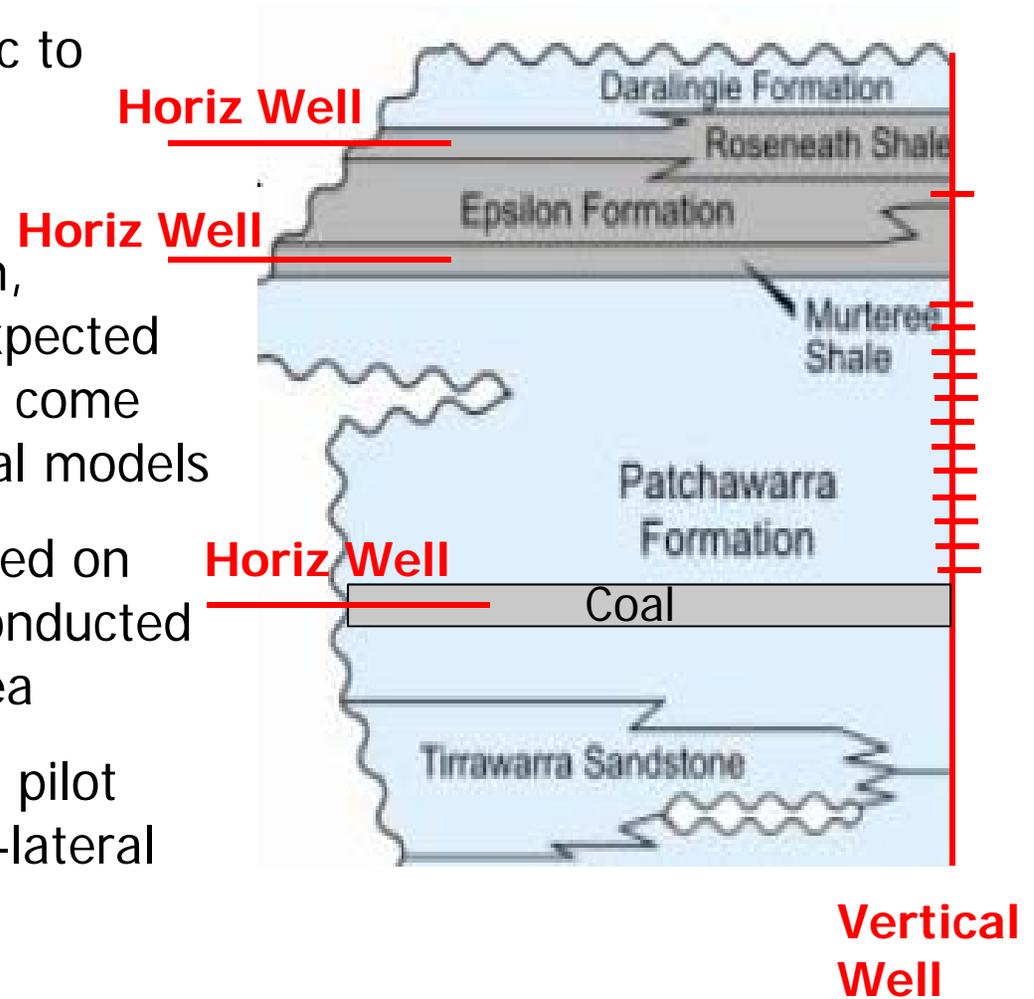
- An analogous reservoir is a commercially-productive accumulation that is similar to that encountered in the discovery well.
- An analog should have similar reservoir characteristics including approximate depth, pressure, temperature, reservoir drive mechanism, original fluid content, reservoir fluid gravity, reservoir size, gross thickness, pay thickness, net-to-gross ratio, lithology, heterogeneity, porosity, permeability, and development plan
- An analog should be in close geographic proximity (within the same play fairway) to the discovered accumulation
- Most importantly, the analog should have sufficient similarity to the discovered accumulation to conclude that it is capable of producing gas at comparable rates and recoveries
- In all cases, the similarities and differences between the analog and the discovered accumulation should be documented

What's A Pilot Project?

- A project represents the link between the petroleum accumulation and the decision making process, including budget allocation
 - In general, an individual project will represent a specific maturity level at which a decision is made on whether or not to proceed (i.e., spend money) and there should be an associated range of estimated recoverable resources for that project
- A pilot project is a small-scale test or trial operation that is used to assess the suitability of a given recovery method
- The pilot needs to be designed to reduce the uncertainty in key reservoir parameters, test various completion/drilling technologies, and assess full-field development issues
- The purpose of the pilot project is to demonstrate commercial production potential

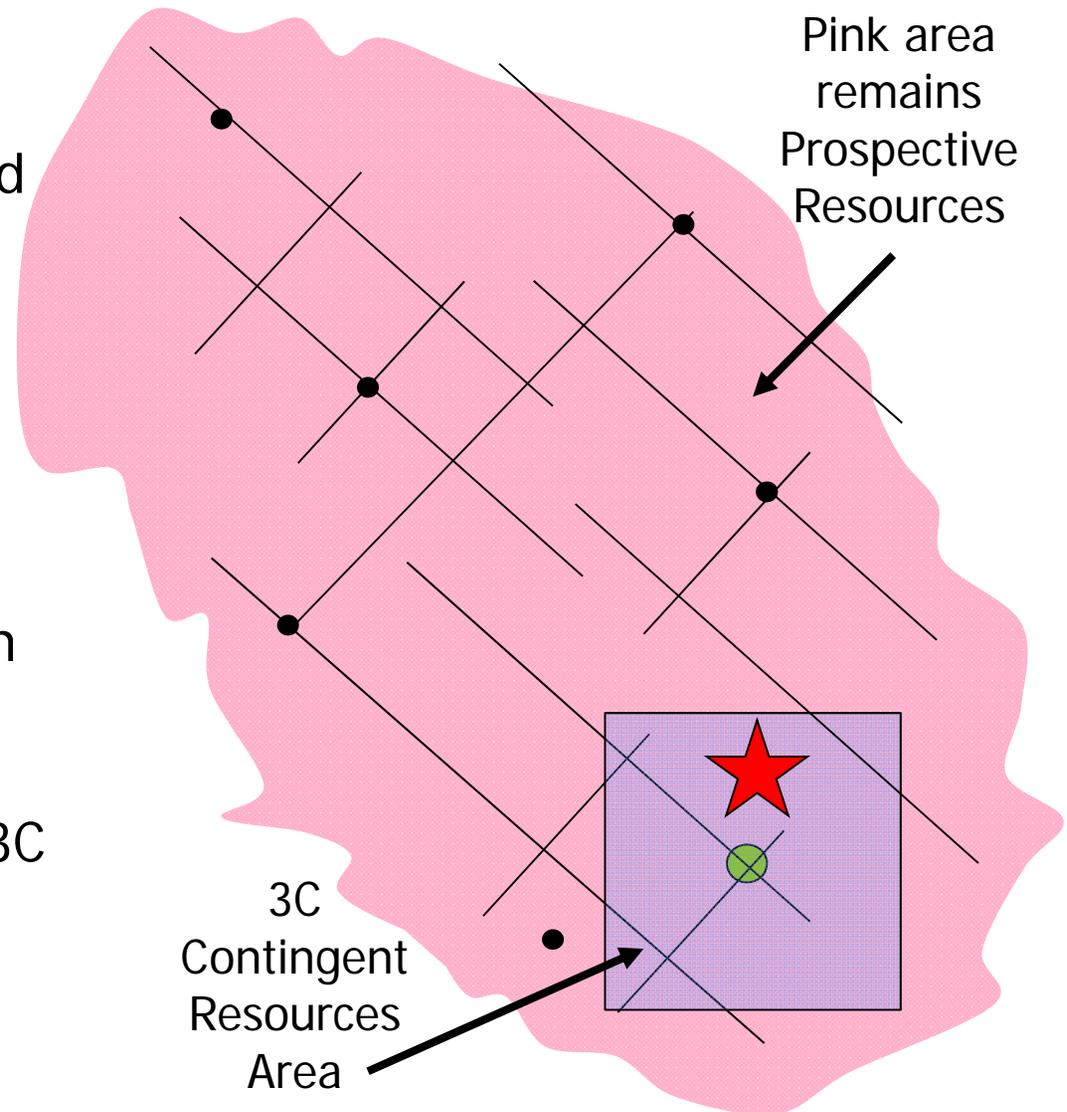
Multiple Pilots for Multiple Targets

- Pilots may be horiz. or vertical wells
- Data collected will be specific to lithology type and reservoir mechanism
- Pilot parameters (well length, completion type, spacing, expected rates and recoveries) should come from analytical and numerical models
- Multiple pilots that are focused on different intervals may be conducted concurrently in the same area
- The commingling of multiple pilot zones using vertical or multi-lateral wells may be necessary for commercial development



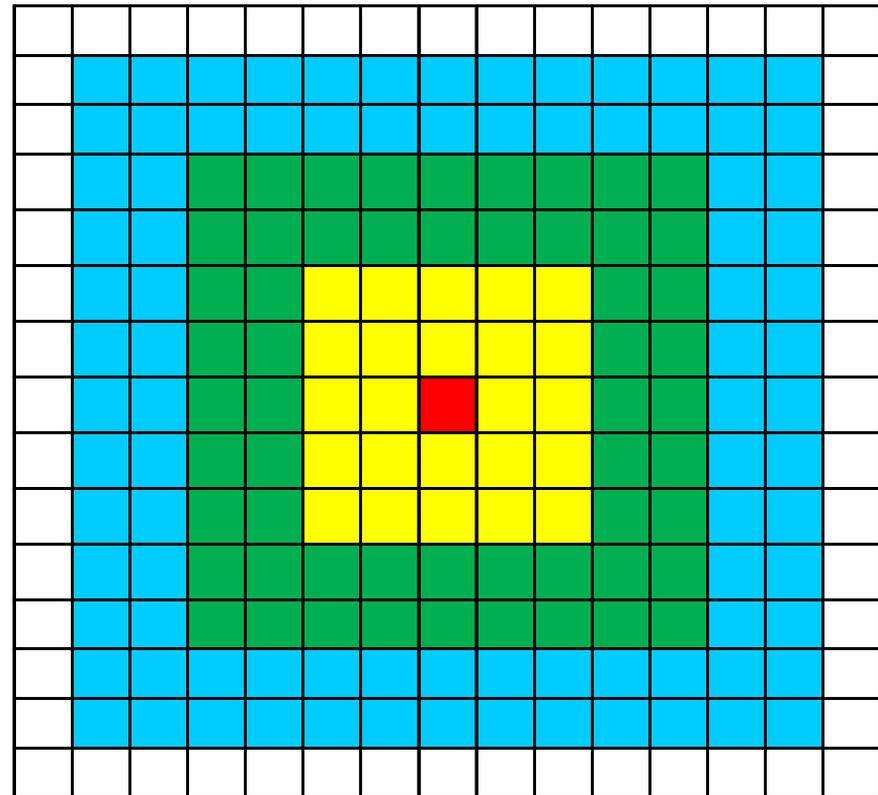
Delineating the Project Area

- The project area to be assigned contingent resources is located around the discovery well
- A planned and budgeted pilot project (★) is located within the 3C Contingent Resources area
- The 3C area is centered on the discovery well (●) and contains concentric rings representing 1C, 2C, and 3C estimates of Contingent Resources



Assigning Concentric Rings

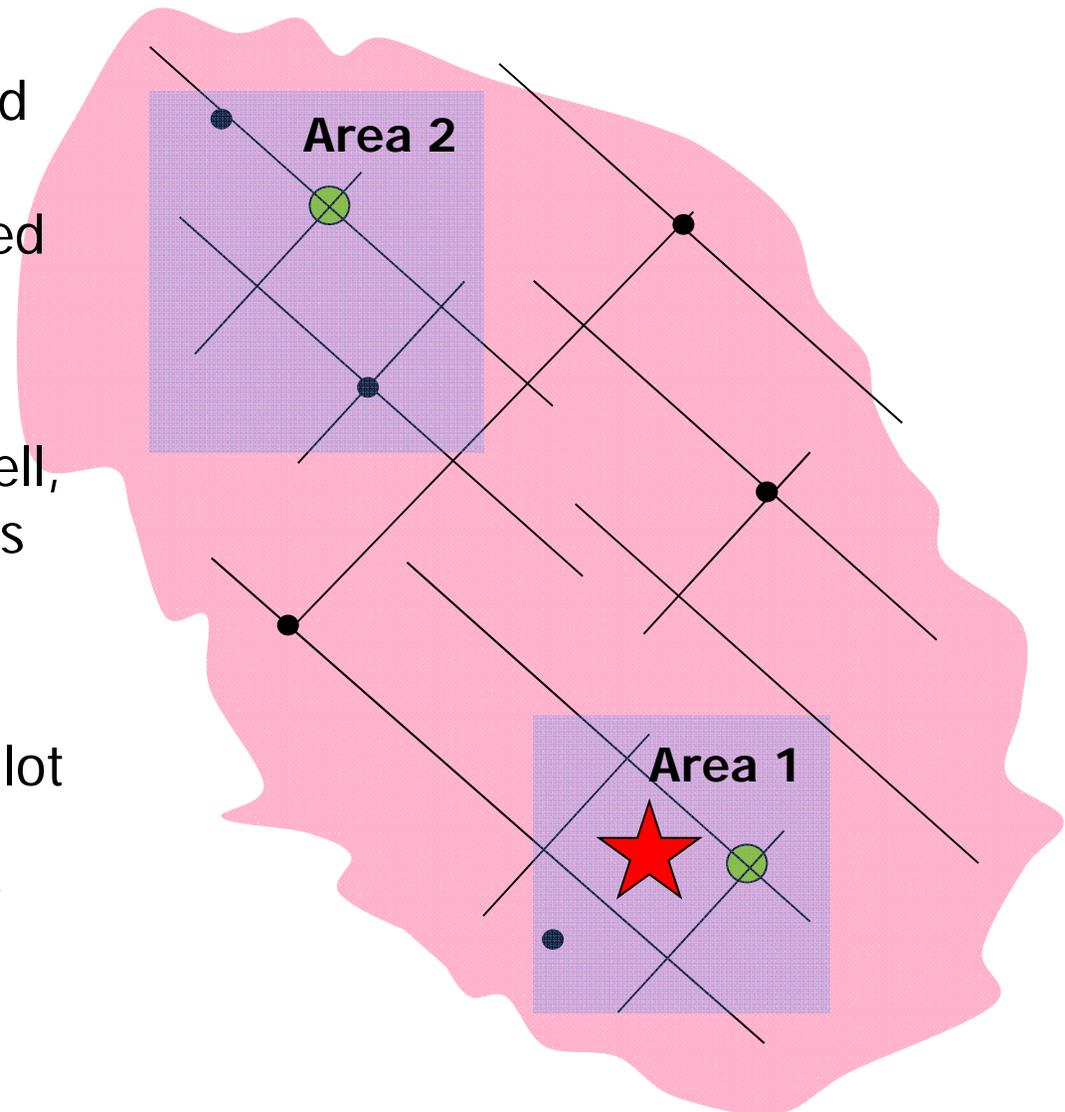
- The technique is referred to as a deterministic (incremental) method
- The red square is the discovery well
- The 1C area (red + yellow) contains 26 wells
- The 2C area (red + yellow + green) contains 81 wells
- The 3C area (red + yellow + green + blue) contains 169 wells



Other configurations are possible, such as one ring each of 1C, 2C, and 3C Contingent Resources, depending on the evaluator's confidence in how reservoir parameters change away from the discovery well

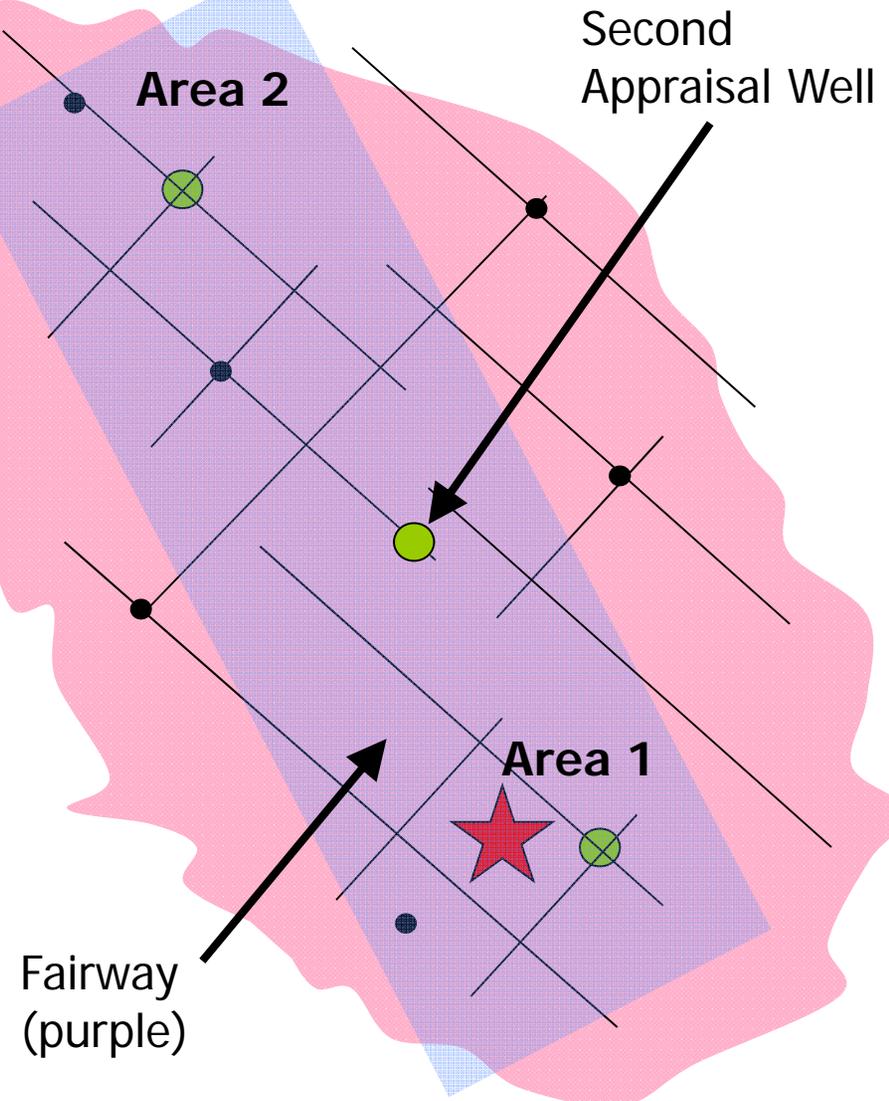
Expanding the Project Area

- Assume that a discovery well is drilled in Area 1 and a pilot is planned. An appraisal well is then drilled in Area 2
- If this well is sufficiently similar to the discovery well, then Contingent Resources can be assigned to Area 2
- If it is not sufficiently similar, then a separate pilot project will have to be planned and budgeted for Area 2 to be assigned contingent resources



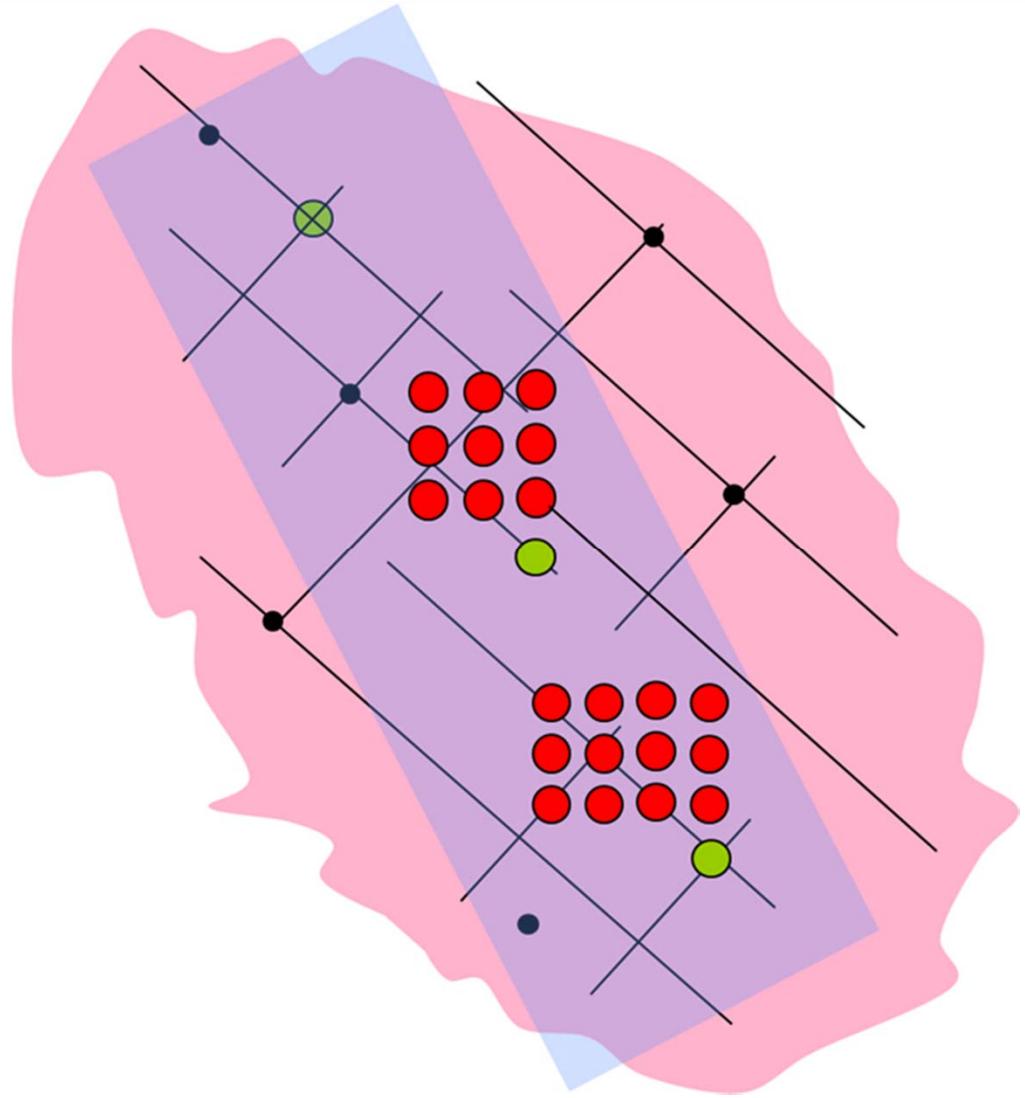
Contingent Resources Fairway

- A second appraisal well between Areas 1 & 2 can be used to designate a contingent resources fairway
- This second appraisal well must be sufficiently similar to the discovery well to conclude that the results of the pilot project will be applicable to the area around it
- If the pilot project is already commercially successful, then it needs to be shown that these wells are an appropriate analog for the second appraisal well



Converting Contingent Resources to Reserves

- The performance of the pilot project, analogous reservoirs, and modeling are used to generate an optimal plan and begin development drilling (●)
- Contingent resources can be converted to reserves once technical and commercial contingencies are resolved and other requirements are met.



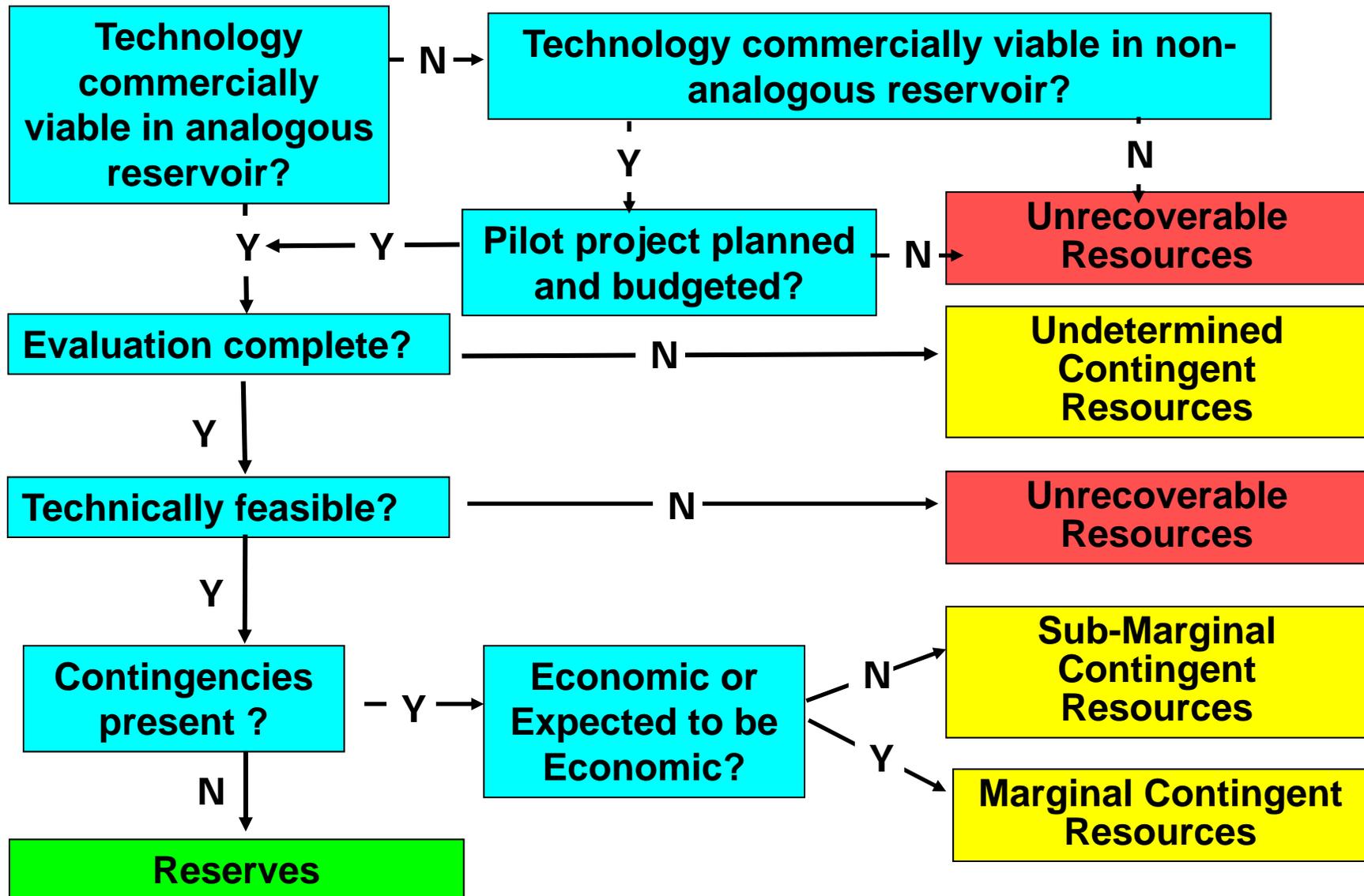
Examples of Project Contingencies

- Technical contingencies
 - Permeabilities are too low
 - Insufficient porosity or gas saturation
 - Inability to dewater coalseams
 - Highly compartmentalized (small sandbody sizes, faults)
 - Ineffective fracture stimulations
- Commercial contingencies
 - Low gas prices
 - No gas treatment or transport facilities
 - Costs are too high (remote location, too deep)
 - Lack of approvals by partners or regulatory agencies
 - Lack of financing or commitment

Risking Contingent Resources

- There are several ways to do this, one of them is to assign contingent resources to *economic subclasses*
 - **Undetermined Contingent Resources**
 - Known (discovered) accumulations where evaluations are incomplete such that it is premature to clearly define the ultimate chance of commerciality
 - **Marginal Contingent Resources**
 - Known (discovered) accumulations for which a development project(s) has been evaluated as economic or reasonably expected to become economic but commitment is withheld because of one or more contingencies
 - **Sub-Marginal Contingent Resources**
 - Known (discovered) accumulations for which evaluation of development project(s) indicated they would not meet economic criteria, even considering reasonably expected improvements in conditions.

CR Classification Flowchart (assumes a discovery)



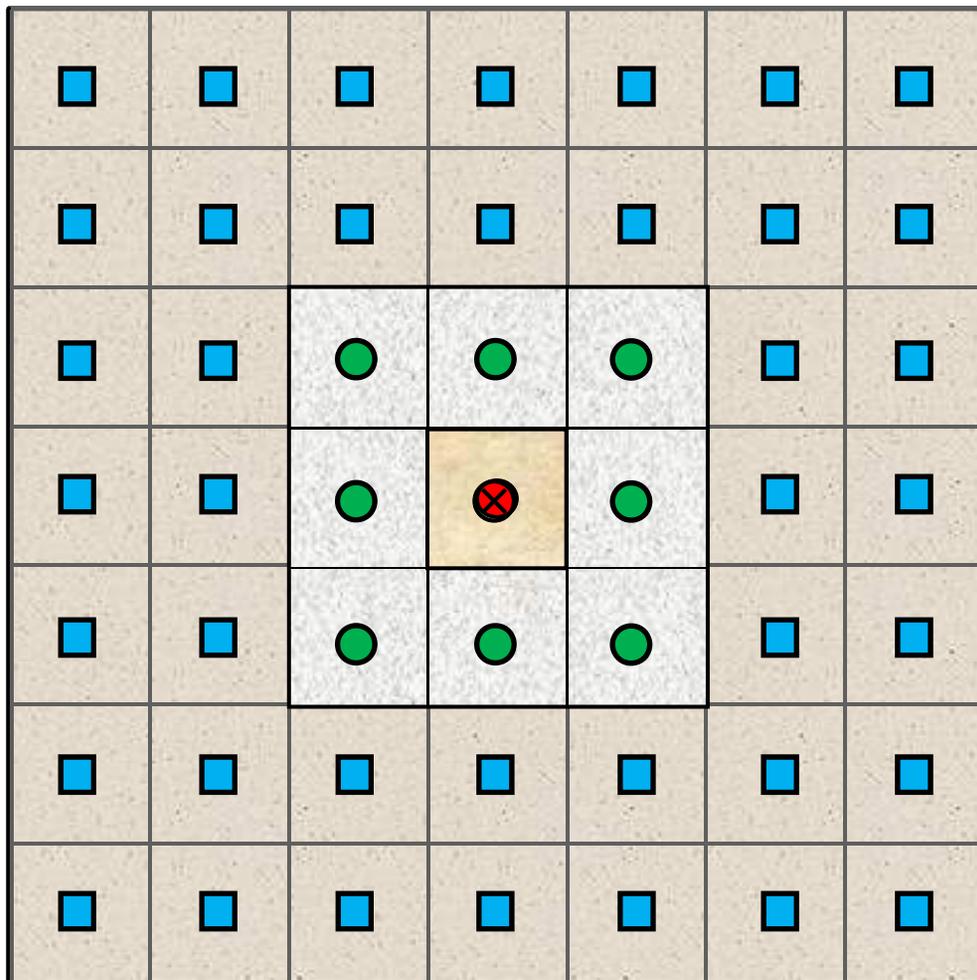
Progressing Contingent Resources to Reserves

- Contingent Resources may be considered commercially producible, and thus Reserves, if the entity claiming commerciality has demonstrated firm intention to proceed with development in a reasonable timeframe (usually 5 years) and such intention is based upon **all** of the following:
 - Evidence to support a reasonable timetable for development.
 - A reasonable assessment of the future economics of such development projects meeting defined investment and operating criteria:
 - A reasonable expectation that there will be a market for all or at least the expected sales quantities of production required to justify development.
 - Evidence that the necessary production and transportation facilities are available or can be made available:
 - Evidence that legal, contractual, environmental and other social and economic concerns will allow for the actual implementation of the recovery project being evaluated.
 - A reasonable expectation that all required internal and external approvals will be forthcoming

Assigning Reserves Categories

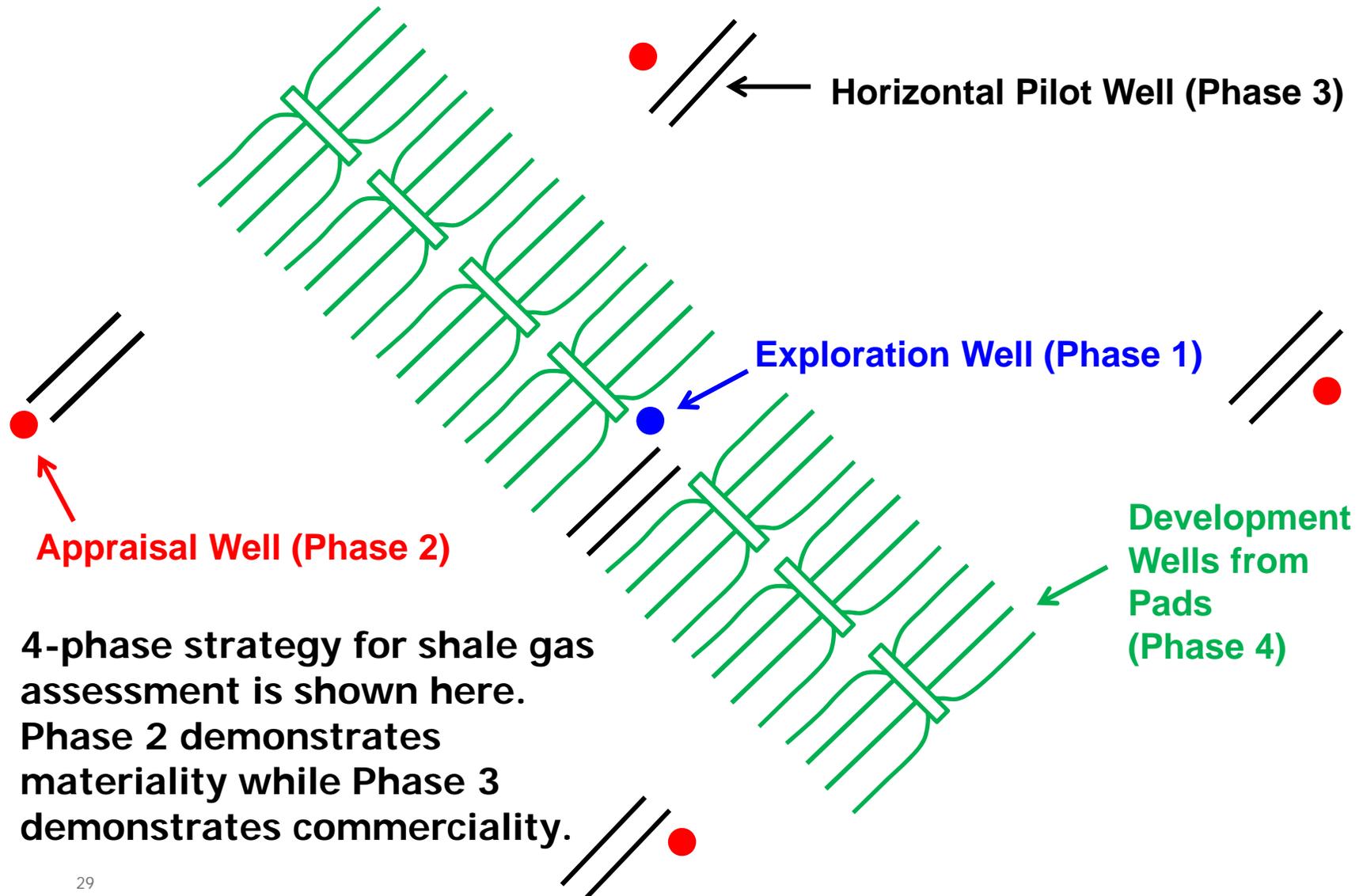
- **Proved Reserves** are those quantities of petroleum which can be estimated with *reasonable certainty* to be commercially recoverable
 - There should be least a 90% probability that the quantities actually recovered will equal or exceed the estimate.
- **Probable reserves** are less likely to be recovered than proved reserves
 - There should be at least a 50% probability that the actual quantities recovered will equal or exceed the 2P estimate.
- **Possible reserves** are less likely to be recovered than probable reserves
 - There should be at least a 10% probability that the actual quantities recovered will equal or exceed the 3P estimate.

Assigning Incremental Reserves



- PDP reserves are assigned to an anchor well once all contingencies are resolved
- PUD reserves are assigned to a single ring around this well and probable reserves are assigned to two rings beyond this
- Possible reserves may be assigned beyond Probable
 - ⊗ Anchor well
 - Proven Developed (PDP)
 - Proven Undeveloped (PUD)
 - Probable

Linking Resource Estimates to Strategies



4-phase strategy for shale gas assessment is shown here. Phase 2 demonstrates materiality while Phase 3 demonstrates commerciality.

Typical Appraisal and Development Strategies

■ **Shales**

- Select a pilot and development well spacing that does not require infill drilling. Develop from well pads.

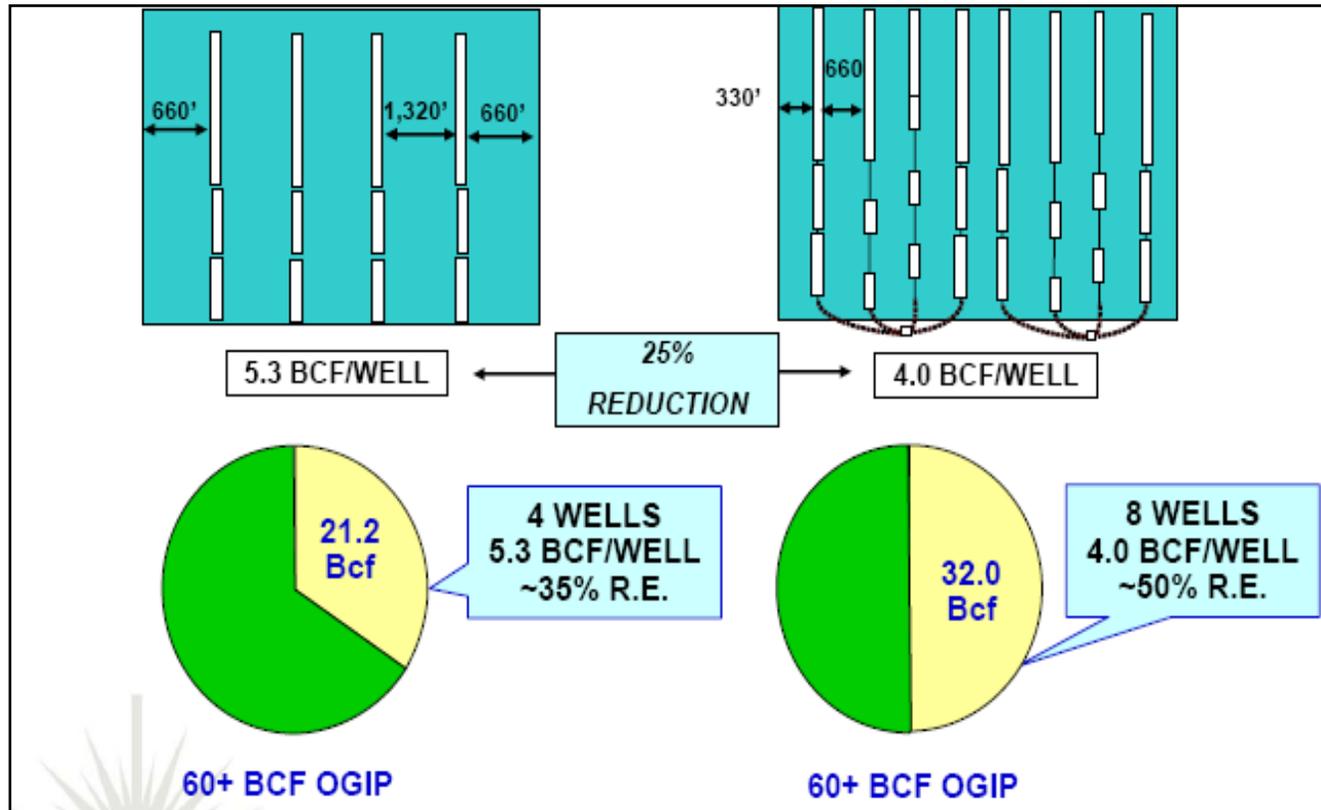
■ **CSG**

- Drill closely-spaced pilot wells to demonstrate the coal can be dewatered and then expand the well spacing for development from well pads

■ **Tight Sands**

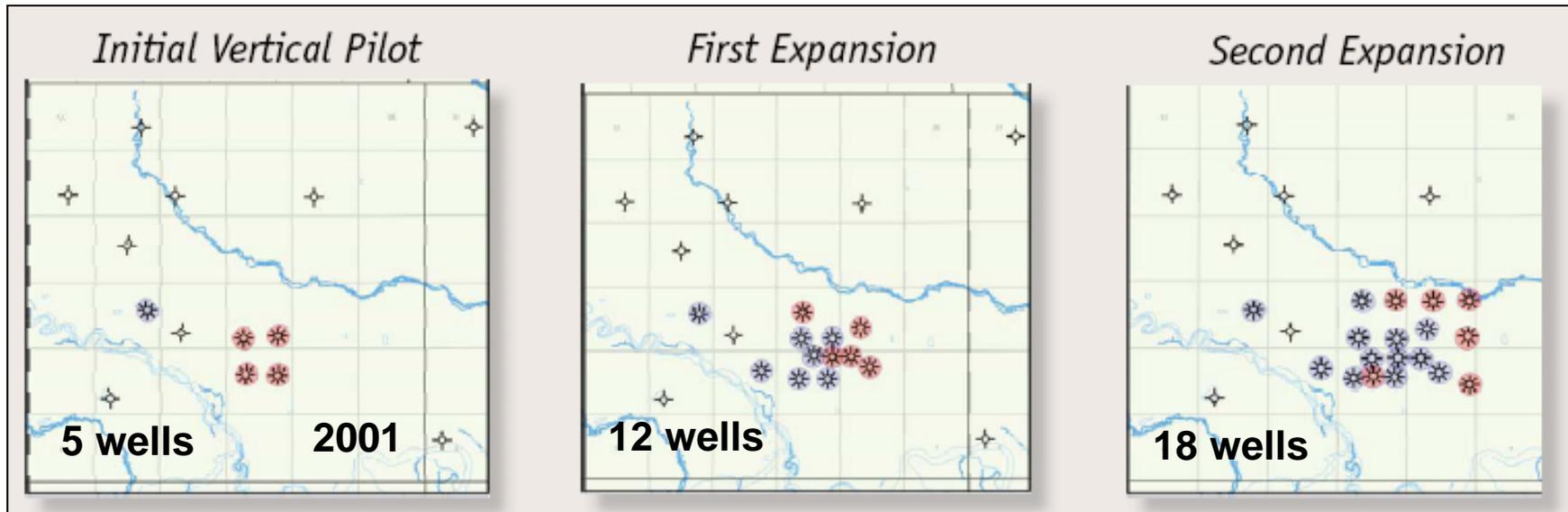
- Drill pilot wells based on the upper limit of sandbody size and allow for at least one round of infill drilling during development from well pads

Poor A&D Strategies: Shales

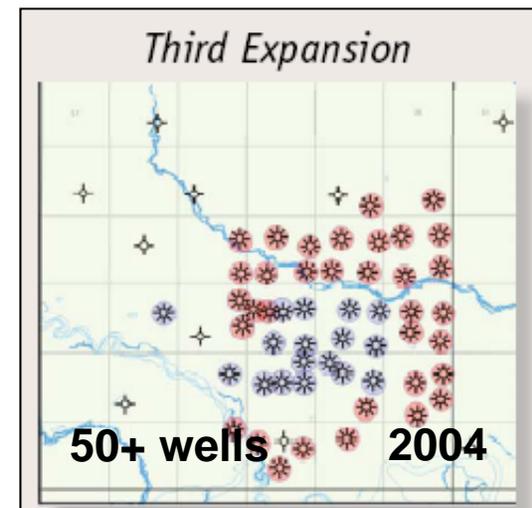


- Four original wells in the Woodford Shale were projected to produce 21.2 Bcf of gas. The four infill wells stole gas from these and therefore were projected to only produce an incremental 11.8 Bcf (which is equal to $32 - 21.2$)

Poor A&D Strategies: CSG



- This project in Alberta was developed by drilling dozens of vertical wells over a multi-year period which were unsuccessful in dewatering the Mannville Coals.
- After all this money was wasted, it was decided to try some horizontal pilot wells which were successful in dewatering the coal



Poor A&D Strategies: Tight Sands



- The Jonah Field was developed through multiple rounds of infill drilling instead of pad drilling, leaving the surface pocked with wellsites

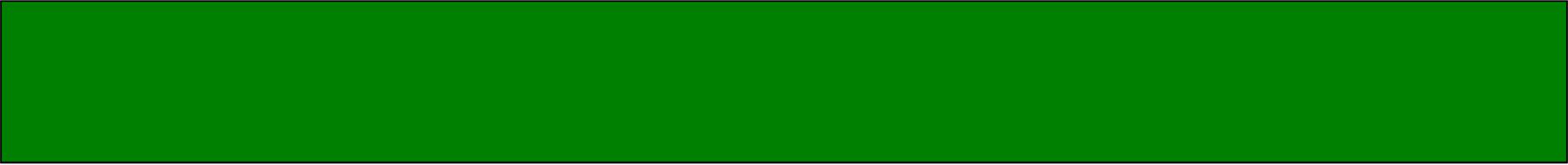
Let's Not Relearn Unconventional Lessons

- Large plays shrink to core areas (fairways)
- Underlying trends must be understood (statistical play mentality)
- A small number of wells provide most of the gas (mean >> median EUR)
- Well performance and gas-in-place is uncertain (models don't eliminate uncertainty, and some don't even bound it)
- A lot of value can be squandered if you don't understand what you have
- Technical understanding and discipline are paramount (herd mentality—late to the game, appraisal shortcuts)
- Companies must be creative and have stamina

And Let's Be Guided by Honesty & Transparency

- Transparency is, by necessity, a two-way street and needs to be addressed by all parties in the discussion.
- The oil and gas industry needs to explain its processes, identify chemicals to the public and improve the well development process where needed.
- The public needs to understand what the industry is doing and be able to engage on a local and national forum with a solid base of understanding.

Taken from SPE 152956, *Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Reporter, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells*, by George E. King



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