Selection and Treatment of Stripper Gas Wells for Protection Enhancement in the Mid-Continent

Presented by:

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TECHNOLOGY CONNECTIONS

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Presentation Outline

- Background
- Project Description
- Prior Work
- Technology
- Current Field Work
- Application Guidelines
- Future Work

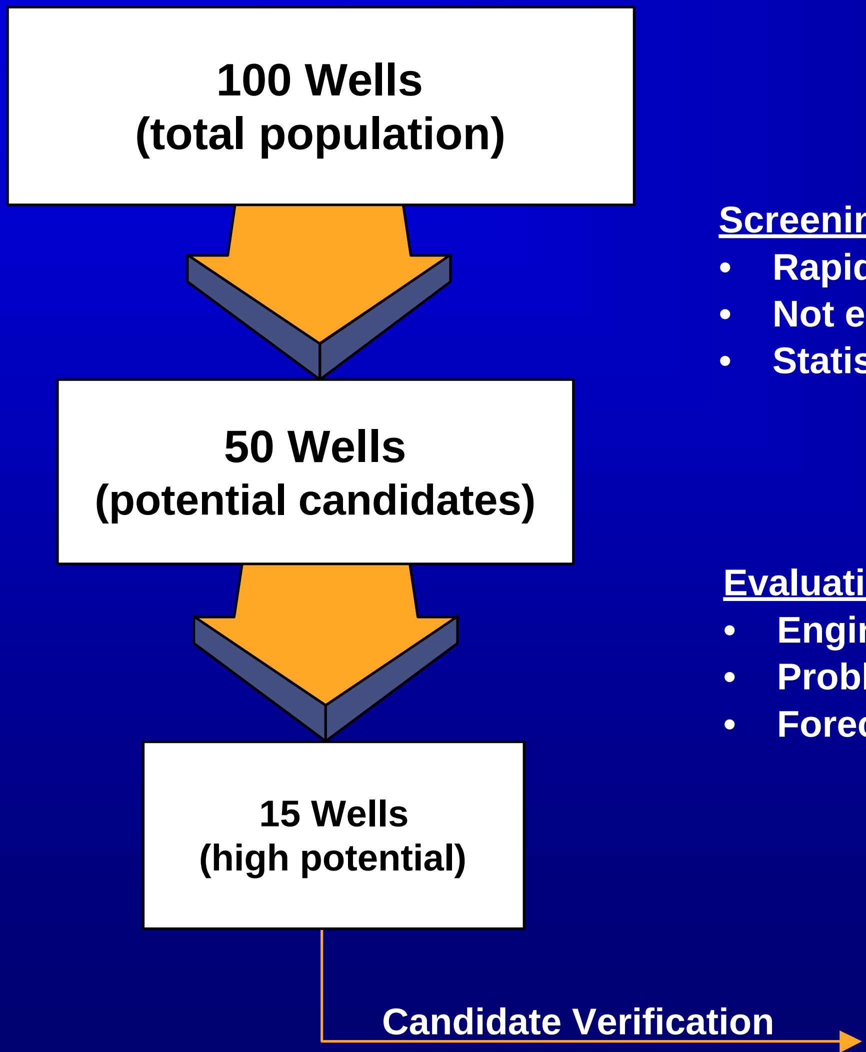
Project Genesis

- In 1996, GRI (now GTI) began investigating potential for natural gas production enhancement via restimulation. Initial findings were:
  - Significant potential
    - >5 tcf incremental reserves in 5 years
  - Low reserve costs when successful
    - $0.10 - $0.20/Mcf
  - Critical success factors
    - Candidate selection (85/15 rule)
    - Problem diagnosis
    - Treatment strategy
- Major obstacles are:
  - Industry's (understandable) reluctance to restimulate "good" wells, which frequently are the best candidates
  - Lack of "tools" or methods to cost-efficiently identify candidates and diagnose well performance problems

Subsequent Work

- GRI initiated a subsequent R&D program in 1998 with four primary objectives:
  - Develop cost-effective, reliable methodologies to identify wells with high restimulation potential in tight sands.
  - Identify various mechanisms leading to well underperformance.
  - Develop new restimulation techniques tailored to selected causes of well underperformance.
  - Demonstrate that with improved candidate recognition, problem diagnosis and restimulation methods, restimulation can be a substantial source of low-cost natural gas.

Candidate Selection Concept

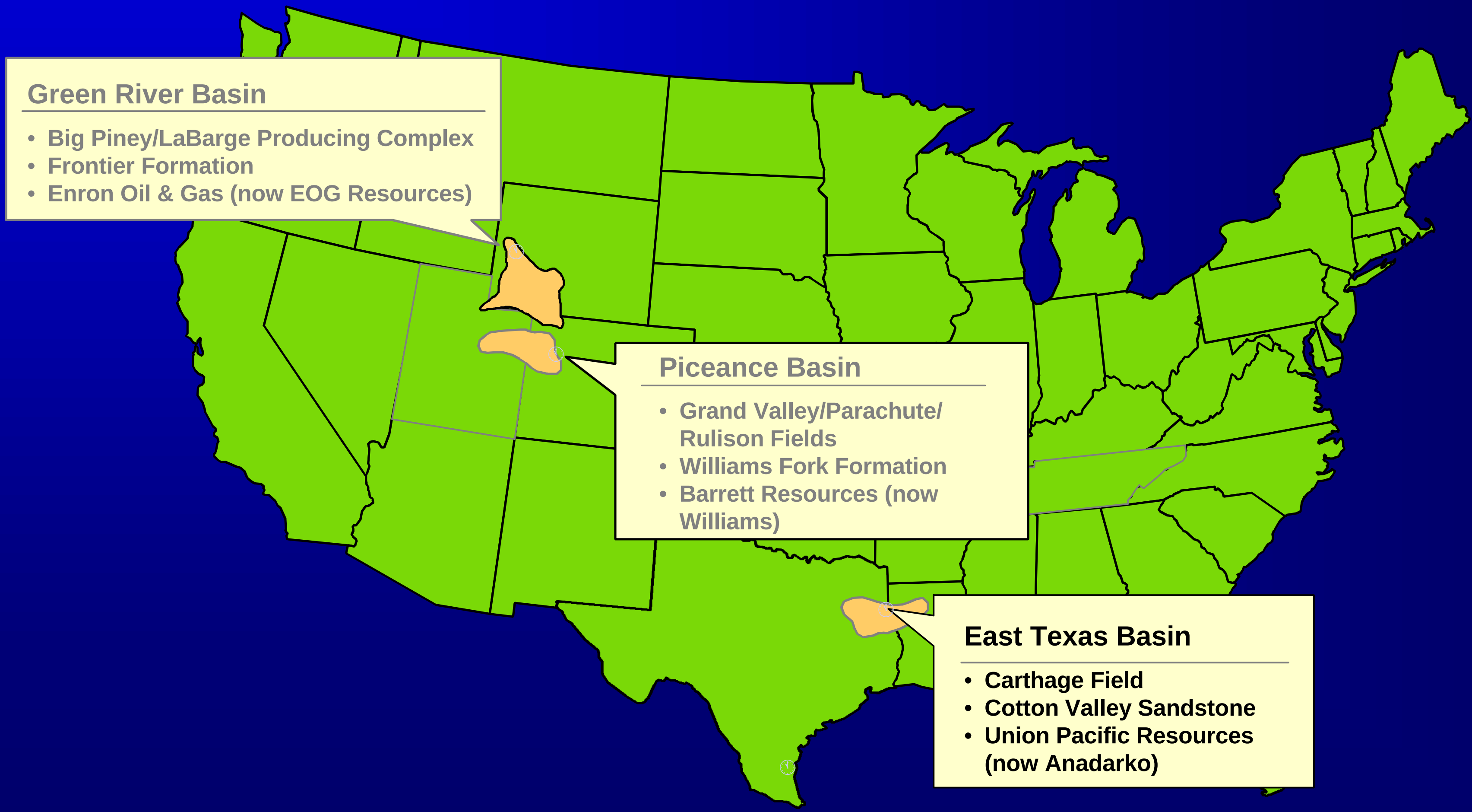


Screening
- Rapid
- Not engineering based
- Statistical, AI approaches

Evaluation
- Engineering-based
- Problem diagnosis, treatment selection
- Forecasting, economic ranking

Sample Outcome
- Well No.
- Incremental Reserves
- Restimulation Economics

Location of Restimulation Project Test Sites



Track Record of Success

- 9 wells restimulated
  - Green River Basin – 4
  - Piceance Basin – 2
  - East Texas Basin – 3
- 7 production improvements, 1 no change, 1 slight decline
- 6 "economic" successes
- Added 2.9 Bcf of reserves at a total reserve cost of \$0.26/Mcf (costs include "failed" restimulations).
- Value of reserves gained by Operators more than offset cost of "R&D" project.

Reference: Study looks at Tight-Gas Restimulation Candidate Wells, Oil & Gas Journal, October 8, 2001.

DOE Stripper Well Program

- Initiated in 2000.
- Objective of sustaining/improving production and reserves from stripper gas wells.
- Technologies developed under earlier GTI sponsorship can be modified for stripper well application.

U.S. Stripper Gas Distribution

Rank	State	Number of Stripper Gas Wells
1	West Virginia	35,594
2	Ohio	33,430
3	Texas	27,368
4	Pennsylvania	26,000*
5	Kentucky	14,126

* Estimated

Rank	State	Production from Stripper Wells (Mcf)
1	Texas	221,513,637
2	West Virginia	198,500,000
3	Oklahoma	114,668,483
4	Pennsylvania	100,000,000*
5	Ohio	79,333,000

*Estimated

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Strategic Objective

- To develop an easy-to-use, low-cost analytic methodology to identify untapped production enhancement potential in stripper gas wells.

Tactical Objectives

- Develop a Candidate Screening & Selection Methodology
- Perform Field Demonstrations of its Application
- Disseminate Results to Industry

Project Scope

- Geographic
  - > Mid-Continent
- Applications ("existing" production)
  - > Restimulation
  - > Production Practices (downhole and surface)

Virtual Intelligence

- Artificial Neural Networks (well performance model)
  - ➢Statistical analogy
  - ➢Pattern recognition
  - ➢No “engineering” or “interpretive” bias
- Genetic Algorithms (best practices, problem identification)
  - ➢Optimized optimization

Type-Curves

- Current Features
  - Two-layer
  - Variable Compressibility
  - Fractured/Unfractured
- New Features
  - Secondary Curves (e.g., cumulative production)
  - Batch Processing
- Utility
  - Differentiate depletion, low permeability, damage, production practices
  - Quantify upside potential

Candidate Selection Approach

- Combine results of VI and TC analyses to identify candidates.
- Develop a screening/selection routine.

Perform Field Demonstrations

Perform Integrated Field Demonstrations

- **Two Sites (+/- 100 wells each)**
  - > Tight Gas Formation
  - > High-Permeability/Low-Pressure Formation
- **Activities**
  - > Collect Data
  - > Perform VI, Type-Curve Analyses
  - > Select Candidates, Remediation Methods
  - > Perform Treatments/Workovers (1-3 per site)

Current Status

- Performing candidate selection analytics at first test site.
- Seeking second test site.

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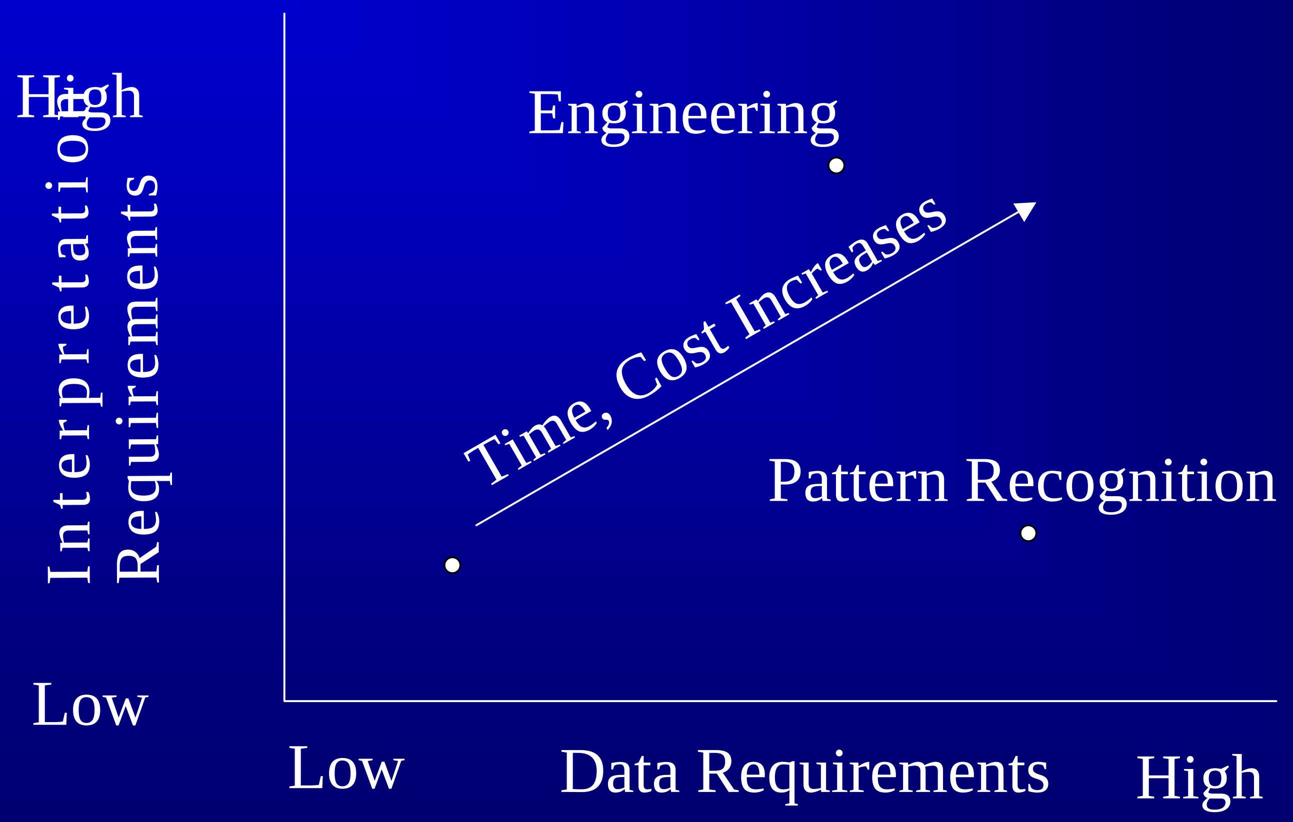
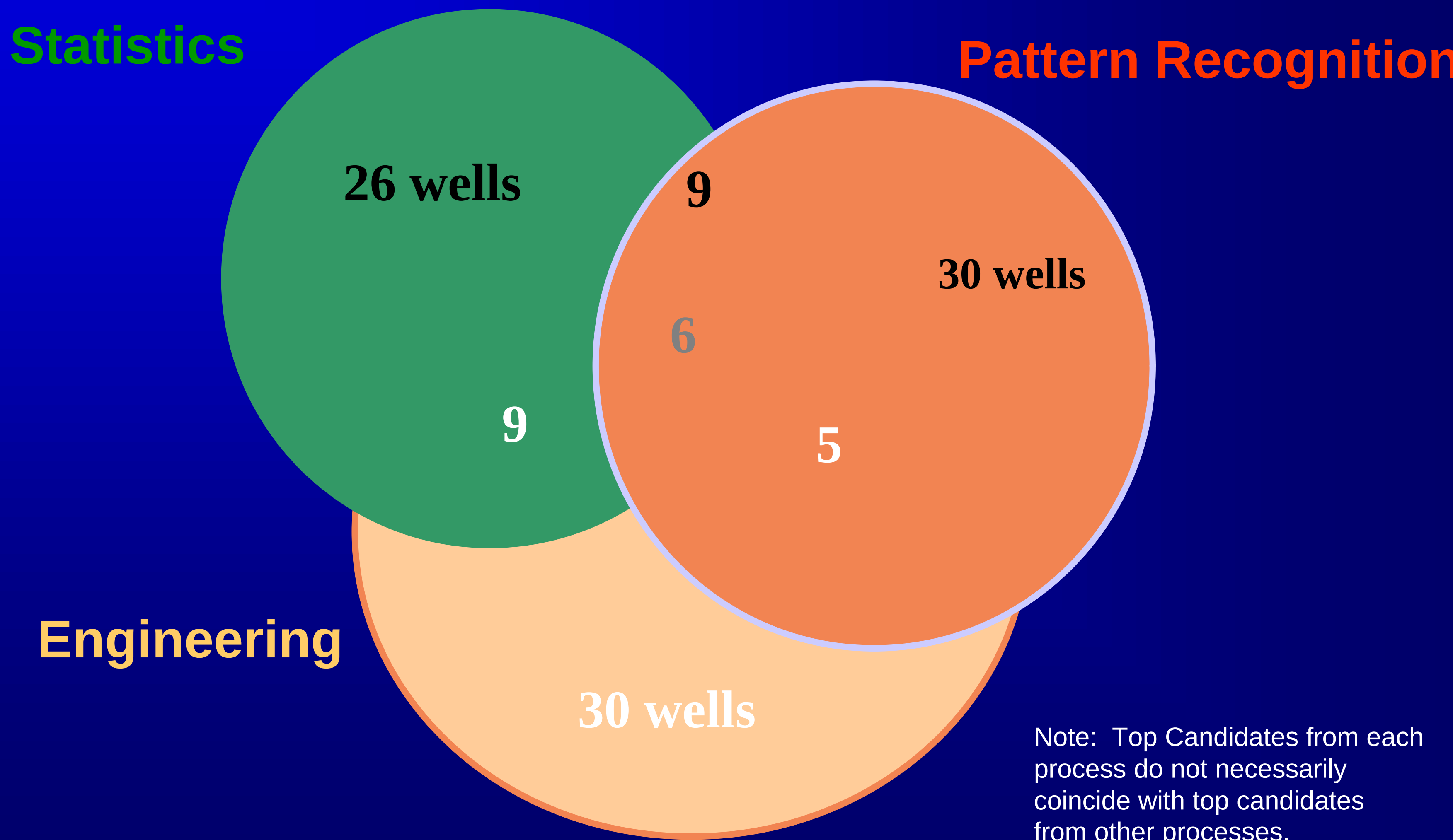
Candidate Selection Methods

- Statistics
  - Public/Easily-Obtained Data
  - Production Statistics
- Pattern Recognition
  - Geologic, Log, Drilling, Completion, Stimulation, Workover Data
  - Minimum Data Interpretation
  - Virtual Intelligence (Artificial Neural Networks, Genetic Algorithms, Fuzzy Logic)
- Engineering
  - Engineering-Based Approach (Type-Curves, etc.)
  - Ranked by Incremental Production Potential

Data and Interpretation Requirements



Coincidence Of “Top 50” Candidate Selections, Green River Basin



Note: Top Candidates from each process do not necessarily coincide with top candidates from other processes.

Benchtop Study

- Create a hypothetical (simulated) field where all reservoir/completion properties are known, and restimulation potential can be readily computed.
- Independently select restimulation candidates with each technique and compare the selections with the known “answer.”
- Make the exercise as realistic as possible.

Comparison of Restimulation Candidate Selection Methods

<u>Approach</u>	<u>Incremental (Bcf)</u>	Efficiency <u>(Top 18 Wells)</u>
Actual	4.566	100%
Best Pre-Restim Rate	3.896	85.3%
Virtual Intelligence	3.807	83.4%
Type Curves	3.421	74.9%
Best 10-Year Cum.	3.272	71.7%
Random	2.150	47.1%
Production Statistics	1.949	42.7%
Worst 10-Year Cum	0.775	17.0%
Worst Pre-Restim Rate	0.735	16.1%

Reference: SPE 63096-Benchmarking of Restimulation Candidate Selection Techniques in Layered, Tight Gas Sand Formations Using Reservoir Simulation.

Ultimate Conclusions

- Better wells make better restimulation candidates.
- Each candidate selection methodology may have specific applicability:
    - ➢Statistics: Reservoir/operating practices broadly uniform.
    - ➢Pattern Recognition: High degree of reservoir heterogeniety & completion/stimulation variation.
    - ➢Engineering: High quality reservoir and production data.

Relevance to Stripper Wells

- Focusing on "best" stripper wells counter-intuitive.
- Adopt an integrated VI & TC approach with a screening criteria to tie them together.
  - Weighting of one approach vs. the other can be a site-specific variable.

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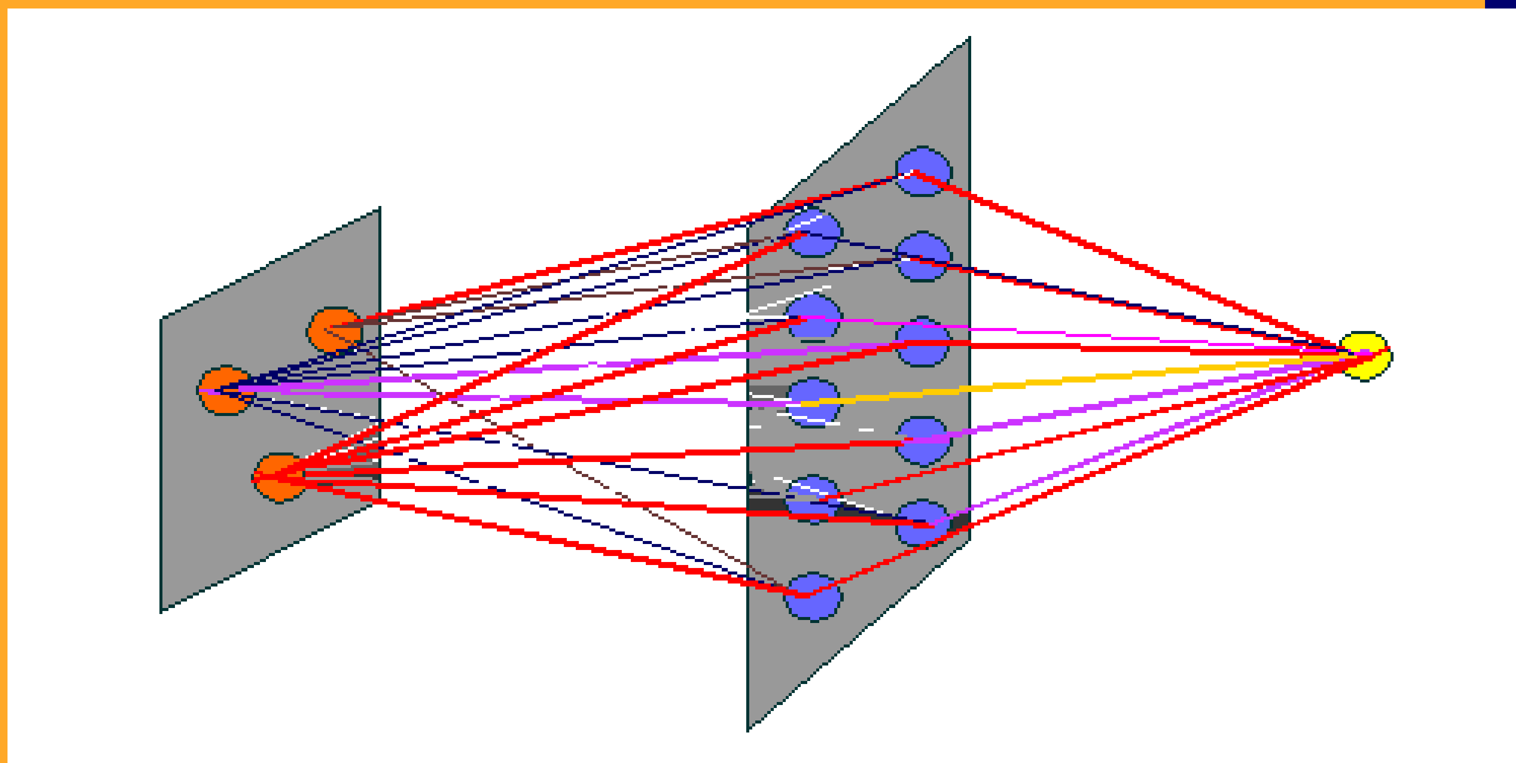
Virtual Intelligence

- Uni-variate analysis
- Multi-variate analysis
- Pattern recognition (artificial neural network).

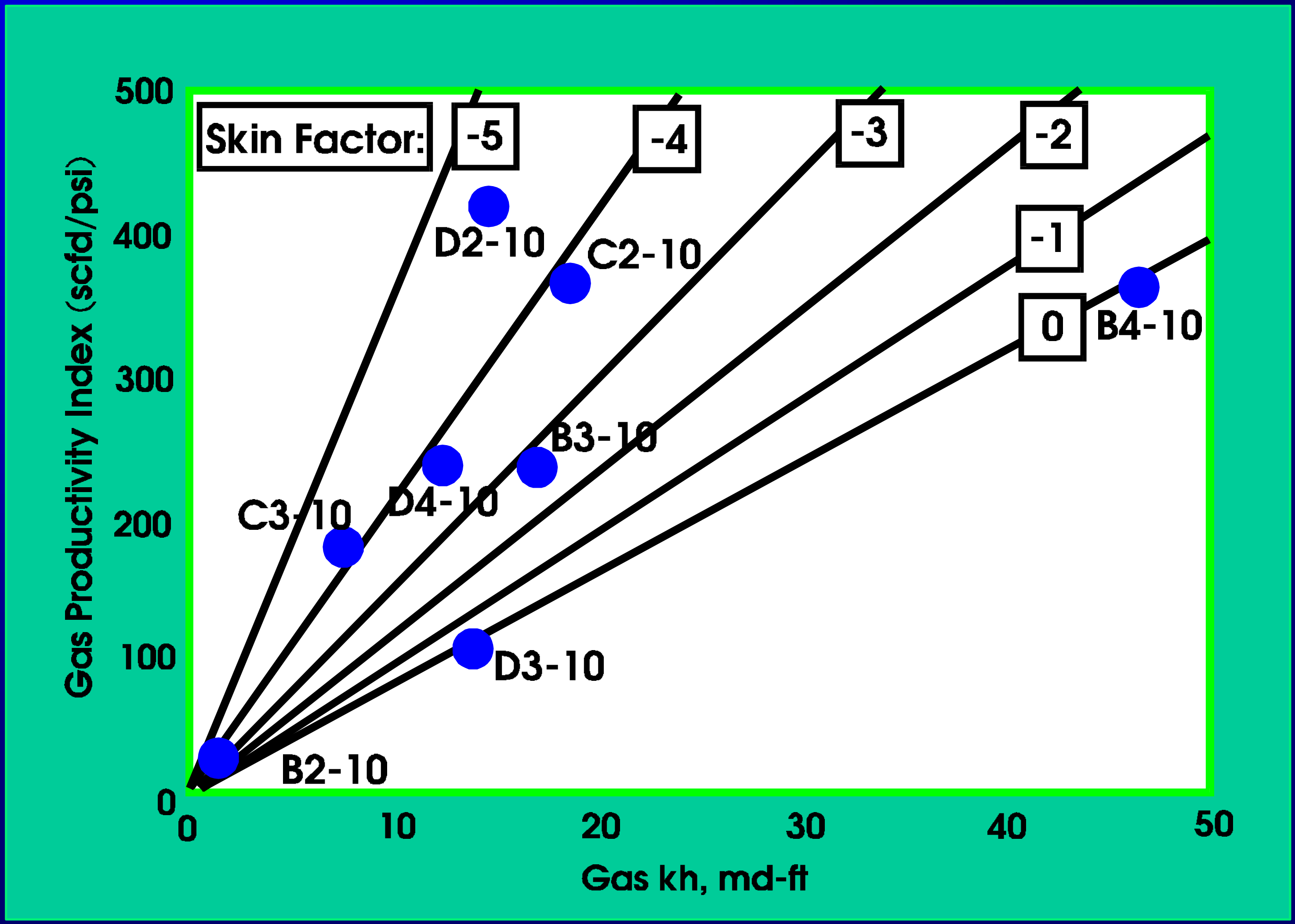
Illustration of ANN Structure



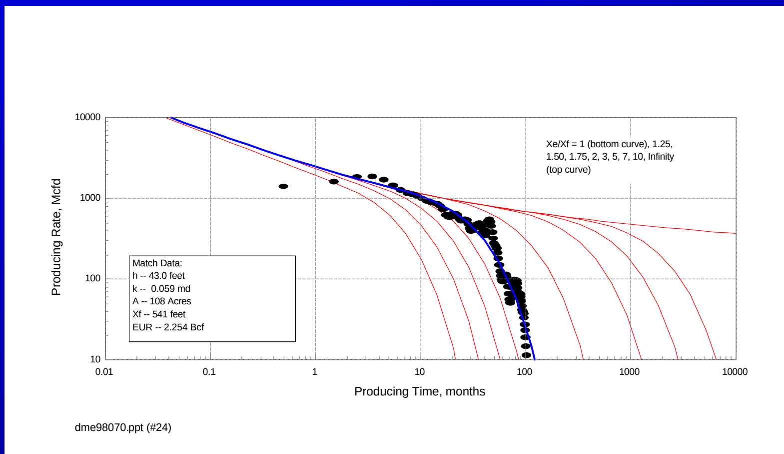
Example Virtual Intelligence Methodology

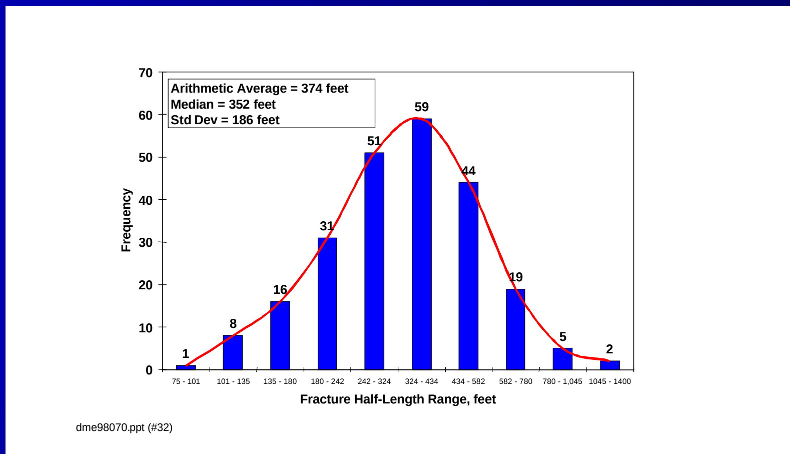
ARTIFICIAL NEURAL NET WORK		GENETIC ALGORITHM
Space:	X, Y, Z	•Total Proppant Volume
Time:	Completion Date	•Total Fluid Volume
Completion:	No. Perf. Intervals	•Fluid Type
	Total Net Thickness	
	No. Fracs	**FUZZY LOGIC**
	Total Proppant Volume	
	Total Fluid Volume	•GA Incremental
	Fluid Type	•Current Reservoir Pressure
Reservoir:	Total phi-h	•Current Producing Rate
	Permeability Indicator	
	Drainage Area	

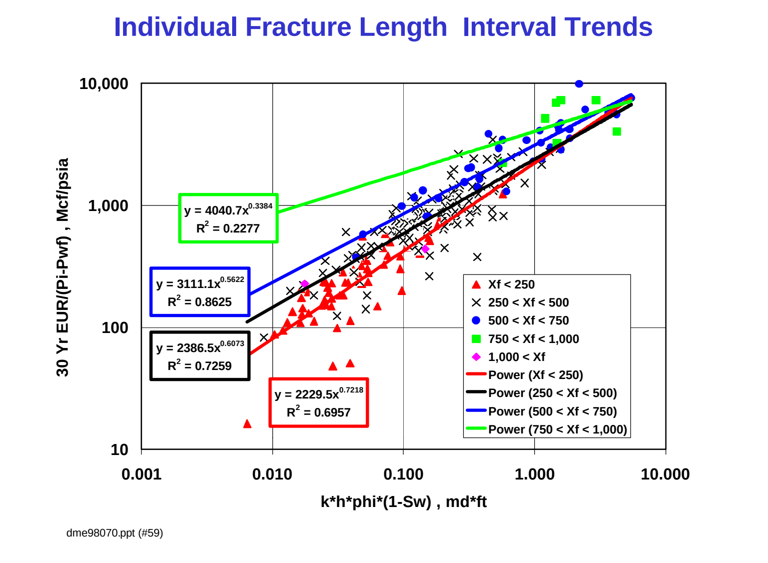
Diagnostic Plot for Selecting Restimulation Candidates, Antrim Shale

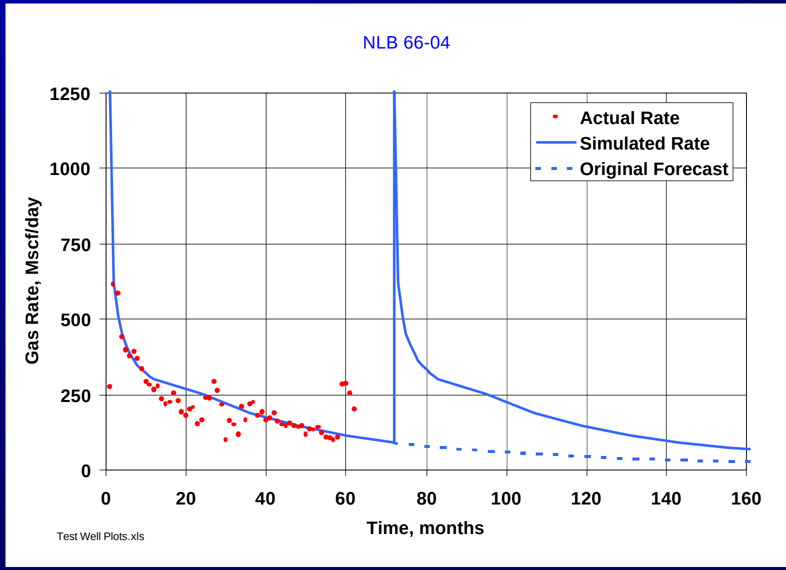


Type-Curves For Production Enhancement Assessment









Screening Criteria

Virtual Intelligence

- Optimized incremental production
  - Stimulation, artificial lift, FWHP

Type Curves

- Forecast incremental production
  - Perm, skin, area

Other

- No. zones per frac treatment
- Current reservoir pressure
- Current producing rates/ratios
- Historical peak rate, time/prod. since then
- Existence of step-change production drops

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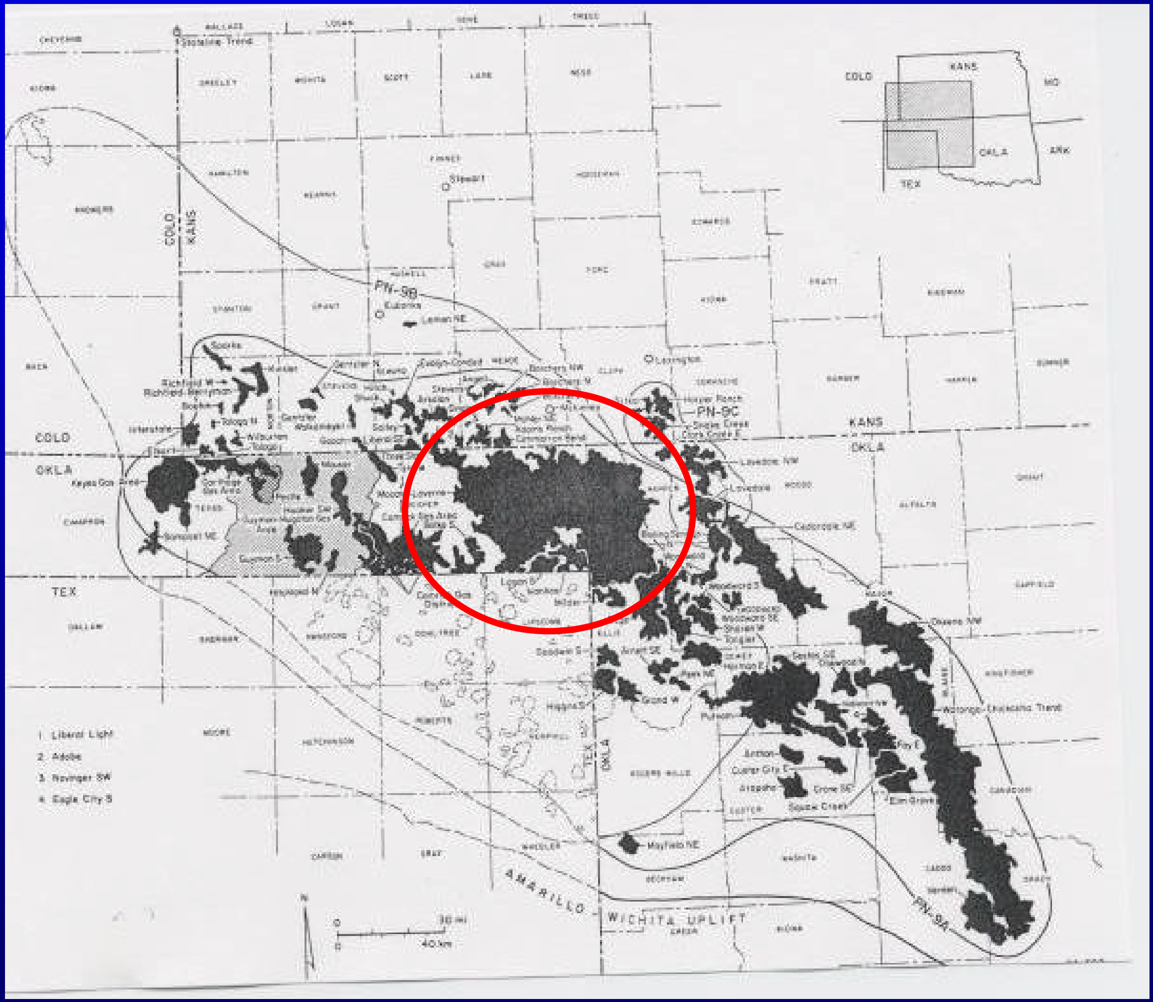
First Test Site, Oklahoma



Mocane-Laverne Gas Area, Oklahoma

- Central Anadarko basin
- Beaver/Harper/Ellis Counties
- Council Grove, Tonkawa, Morrow, Chester
- 2nd-largest Midcon gas play (Morrow), after Hugoton Wolfcamp.
- 2nd-largest Morrow field, after Watonga-Chickasha Trend.
- +/-100 well study
- Oneok Resources

Figure reproduced from: Atlas of Major Midcontinent Gas Reservoirs, 1993.

Structure/Stratigraphy*

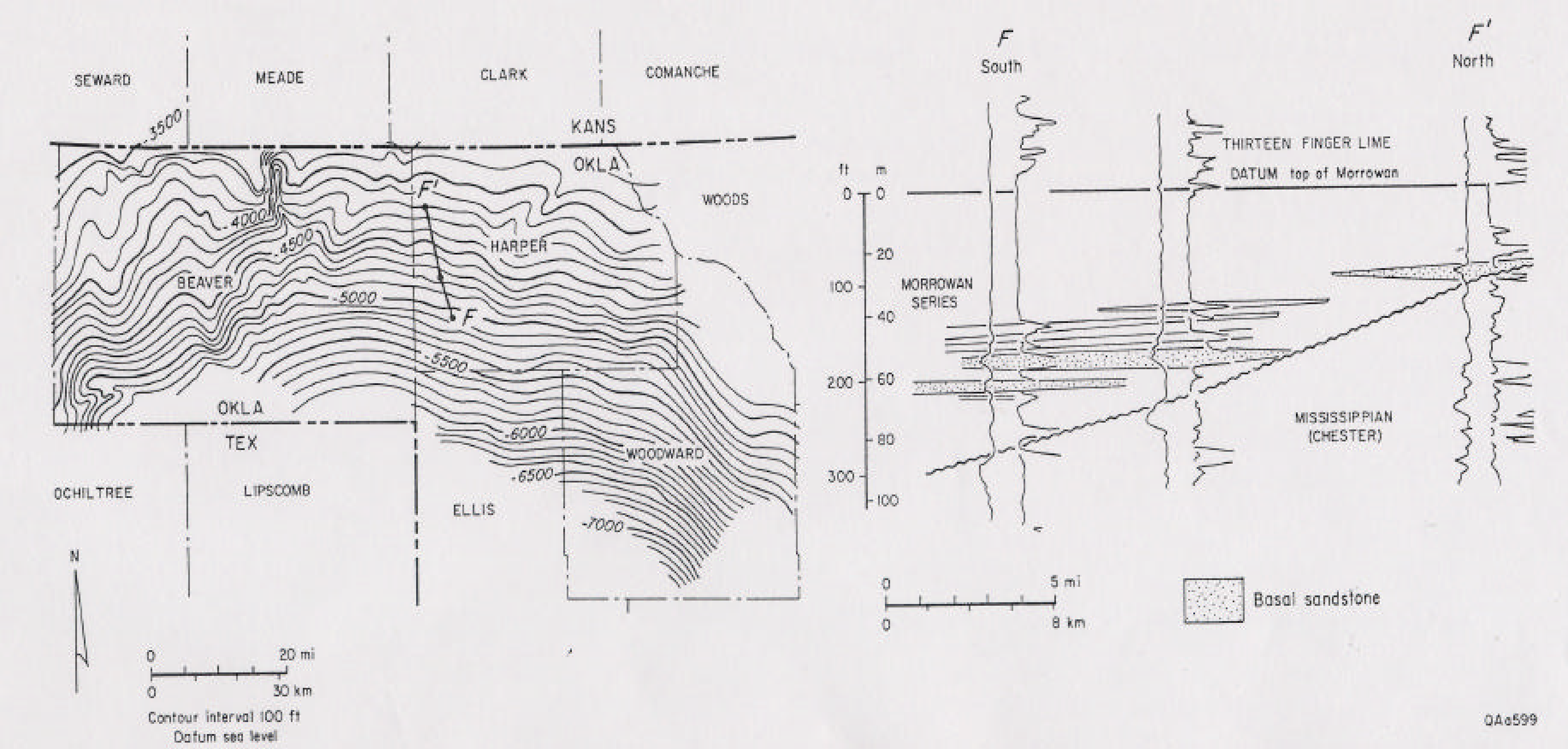


*Figure reproduced from Atlas of Major Midcontinent Gas Reservoirs, 1993.

Formation Descriptions

Formation	Age	Lithology	Gas Atlas Code*
Morrow	Lower Pennsylvanian	Sandstone	PN-9A
Chester	Upper Mississippian	Limestone	MS-5

*Atlas of Major Midcontinent Gas Reservoirs, 1993.

Reservoir/Fluid Properties*

	Morrow	Chester
Pay	20 ft	18 ft
Porosity	12%	8%
Water Saturation	38%	30%
Permeability	25 md	1 md
Gas Gravity	0.75	0.64

*Atlas of Major Midcontinent Gas Reservoirs, 1993.

Well Breakdown

					Well Omission Summary				
	Total*	Well Files On-Hand	Production Streams	Study Streams**	Zone	Inactive	Completion Date	IHS Data	Total
Min	77	49	55	33	8	4	7	3	22
Not Min	59	35	46	25	14	5	0	2	21
Total	136	84	101	58	22***	8	7	5	43

*Active Wells

**Study well crieria:

- Morrow/Chester completion
- Currently active
- Completion prior to Jan-00
- IHS data available.

***Other Zones included:

- Tonkawa(10)
- Hoover (7)
- Other (5)

General Well Profiles

Parameter	Range	Average
Completion Date	1957-1999	-------
Depth (ft)	4700-8900	6900
EUR		
–Gas (MMcf)	10-8595	2174
–Oil (Mbbls)	0-47	5
Current Gas* Rate (Mcfd)	0-263	69

Note: About half of study wells currently produce less than 60 Mcfd.

Completion/Production Practices

Completion

- Morrow typically fractured; many different fluids; older treatments were very small.
- Chester typically acidized; occasionally acid-fractured.

Production

- Some form of artifical lift typically installed at some point to lift liquids.

“Flat File” Design for VI Analysis

Space & Time

- X (Long)
- Y (Lat)
- Top Morrow perf.
- Top Chester perf.
- Completion date

Completion/Stimulation

- Interval
- Treatment Type
- Fluid Type
- Fluid Volume
- Proppant Volume
- No. Stages

Reservoir

- No. perf. intervals
- Net perf. thickness

Subsequent Events

- Date
- Interval
- Activity

Test Site Status

- Data Collected
  - IHS Energy
  - In-house production/reserve records
  - Well files
- Challenges being encountered
  - Diversity of producing intervals which change and are reworked over time.
  - Little digital data (except production).
  - Little geologic/reservoir data.
- Status
  - Manually creating “flat-file” for VI analysis.
  - Performing TC analysis.

Next Steps

- Complete VI & TC analyses.
- Develop screening criteria, select candidates.
- Perform remedial work, observe/document results.

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Application Guidelines

Why

To boost reserves and economic performance of marginal gas wells.

Where

Almost any setting is a valid target (complexity varies however).

How

•Build database
•Perform VI & TC analyses
•Select candidates
•Remediate Wells

When

Now.

Who

Operator.

Observations/Recommendations

- Most costly (analytic) elements are:
  - Data collection/digitization/organization.
  - Reporting (if required)
- Operators should invest in creating a digital database of all available well information (even simple spreadsheets are fine):
  - Any sophisticated analysis will eventually require this.
  - Cost of manually examining well files will eventually exceed investment in database.
- Each field will possess specific nuances:
  - Must capture existing field experience.
  - Design of VI application.
  - Screening algorithm
- Larger-scale programs will provide better overall results due to efficiencies of scale.

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Future Work

- Complete analysis of Mocane-Laverne wells, perform/document results of remedial treatments.
- Perform a similar analysis at a second site (sites currently being solicited).
- Technology transfer.
  - Publish results
  - "How To" manual
  - Software
- Completion date:
  - March 31, 2002.

Research Partner Information

Advantages

- Assessment of production enhancement for +/- 100 wells.
- Introduction to VI and TC applications.
- Keep tools for future in-house use.

Requirements

- Operator of +/- 100 stripper gas wells in a single play.
- Data availability (preferably in electronic format)
- Willingness/ability to perform 1-3 remediation treatments/workovers.
- Agree to release results into public domain.

Contact

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