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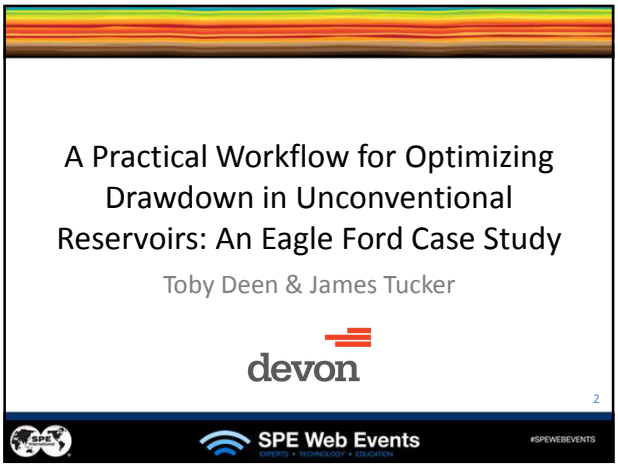
A Practical Workflow for Optimizing Drawdown in Unconventional Reservoirs: An Eagle Ford Case Study
Toby Deen & James Tucker
devon
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Poll: What region do you work in?
North America
South America
Europe
Australia
Asia
Africa
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Poll: What play do you primarily work?

- NE U.S. (Utica/Marcellus)
- Rockies (including Bakken)
- Permian
- Mid-con (Woodford/STACK/SCOOP)
- Barnett
- Eagle Ford or Haynesville
- Canada
- Other

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Poll: What is your primary job?

- Production Engineer
- Completions Engineer
- Reservoir Engineer
- Field Operator/Foreman
- Flowback Vendor/Service Provider
- Consultant
- Academic Researcher
- Other

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Presentation Outline

- Introduction
- Workflow for optimizing drawdown in unconventional reservoirs
- Eagle Ford case study
- Conclusions
- Q&A

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- What is drawdown?
  - Refers to the differential pressure between the reservoir and wellbore
  - Directly related to production rates
  - Typically controlled via mechanical chokes at the surface
  - Subject is often referred to as “choke management”
- Our focus will be on managing drawdown in unconventional reservoirs
  - Low permeability resource plays
  - Multi-stage fractured horizontal wells
  - This presentation concentrates on the initial flowing periods of a well’s life

- Why is managing drawdown important?
  - Directly controls production rates and cash flow
  - Maintain safe operations of surface equipment
  - Impacts well productivity
    - SPE-166101, SPE-36468, SPE-179159
  - Potential to damage the wellbore, completion and reservoir
    - SPE-15250, SPE-167698, SPE-168744
  - Influences well performance analysis and forecasting
    - SPE-171636, SPE-165721, SPE-137755
  - Provides insight into key reservoir and completion properties
    - SPE-1934785, SPE-175983, SPE-49223

Why is managing drawdown in unconventionals important continued…

- 4 main categories to consider:
  - Safe field operations
  - Well economics & productivity
  - EUR preservation
  - Data capture & analysis

Disclaimer: this webinar will only cover these three topics

- Managing surface facilities and EHS risk are out of scope for this presentation


Introduction
Proposed Workflow
Eagle Ford Study
Conclusions
Know the Goal
Rank Performance Drivers
Identify Risks & Contingencies
Own the Data
Adapt to Change
Poll: What is your #1 goal of your flowback or drawdown procedure?
• Maximum initial production rates
• Reach stable flowing conditions
• Fracture fluid cleanup
• Economics (NPV,ROR, etc.)
• Wellbore cleanup (sand, debris, etc.)
• Prevent damage to the well, completion or reservoir
• Surface facility optimization
• Data gathering & analysis
• Other
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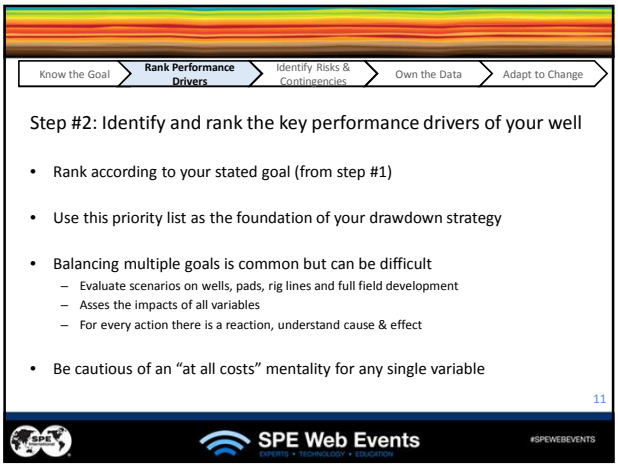
Know the Goal
Rank Performance Drivers
Identify Risks & Contingencies
Own the Data
Adapt to Change
Step #2: Identify and rank the key performance drivers of your well
• Rank according to your stated goal (from step #1)
• Use this priority list as the foundation of your drawdown strategy
• Balancing multiple goals is common but can be difficult
– Evaluate scenarios on wells, pads, rig lines and full field development
– Asses the impacts of all variables
– For every action there is a reaction, understand cause & effect
• Be cautious of an “at all costs” mentality for any single variable
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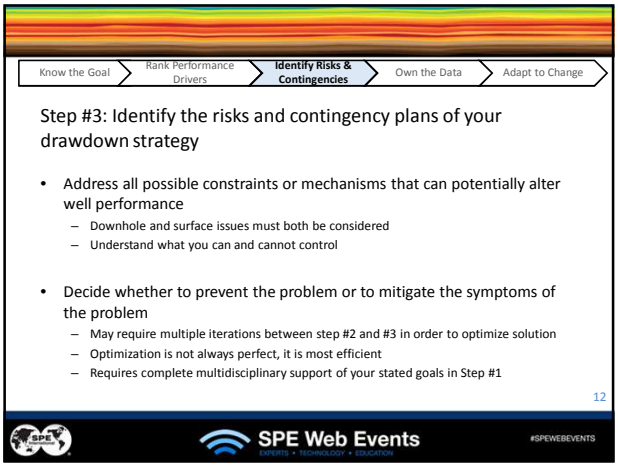
Know the Goal
Rank Performance Drivers
Identify Risks & Contingencies
Own the Data
Adapt to Change
Step #3: Identify the risks and contingency plans of your drawdown strategy
• Address all possible constraints or mechanisms that can potentially alter well performance
– Downhole and surface issues must both be considered
– Understand what you can and cannot control
• Decide whether to prevent the problem or to mitigate the symptoms of the problem
– May require multiple iterations between step #2 and #3 in order to optimize solution
– Optimization is not always perfect, it is most efficient
– Requires complete multidisciplinary support of your stated goals in Step #1
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Know the Goal | Rank Performance Drivers | Identify Risks & Contingencies | **Own the Data** | Adapt to Change

Step #4: Implement data management procedures that support a data driven decision-making process

- Provide standardized, clear instructions for data acquisition
  - You can't manage what you can't track
  - What rates are recorded, where are they coming from, how are they measured?
  - Find a data frequency that is right for your situation
- Consistently inaccurate data is better than inconsistently accurate data, as long as the errors are understood correctly
- Develop procedures that use well performance data to drive operational decisions
  - Procedures that don't rely on well performance data are arbitrary
  - Multidisciplinary collaboration should be required

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Know the Goal | Rank Performance Drivers | Identify Risks & Contingencies | Own the Data | **Adapt to Change**

Step #5: Adapt your strategy to changing conditions

- An "optimum" strategy is governed by the specific conditions and assumptions used in your evaluation
- A dynamic operating environment might change your goals or the assumptions used to rank performance drivers
  - Every component of the well stream is likely to change over time
  - Does a 70% drop in oil prices change your operations?
  - What about pipeline pressures, infill drilling, artificial lift plans, etc.?
- Tracking KPIs is essential to improving efficiencies, predicting performance and monitoring for possible problems
- Stay current on new technologies and industry practices
  - Seek out verification opportunities (reservoir simulations, analytical models, production history matching, etc.)

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Introduction | Proposed Workflow | **Eagle Ford Study** | Conclusions

Field Overview: Eagle Ford – DeWitt County, Texas

- Devon acquired asset and operations in Q4 2013 with 360 producing wells
- JV partner drills and completes the wells prior to handover

- TVD ~11,500 - 13,500 ft
- Avg. lateral length ~ 5,300 ft
- Initial reservoir pressure ~10,000 - 11,500 psi
- Varying phase windows
  - GOR 750-20,000 scf/bbl
  - 47-60º API gravity

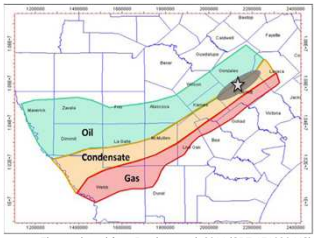

Figure adapted from Ramirez, et al. 2014 (SPE-171626-MS)

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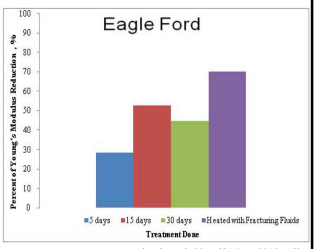
Introduction | Proposed Workflow | **Eagle Ford Study** | Conclusions

Legacy Choke Management Strategy

- Industry practices use predetermined procedures
  - Ours was a choke size schedule
- Published works present opposing viewpoints
  - Forced Closure: SPE-15250-PA
  - Aggressive: SPE-36468-MS
  - "Slowback": SPE-119894-MS
- Soft, over-pressured formations can be damaged by excessive drawdown
  - What is excessive?



Akrad, et al. 2011 (SPE-146658-MS)

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Introduction | Proposed Workflow | **Eagle Ford Study** | Conclusions

Possible Downhole Damage Mechanisms

- Proppant & fines migration → Preventable – function of drawdown rate
- Pressure dependent deliverability
- Mineral precipitation
- Condensate banking
- Changes to relative permeability
- Residual gel damage & thermal degradation of proppant

→ Cannot prevent with drawdown management

- Fracture cleanup, water blockage → Considered a non-issue in our field
- Combination of mechanisms → Probability & severity increase as a function of time

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Introduction | Proposed Workflow | **Eagle Ford Study** | Conclusions

Basis New Drawdown Strategy

- Predetermined strategies cannot truly be optimal
  - Dynamic variables drive well performance (completions, geology, well spacing, frac interference, etc.)
  - Forecasting performance is difficult and evolving
- Fines/proppant migration is the only preventable damage mechanism via drawdown strategy
- Delayed production increases risk to EUR
- Goal: maximize NPV without damaging the well
  - Maximize rates
  - Monitor for damage, don't try to predict it

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Introduction | Proposed Workflow | **Eagle Ford Study** | Conclusions

Quantifying the value

Q: What is the value of accelerating reserve recovery?

Q: What is the value if I erode reserves?

Q: Do commercial variables out weigh benefits to reservoir optimization?

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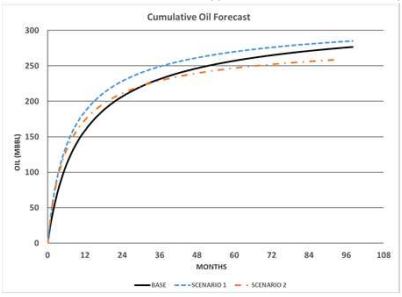
Know the Goal | Rank Performance Drivers | **Identify Risks & Contingencies** | Own the Data | Adapt to Change

Hypothetical Economic Analysis



SCENARIO	EUR (MBO)	IP (BOPD)	Di (%)	b
BASE	300	1,000	80.3	0.6
1	300	1,500	87.7	0.6
2	270	1,500	89.1	0.6

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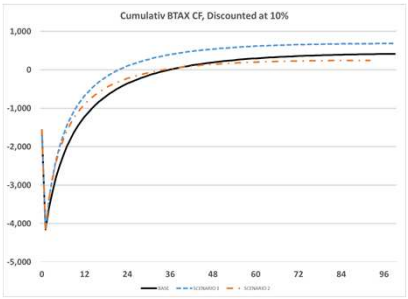
Know the Goal | Rank Performance Drivers | **Identify Risks & Contingencies** | Own the Data | Adapt to Change



Scenario	BTAX ROR (%)	BTAX NPV10 ($MS)
BASE	20	369
1	32	622
2	17	176
Price Forecast	**Oil ($/BBL)**	**Gas ($/MCF)**
FLAT	30	2

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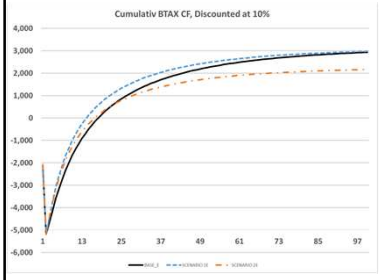
Know the Goal | Rank Performance Drivers | **Identify Risks & Contingencies** | Own the Data | Adapt to Change



Scenario	BTAX ROR (%)	BTAX NPV10 (MS)
BASE	62	3111
1	78	3060
2	58	2204
Price Forecast		
ESCALATING		

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How do I monitor for damage?

Critical Factors

I. Reservoir Assumptions

II. Data Quality

III. Execution

Pre-Analysis Checklist

- ✓ **PVT & Reservoir properties are accurate and critical assumptions identified**
  - Example: What is the expected saturation pressure? Will my analysis be affected by multi-phase flow?
- ✓ **What is the frequency of the data and the timing of updates?**
- ✓ **Will there be any surface operations that effect the data?**
  - Understand points of measurement and all potential flow paths
- ✓ **Create a game plan**
  - What are the expected rates & pressures?
  - Will there be surface constraints ?
  - What are the possible contingency plans?
  - How will we meet most of our objectives?

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Eagle Ford Toolbox

Rate-Time — **Surface Down Understanding**

Log-log Normalized Time vs Rate
Pressure vs Normalized Time
Cumulative Production vs. Time — **Initial Well Performance Analysis**

Pressure calibrated plots: — **Understand Well & Reservoir Productivity**

- Square-Root Time vs Normalized Pressure
- Material Balance/Superposition Time vs Normalized Pressure
- Pressure vs Cumulative Production
- Pad/Unit/Area comparative plots

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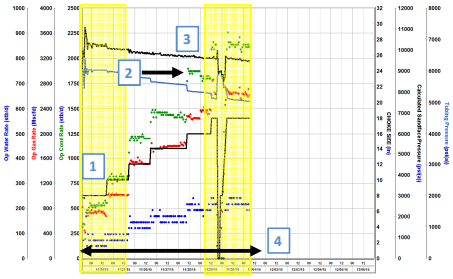
Well #1



1) Pipeline requirement
2) Verify flow path and measurement point
3) Unplanned event
4) Flowback duration

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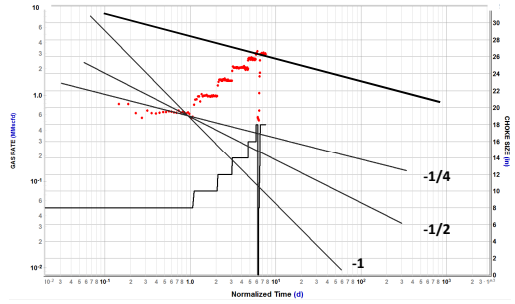
Well #1



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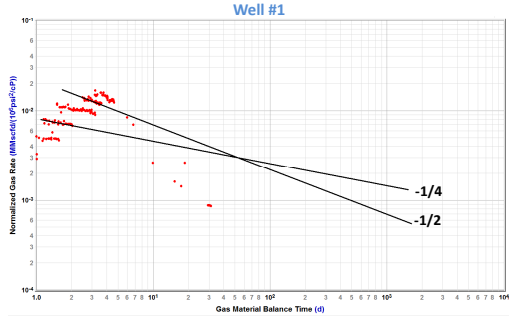
Well #1



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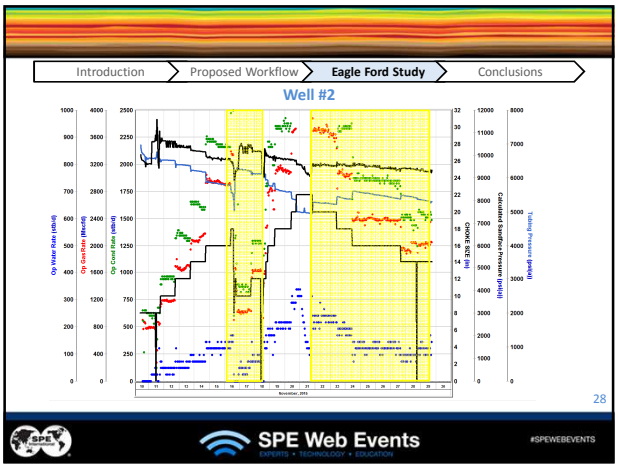
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Well #2
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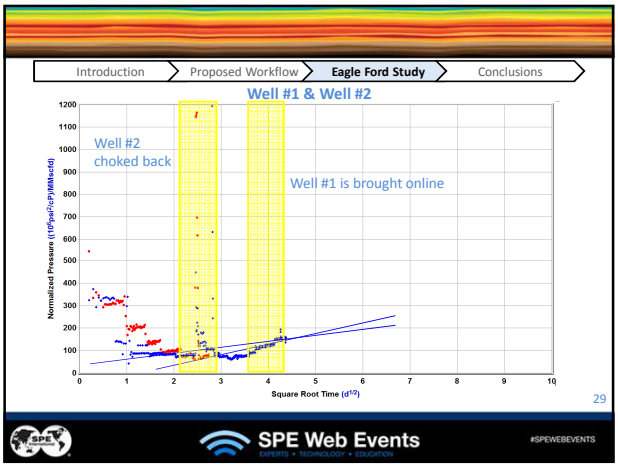
Introduction
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Eagle Ford Study
Conclusions
Well #1 & Well #2
Well #2
choked back
Well #1 is brought online
Square Root Time (d^1/2)
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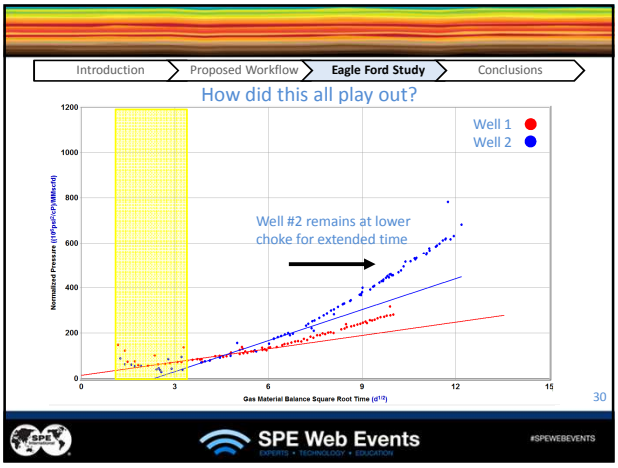
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Conclusions
How did this all play out?
Well 1
Well 2
Well #2 remains at lower
choke for extended time
Gas Material Balance Square Root Time (d^1/2)
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Introduction | Proposed Workflow | **Eagle Ford Study** | Conclusions

- RTA cannot predict damage but doing it real time provides context and practicality
- Scrutinizing early well performance fosters a better understanding of reservoir behavior and ultimately what drives productivity

So what is optimal and how do you maximize it?

- Dynamic workflows allow for optimization at small and large scales
- Maximizing deliverability requires a holistic approach

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Introduction | Proposed Workflow | **Eagle Ford Study** | Conclusions

Other Risks and Contingency Plans

Optimization truly requires multidisciplinary approach

- Individual well production 1000→2000 BOPD
  - 5 well pad 5000→10,000 BOPD
  - Exceeded field takeaway capacity
  - Altered development plan
- Fluid temperatures 120→220°F
- Artificial lift installation timing 18→5 months
- Sand production mitigation
- Managing flowback crews
- Countless economic sensitivities with changing price decks
- Reservoir damage studies
  - Funded research project behind SPE-178639-MS
  - In-house analytical and numerical models
  - Consulted independent SMEs
  - Core & PVT studies
  - Buildup and interference tests (prove conductivity over time)
  - Field trials
- Long-term damage mechanisms associated with drawdown should be evaluated and understood through more rigorous modeling and lab experimentation
  - SPE 178639
  - SPE 175029

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Innovative Operational Workflow

ILLUSTRATIVE

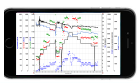
FIELD	DECISION SUPPORT CENTER	OPERATIONS & TECHNICAL TEAM
FLOWBACK VENDOR & PRODUCTION OPS TEAM	FLOWBACK ENGINEER	RESERVOIR & OPERATIONS ENGINEERS

Focusing on managing data quality	Conducting high frequency analytics to evaluate well performance	Building multi-disciplinary collaboration team
▪ Systematic, accurate, & consistent data acquisition ▪ Real-time monitoring, Data QA/QC, & standardized reports	▪ Support improved prioritization & efficiency ▪ Automated performance analysis & visualization tools	▪ Improved understanding of well performance ▪ Shared knowledge to drive optimum choke strategy

Daily Field Reports:

Oil	1000	bbl
Water	500	bbl
Gas	2000	mcf
WHP	700	psi
Choke	12/64	inch

Real-time Performance Analysis



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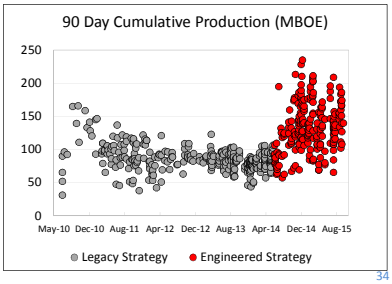
Introduction > Proposed Workflow > **Eagle Ford Study** > Conclusions

Exceptional Full Field Results

- Shows every DVN operated well in DeWitt County
- Effects from infill drilling, well interference, downtime, etc. are all included

Average 90 Day Production (MBOE)	
Legacy Strategy	86
New Strategy	132



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Introduction > Proposed Workflow > Eagle Ford Study > **Conclusions**

Key Takeaways

- Drawdown strategies can be critical to well performance, field operations and reservoir analysis
- Existing diagnostic techniques can evolve beyond historical performance review tools
- High frequency data analysis can accelerate interpretations and drive efficiencies
- Developing practical applications of technical interpretations to drive operational decisions has proven to be superior than legacy industry practices
- The flowback period is a crossroads for well operators, midstream personnel, reservoir, completions, production and facilities engineering – multidisciplinary collaboration is vital to optimization

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Introduction > Proposed Workflow > Eagle Ford Study > **Conclusions**

Tips for Developing Your Drawdown Strategy

- Peer benchmarking can be a great starting point but don't make conclusions until you know the assumptions
  - Understanding your goals and operating conditions is the most important consideration for developing your optimal drawdown strategy
- Pre-determined procedures might "get the job done" but can never be truly optimal across a field
- Implement your strategy with data driven decision making
- Well production data is the only single source of information that is influenced by, and therefore provides insight into, all of the dynamic variables that drive well performance
- Define the boundaries early in development – verify the complete range of outcomes in order to maximize the field's value

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Acknowledgements

- SPEI Production & Operations Committee for organizing this webinar
- Dave Anderson – moderator
- Devon Energy for allowing us to share this project
- Eagle Ford Asset Team

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Appendix

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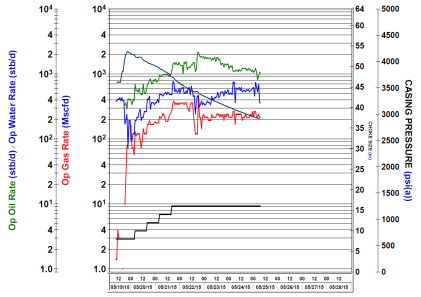
Lower Productivity Example: Well #3



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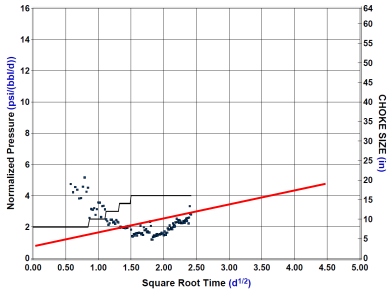
Well #3



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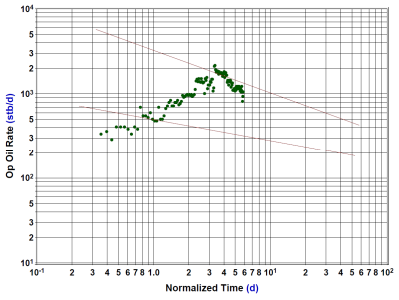
Well #3



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