IOGCC Midyear Issues Summit Meeting

WELL CONSTRUCTION AND COMPLETIONS

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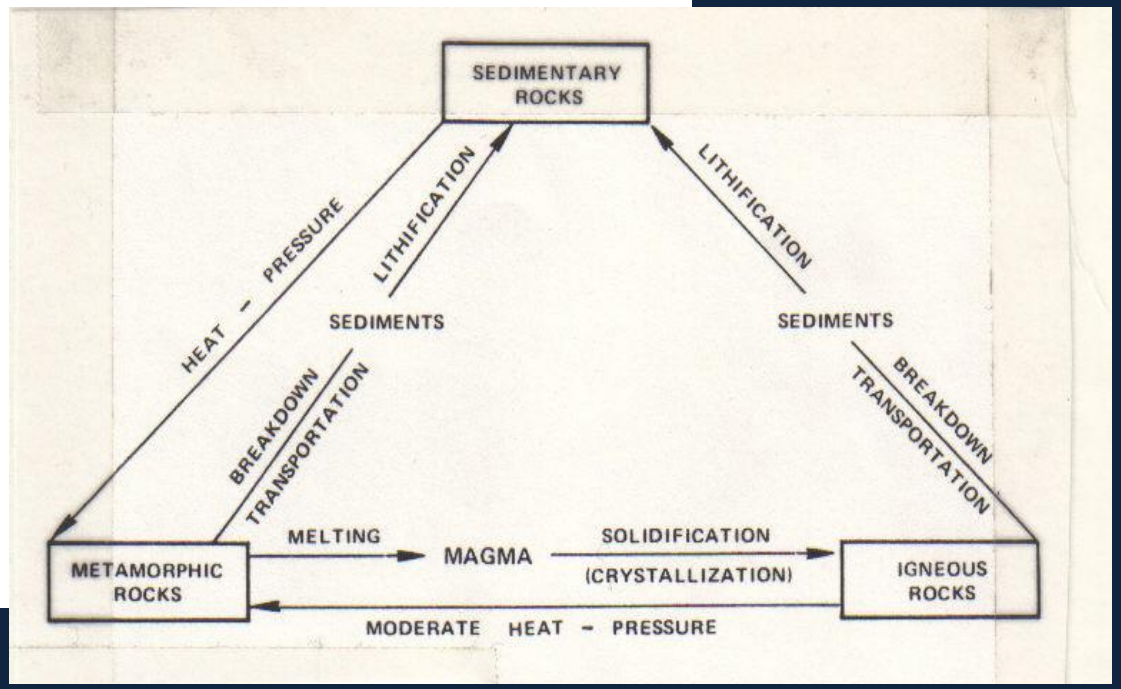
Griffin Gate Marriott Hotel
Lexington, Kentucky
May 24, 2010

Topics for Today's Discussion

- Basic Geology – Geology Considerations
- Geological Exploration
- Land Management
- Drilling - Cable Tool Method
- Drilling - Rotary Drilling Method
- Drilling Process
- Well Casing
- Cementing Process
- Logging and Well Interpretation
- Well Stimulation
- Chemicals Used
- Water Management

Well Construction – GEOLOGICAL CONSIDERATIONS

- **Physical Geology**
  - Basic Classification of Rocks
    - Igneous
    - Metamorphic
    - Sedimentary
  - Geologic Processes



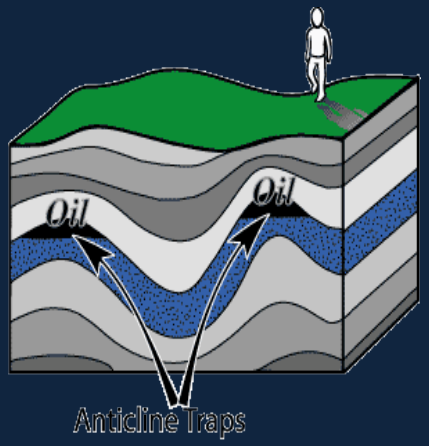
Well Construction – GEOLOGICAL CONSIDERATIONS

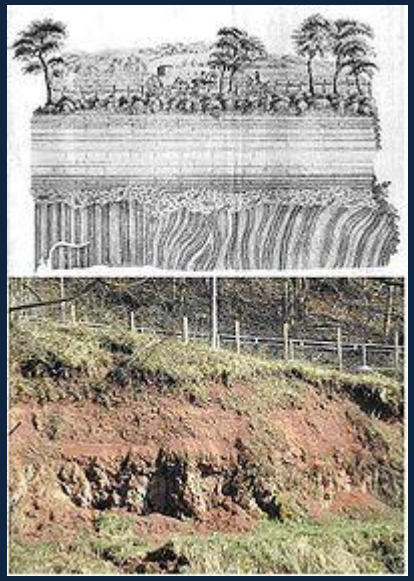
<u>Conventional Reservoir Traps</u>

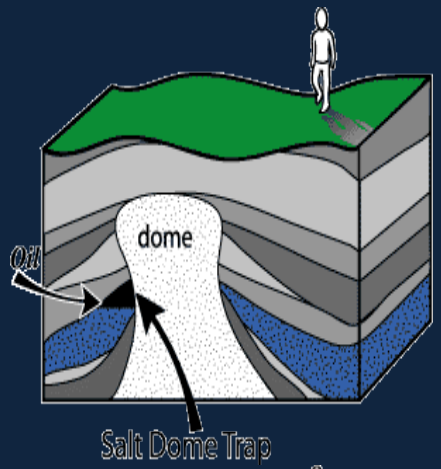
- **Domal and Anticlinal Structures**
- **Faults**
- **Unconformity**
- **Salt domes**
- **Sand lenses.**

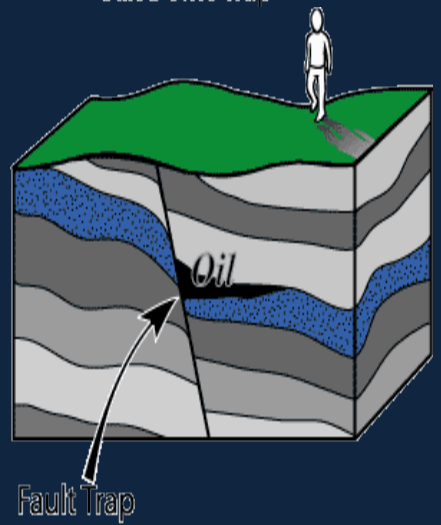
<u>Unconventional Reservoirs</u>

- **Marcellus Shale**
- **Coalbed Methane**



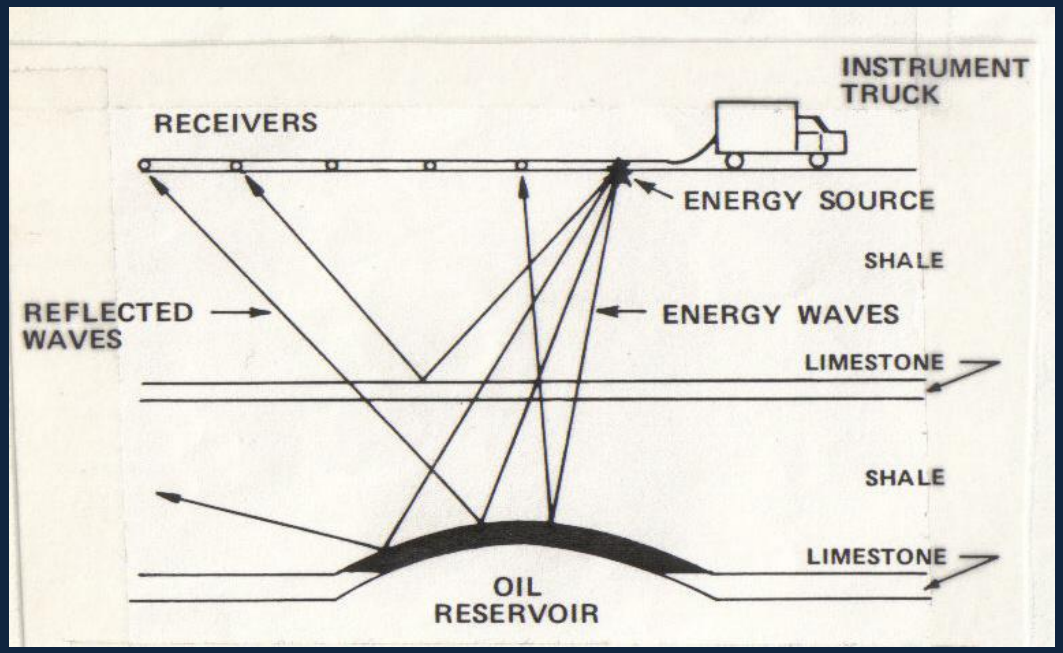


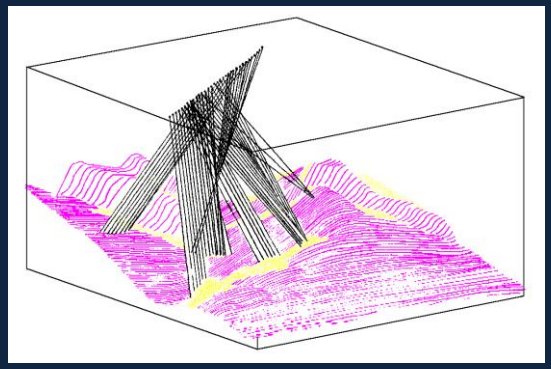




Well Construction – GEOLOGICAL EXPLORATION

- Geophysical Techniques
  - Seismic Techniques
  - Magnetic Method
  - Gravity Method





Well Construction – LAND MANAGEMENT

Land Rights

Surface Rights (depends on the nature of work)

- Right of ways (for pipelines and roads)
- Surface lease (for surface facilities)
- Permits (usually for geophysical exploration)
- Purchases (for building facilities, e.g. refinery)
- Surface damage rights

Mineral Rights

- Oil and gas only or coal only
- Royalty only

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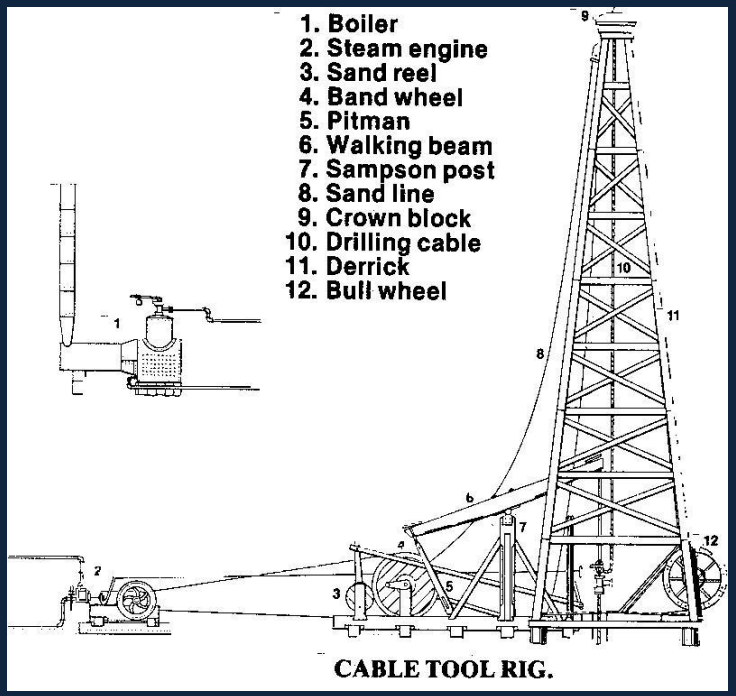
Well Construction – DRILLING

Cable Tool Drilling



Well Construction – DRILLING

Rotary Drilling

Rotary Drilling Types

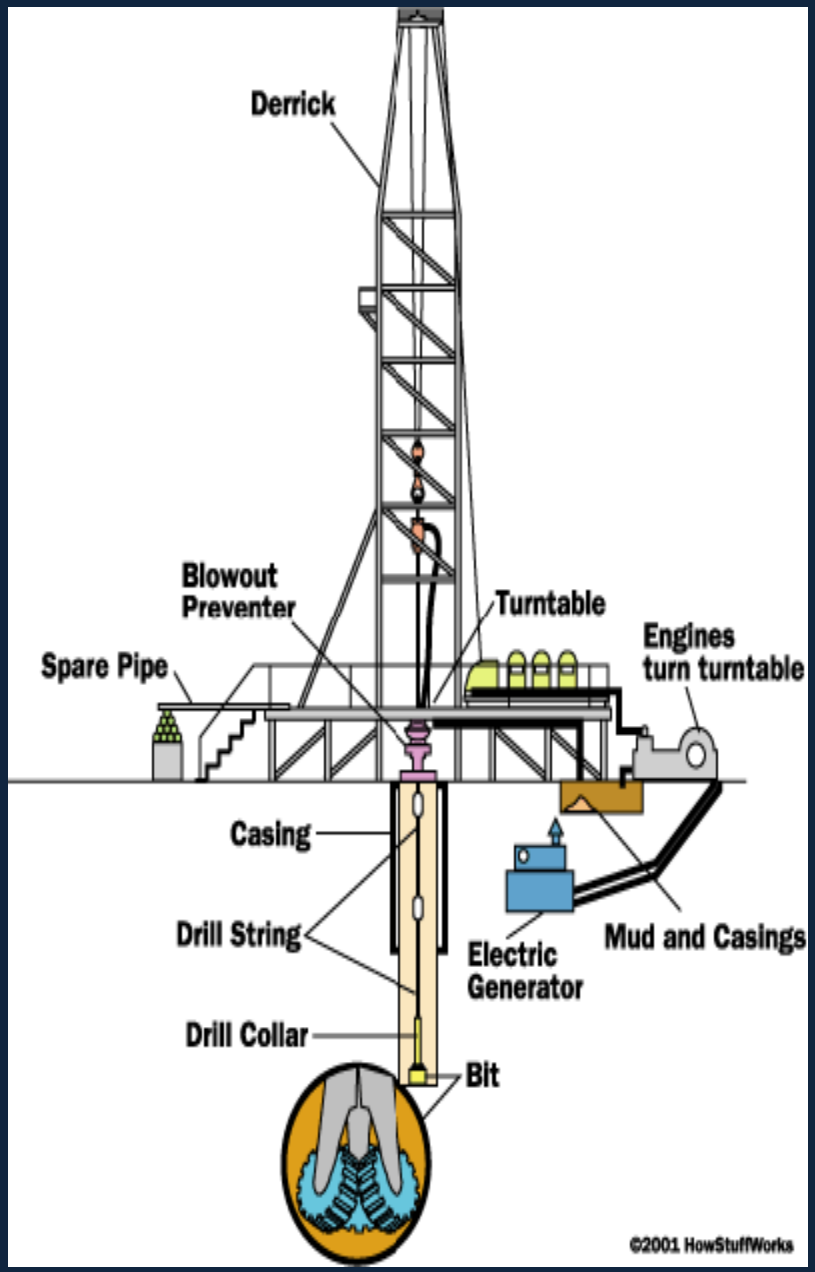
- **Rotary Table**
- **Top Drive**
- **Downhole Motors**
- **Casing and liner drilling**

Well Construction – DRILLING

Rotary Drilling

Major Systems (Components):

- Drill string and the bit (rotary system)
- Fluid circulating system
- Hoisting system
- (Rig) Power system
- Well control system (Blowout prevention system)
- Well monitoring system



Well Construction – DRILLING

Rotary Drilling

Pumps:

Single-acting: Triplex

Double-acting: Duplex

Well Construction – DRILLING

Rotary Drilling

Well Control System

Well Construction – DRILLING

Rotary Drilling

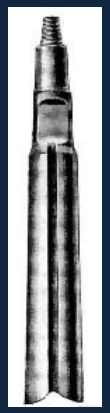
Well Monitoring System

Well Construction – DRILLING

Rotary Drilling

Bit Types:

- **Drag bits (Fishtail bits)**



- **Roller cone bits**
  - Two-cone bits
  - Three-cone bits
  - Four-cone bits

- **Polycrstalline diamond compact bits (PDC)**

- **Diamond bits**
- **Hammer bits**

Well Construction – DRILLING PROCESS

- **Common Types of Well Completion**
  - Open hole
  - Uncemented liner or screen
  - Cemented casing or liner
  - Slotted or perforated liner
  - Slotted liner with or without external packers

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Well Construction – DRILLING PROCESS

Casing Types

- Drive Pipe
- Conductor Casing
- Surface Casing
- Intermediate Casing
- Production Casing
- Liner
- Tie-back Liner

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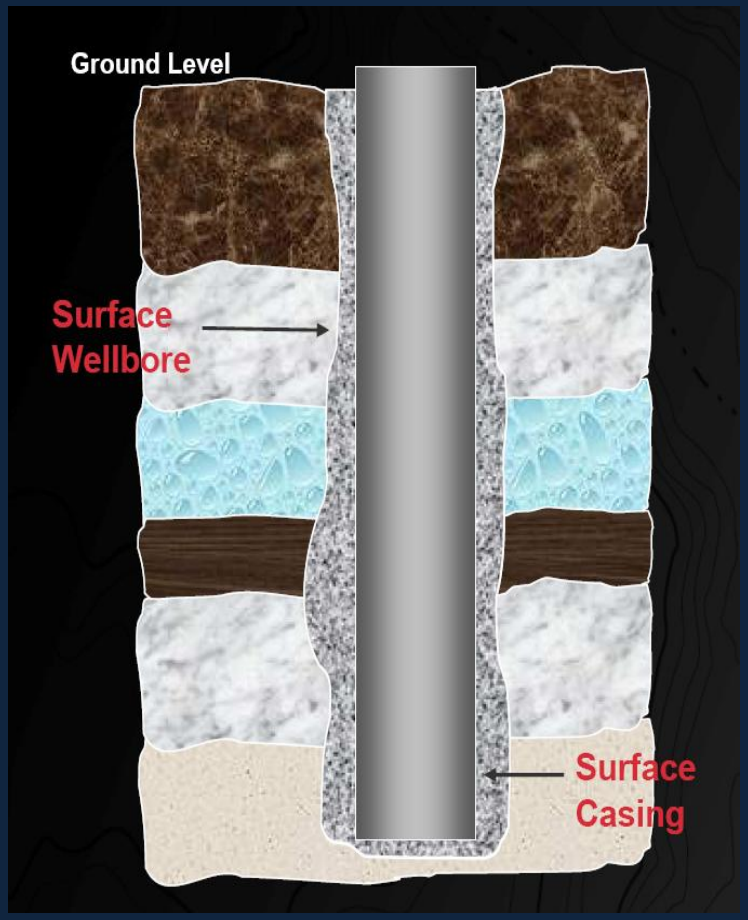
Well Construction – DRILLING



Typical Well – Surface Casing

Purpose

- Protect ground water
- Provide stable wellbore during drilling operation
- Provide well control during drilling

Depth Requirements

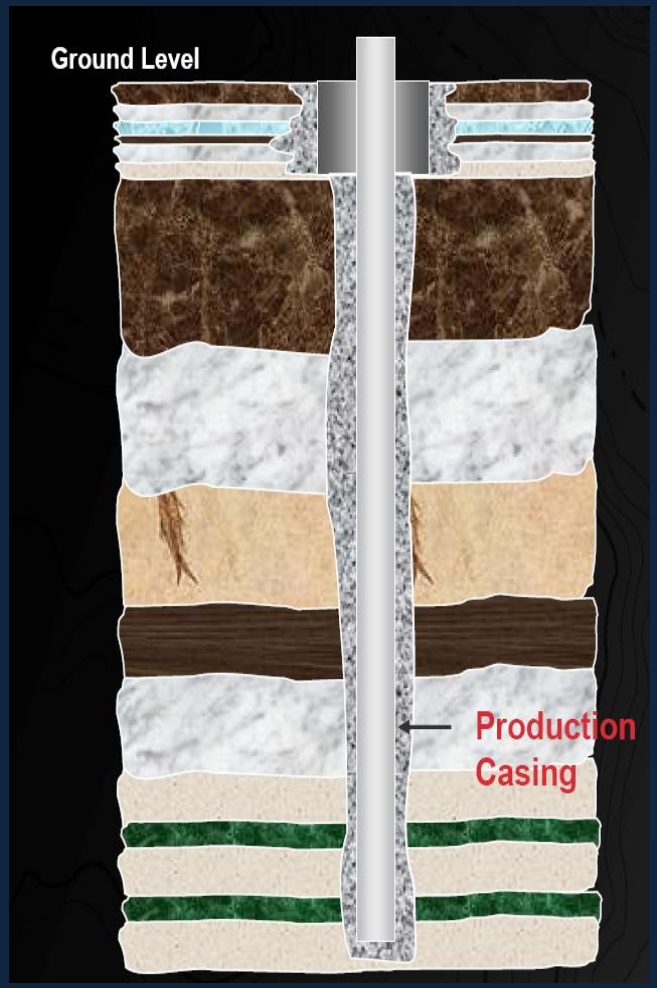
- Set by State regulations
- Set by BLM regulations
- 1,000 to 4,000 ft

Cement

- Protects casing from corrosion
- Provides zonal isolation

- Support casing in wellbore

Well Construction – DRILLING



Typical Well – Production Casing

Purpose

- Provide zonal isolation
- Provide well control
- Well path to productive intervals

Cement Requirements

- Set by State regulations
- Set by BLM regulations
- Operator requirements

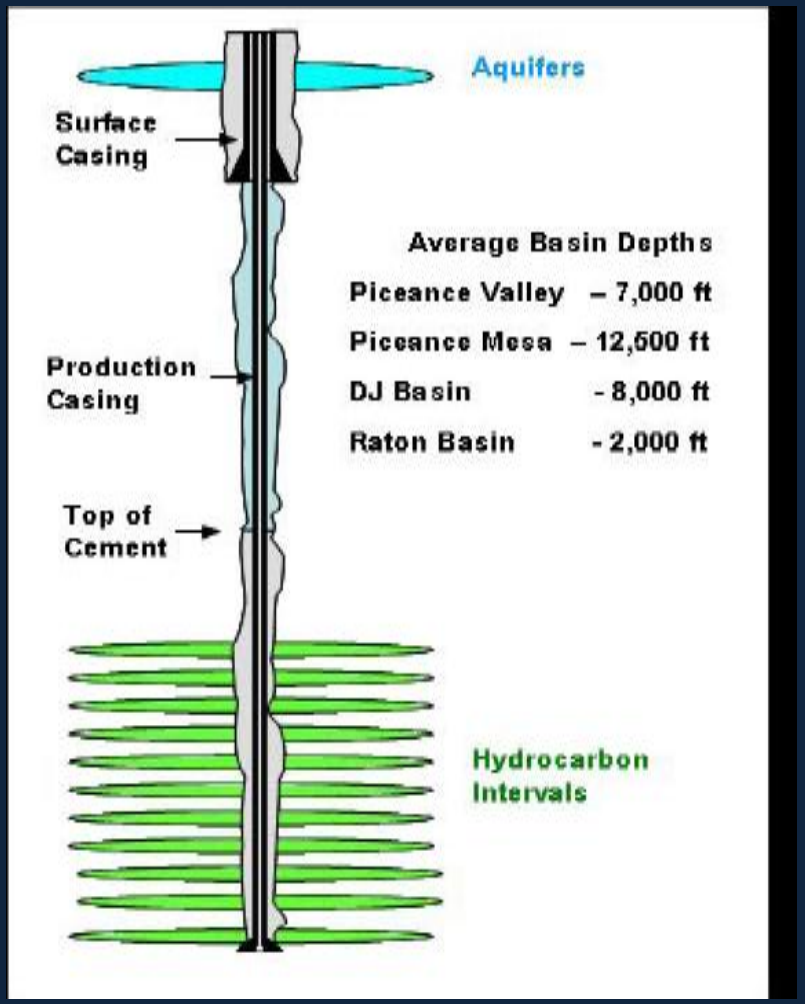
Cement

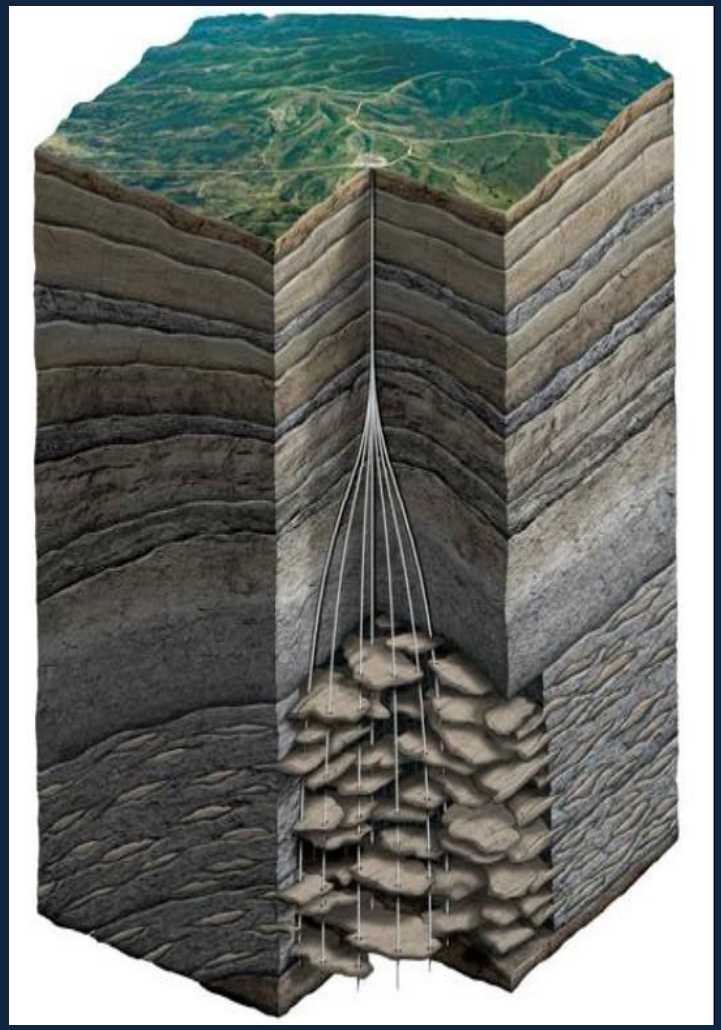
- Protects casing from corrosion
  - Provides zonal isolation
    - Completion and Production

- Support casing in wellbore

Well Construction – DRILLING

Primary Well Design





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Multiple-Zone Completions:

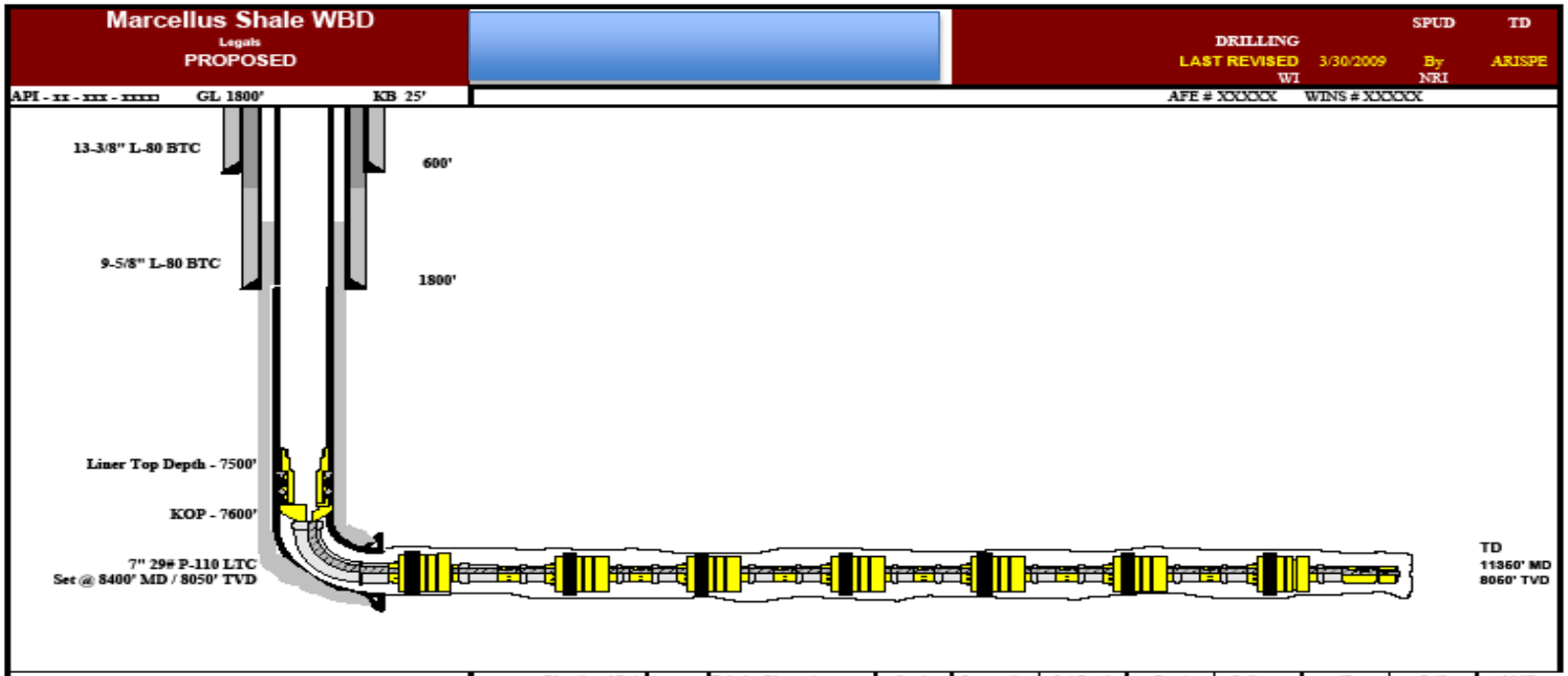
Criteria:

- Higher production rates
- Faster payout
- Multi-reservoir control requirement

1. Single String – Single Packer
2. Single String – Dual Packer
3. Parallel String – Multiple Packer
4. Single String – Multiple Packer

Well Construction – DRILLING

Well Drilling Process Open Hole Design

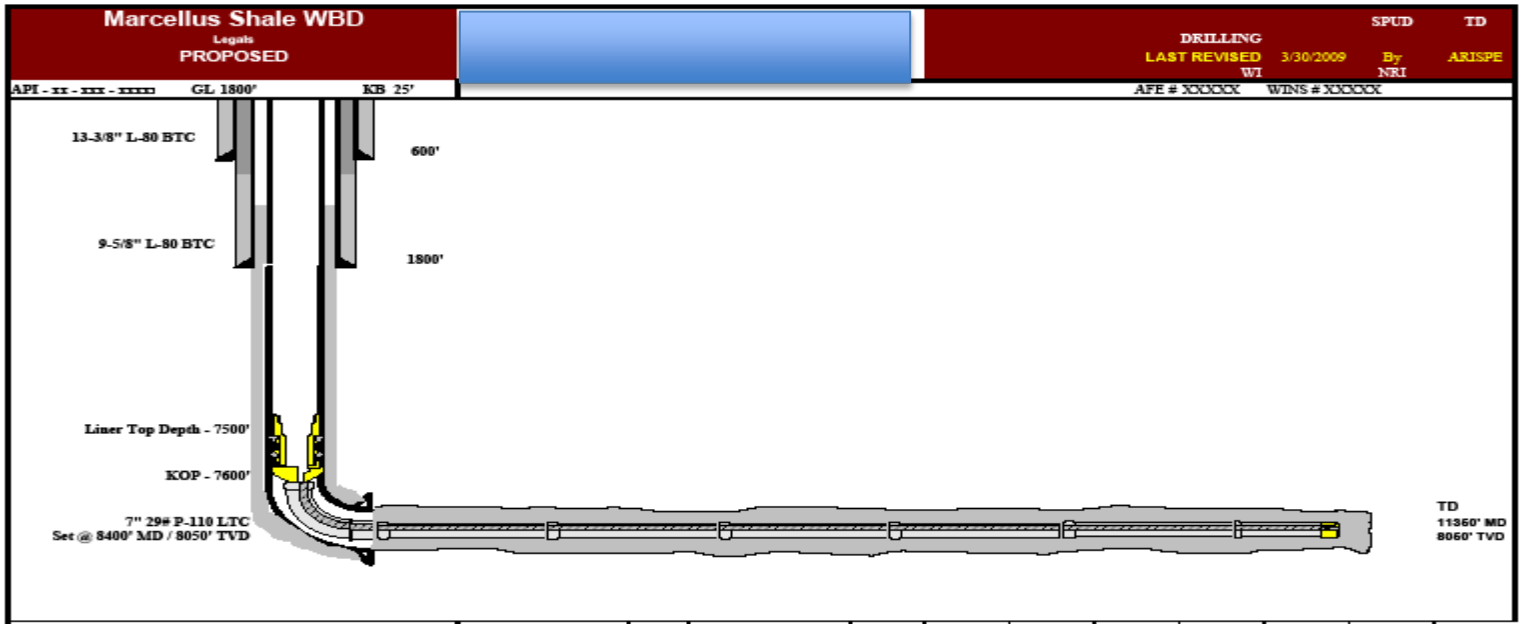


Directional Data		Tubular Dimensions		Grade	Connection	Set Depth	Burst	Collapse	ID	Drift	bbl/ft
KOP		13-3/8"				600'					
Max Dev		9-5/8"		L-80	BTC	1800'					
Deg Sev.		7"	29#	P-110	LTC	8400'	8510	11220	6.184	6.059	0.03566
		4-1/2"	15.1#	P-110	LTC	11350	14420	14320	3.826	3.701	0.01554
		2-3/8"	4.7#	L-80	8 rd EUE	N/A			1.995	1.901	0.00386

Marcellus OH Packer Well.xls

Well Construction – DRILLING

Rotary Drilling – Cased Hole Design



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		4-1/2"	15.1#	P-110	LTC	11350	14420	14320	3.826	3.701	0.01554
		2-3/8"	4.7#	L-80	8 rd EUE	N/A			1.995	1.901	0.00386

Marcellus Cemented Liner.xls

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Cementing Services

Purpose of Cementing

- Isolate Productive Zones
- Prevent Unwanted Production
  - Prevent Inter-zonal Communication
- Protect Casing
  - Corrosion
- Strengthen Casing

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Composition of Portland Cement

Clinker	CCN	Mass %
Tricalcium silicate $(CaO)_3 \cdot SiO_2$	C_3S	45-75%
Dicalcium silicate $(CaO)_2 \cdot SiO_2$	C_2S	7-32%
Tricalcium aluminate $(CaO)_3 \cdot Al_2O_3$	C_3A	0-13%
Tetracalcium aluminoferrite $(CaO)_4 \cdot Al_2O_3 \cdot Fe_2O_3$	C_4AF	0-18%
Gypsum $CaSO_4 \cdot 2 H_2O$		2-10%

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Factors that Influence Slurry Properties

- Water ratio of cement slurries (gal/sk)
- Slurry Density – How dense we mix the slurry (lb/gal)
- Fact: There are at least 41 known chemical reactions that occur when water is mixed with dry cement.

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Common Cement Types

- Class A – used for shallow wells
- Class B – used for shallow wells
- Class C – High early strength for shallow wells
- Class G – High strength, used world wide
- Class H – High strength, primarily in domestic US.

Guidelines for cementing are set by the American Petroleum Institute.

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Effects of Water with Cement

- Too much water – Results in thin slurries with poor strength development, extended pump times and free water.
- Too little water – Results in thickened slurries with higher strength developed but reduced pump times are and are difficult to pump.

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Other Common Cement Properties

1. If you stop pumping during a job for any extended period of time, the thickening time is virtually cut in half.
2. **Inorganic materials, such as calcium chloride tend to reduce thickening time.**
3. **Organic materials, such as sugar tend to extend thickening times.**

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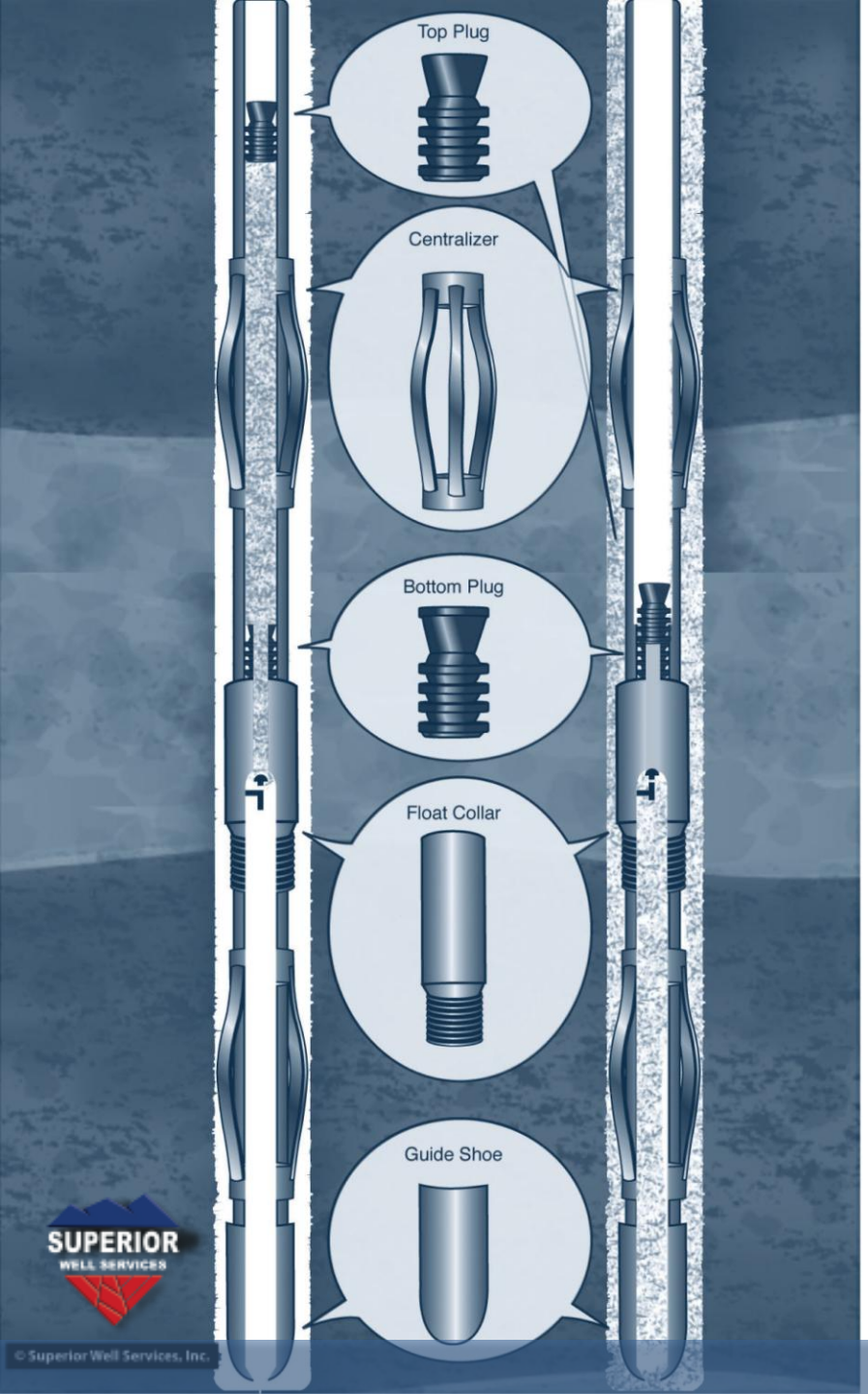
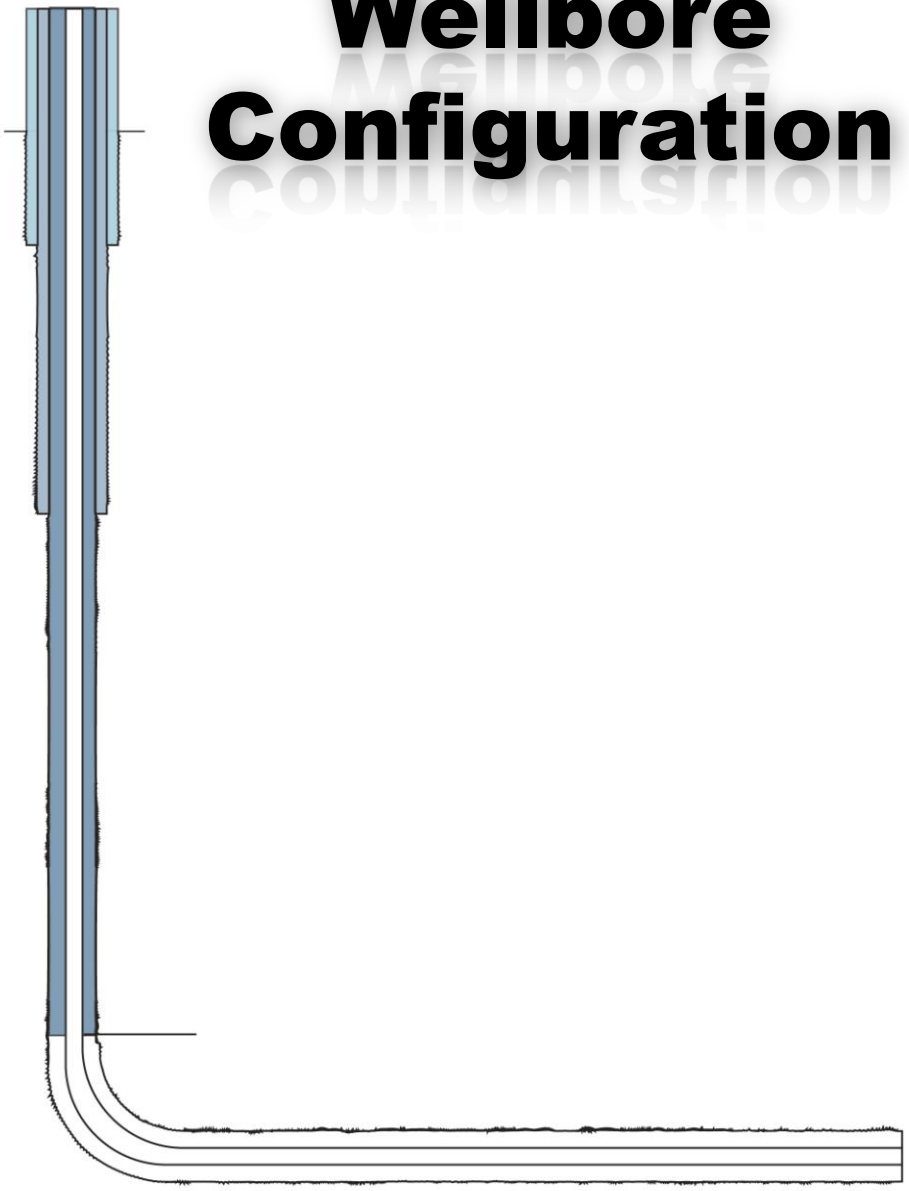
Wellbore Configuration





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Wellbore Environment

- Formation Information
  - Pay Zone Location
  - Sensitivity To Water
  - Fresh Water Zones
  - Gas Zones
  - Salt Zones
  - Water Flows
- Fracture Gradients
- Formation Pressure

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Wellbore Environment

- Temperature
  - Circulating Temperature
  - Static Temperature
  - Cement Column Temperature Differential
- Drilling Fluid Data
  - Mud Type/Chemistry
  - Density
  - PV/YP
  - Fluid Loss
  - Gel Strength Development

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Slurry Design Factors

Wellbore Conditions Dictate Slurry Selection!

- Density
- Retardation
- Filtration Control
- Slurry Stability
- Gas Migration Control
- Waiting on Cement Time
- Mechanical Properties

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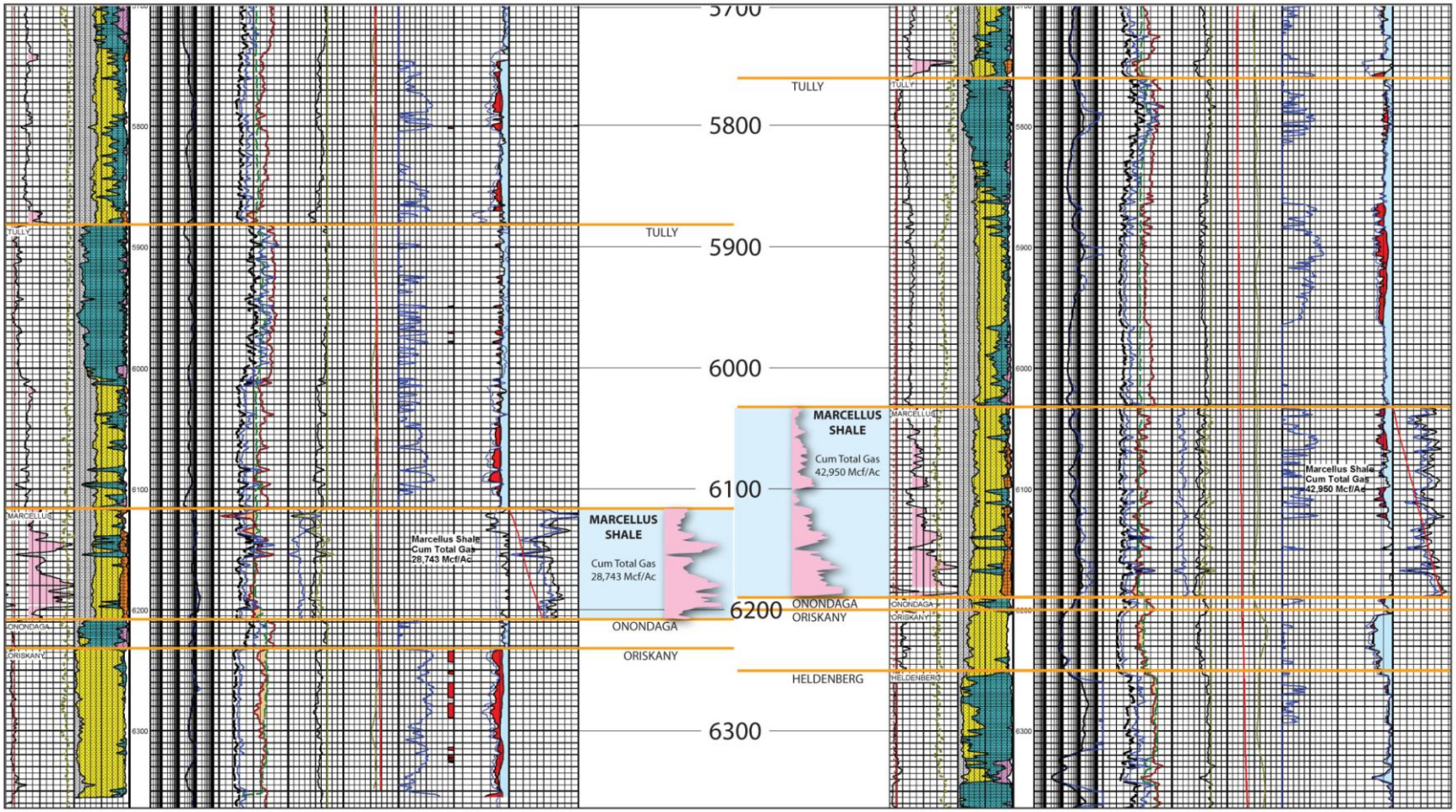
Wireline Services

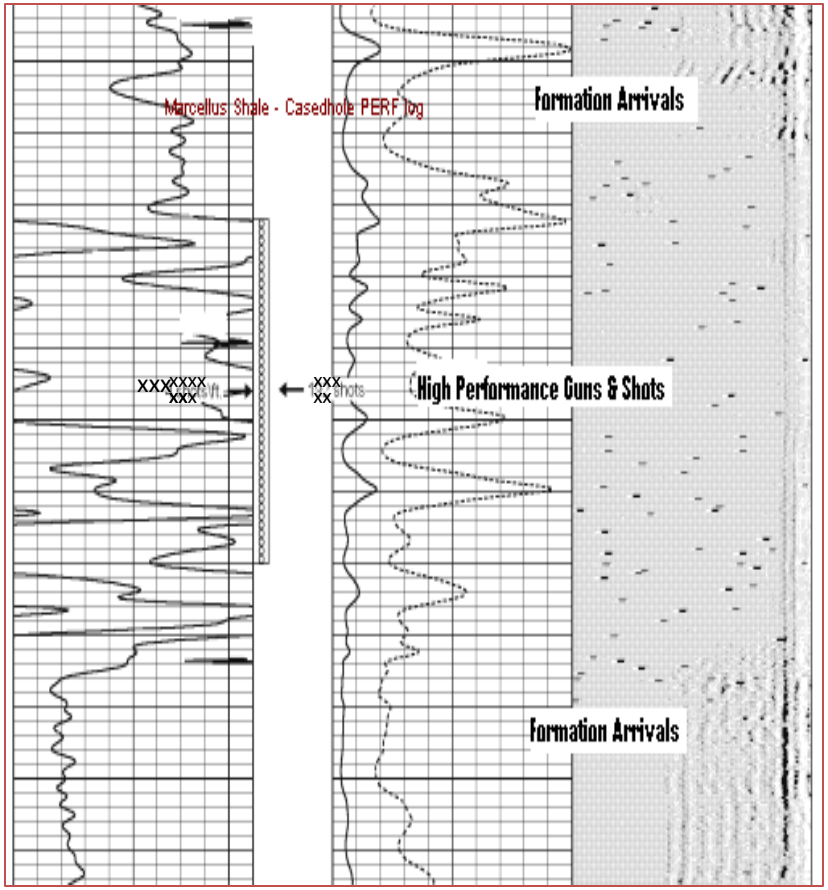
Purpose of Wireline

- Open-Hole Logging for Identifying Target Zone Characteristics
- Cased-Hole Perforating, Explosives to Penetrate the Producting Zones

Marcellus Log Interpretation

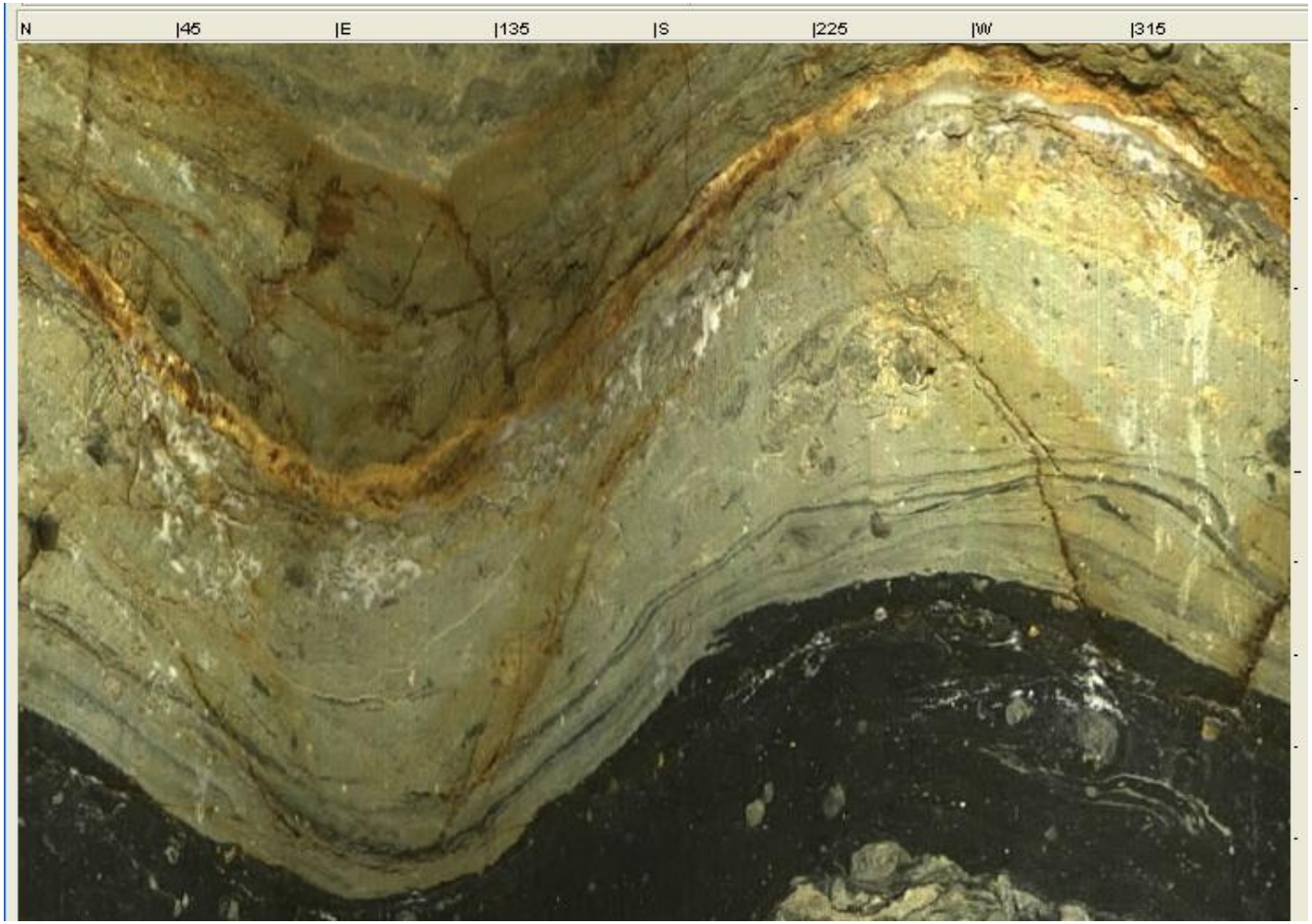


Marcellus Shale Cased Hole

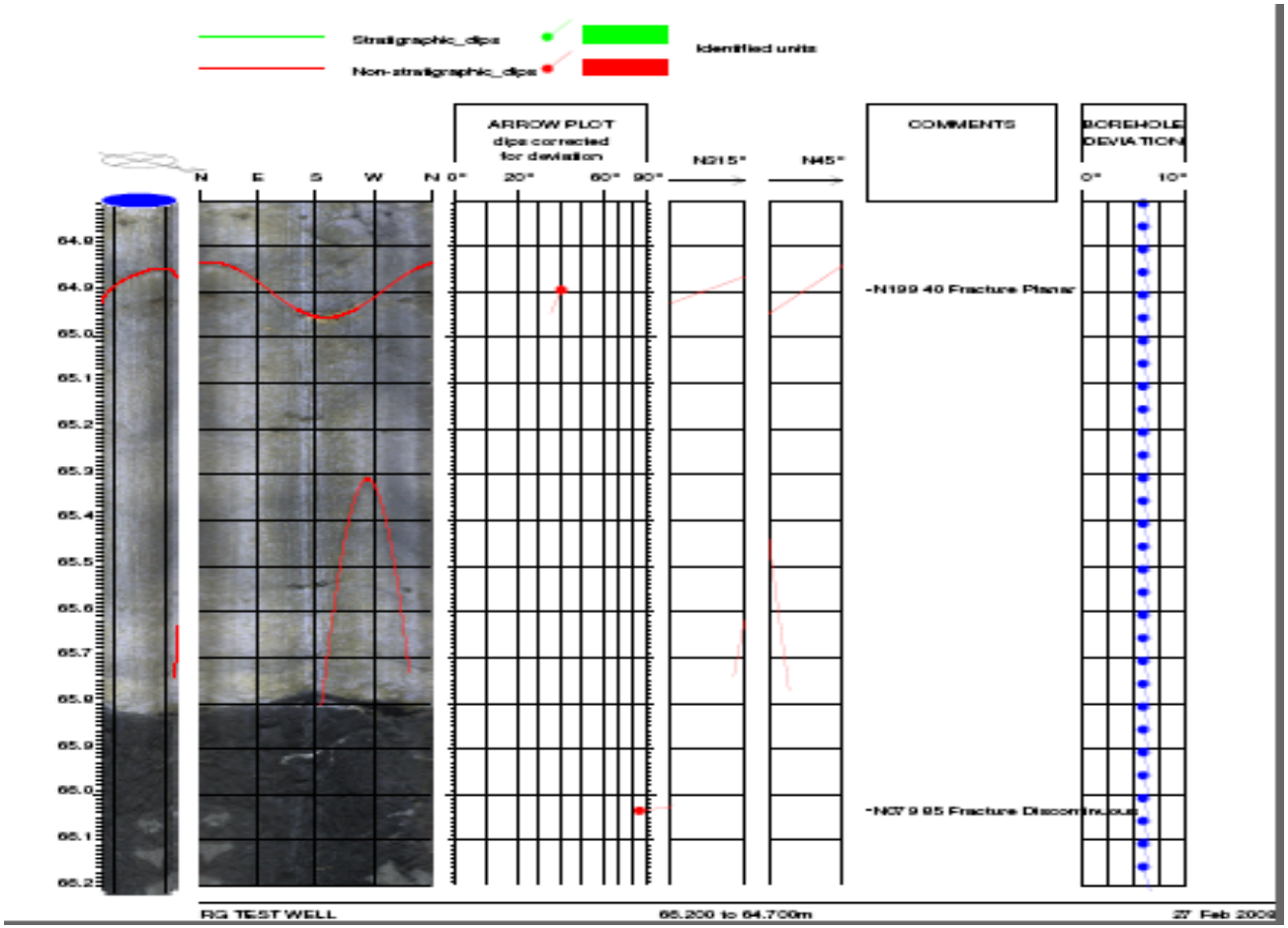


- 2-3/4” CBL/VDL-GR-CCL
- High Performance Shots
- High Shot Density

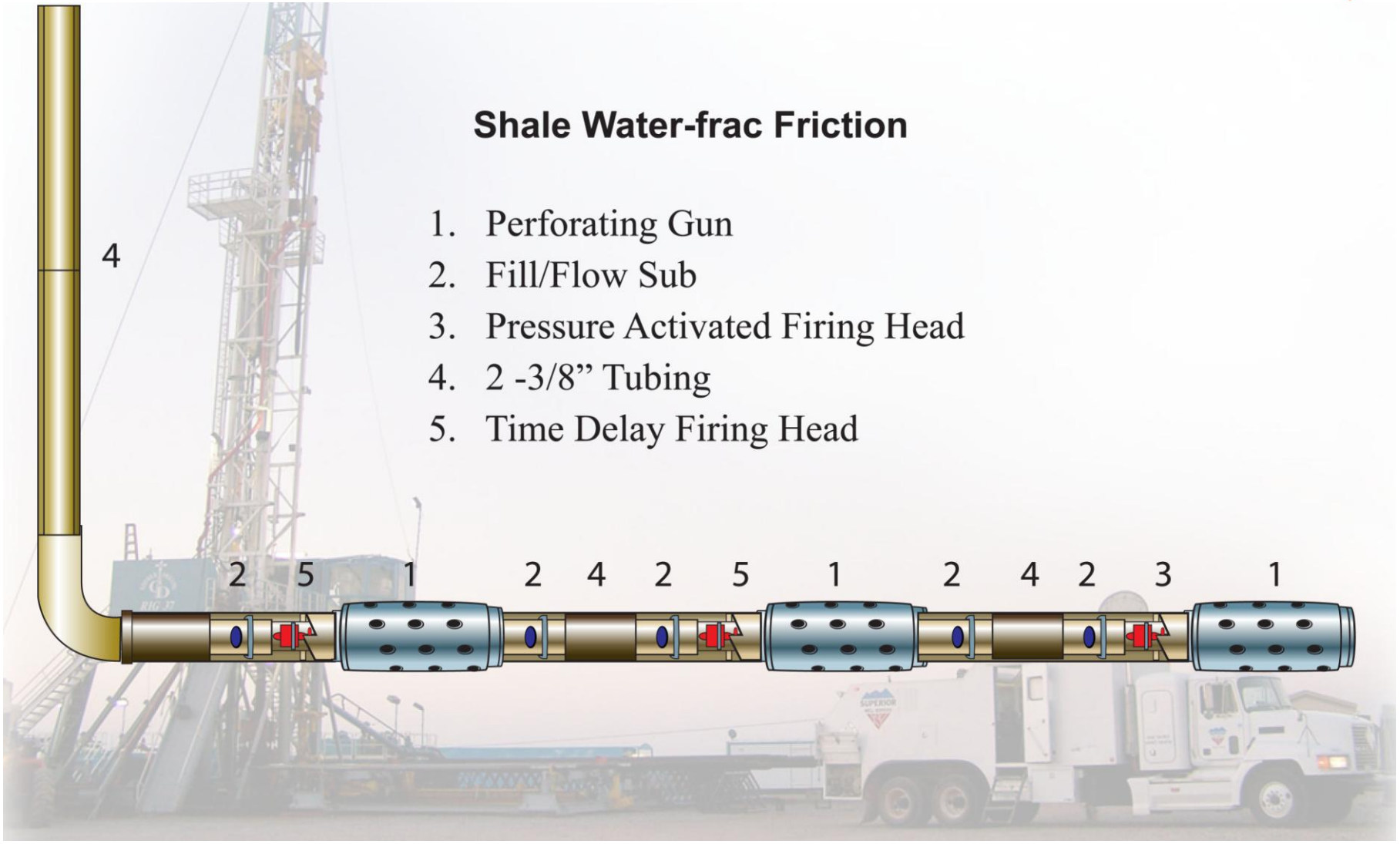
Fracture Identification Log



Fracture Identification Log

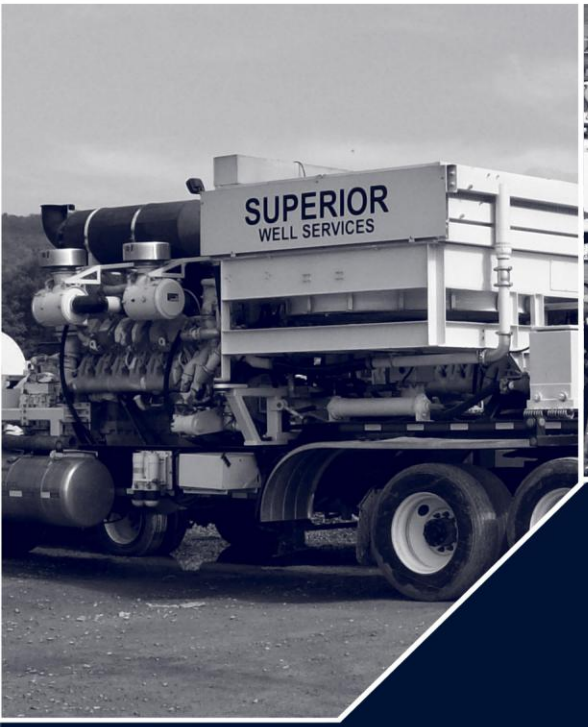


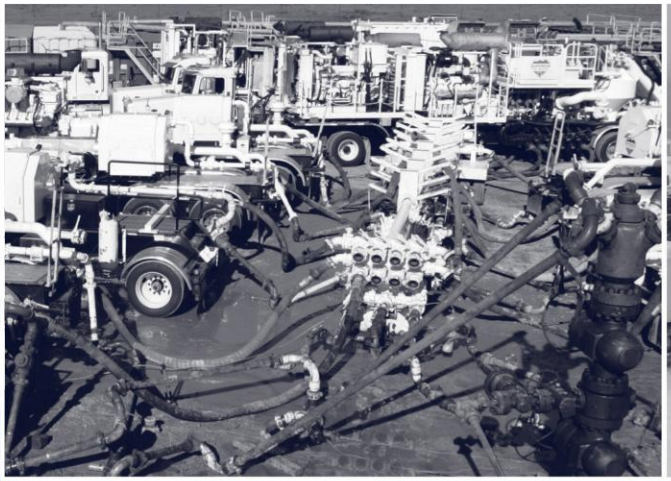
Typical TCP Hookup



Shale Water-frac Friction

1. Perforating Gun
2. Fill/Flow Sub
3. Pressure Activated Firing Head
4. 2 -3/8” Tubing
5. Time Delay Firing Head





Stimulation Services

Purpose of Stimulation

- Increase the **Rate at which the well is capable of producing oil or gas**

- Most "Unconventional Formations" **Require hydraulic fracturing to be economic**

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What is “Hydraulic Fracturing”?

- The use of fluids to create a crack by hydraulic pressure
- The continued injection of fluids into the created crack (“fracture”) to make it grow larger
- The placement of small granular solids into the crack to insure the crack remains open after the hydraulic pressure is no longer being applied

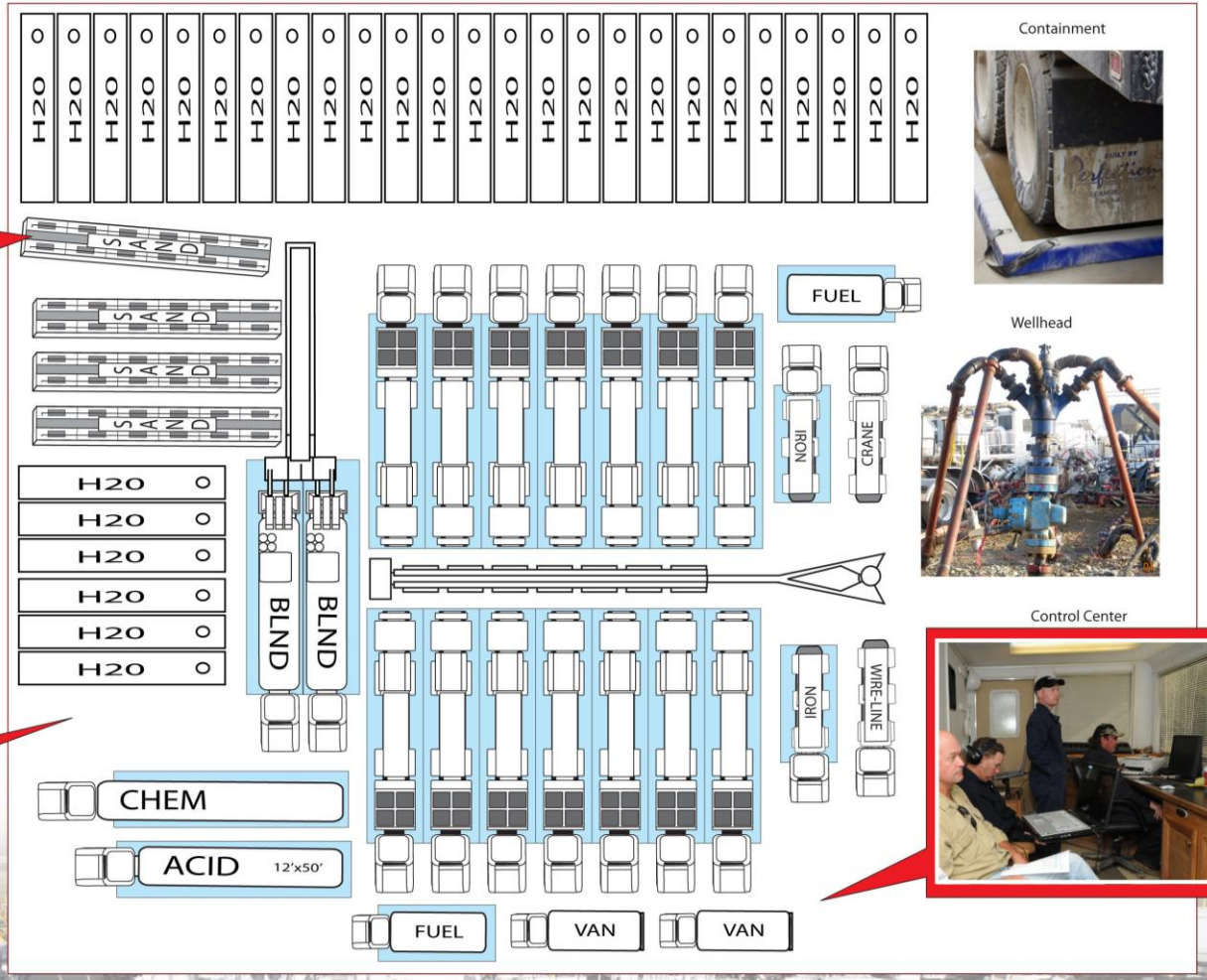
Basic Well-Site

1. Control Center
2. Blenders
3. Proppant
4. Pumper
5. Fluid storage tanks
6. Lined frac water containment pit
7. Fuel
8. DatSat
9. Iron

Basic Well-Site

Sand Movers

Blenders, Propant conveyors, Water Tanks



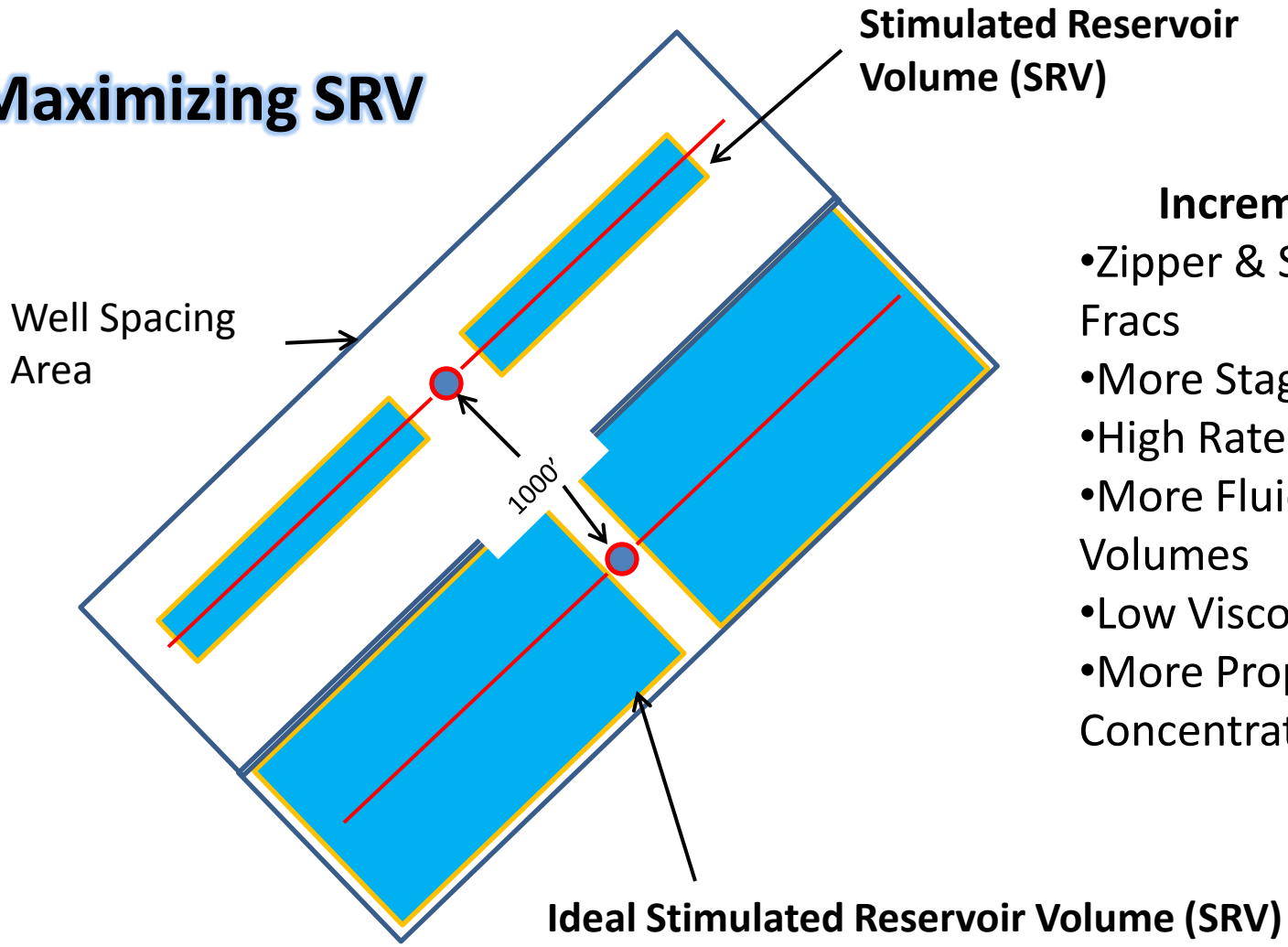
On Site Monitoring

datSAT – Data Transmission

- Data Transmission from Remote Site via satellite transmitter on location
- Access data on receiing end via internet connection and secure login credentials
- All data that is recorded on location can be transmitted live
- Can run real time frac model from office (MFrac, FracPro, etc.) without being on location

Stimulated Reservoir Volume

Maximizing SRV



Incremental SRV

- Zipper & Simultaneous Fracs
- More Stages
- High Rates
- More Fluid & Gas Volumes
- Low Viscosity Fluid
- More Proppant At Low Concentrations

Marcellus Frac – Extremely Complex Fracture vs Simple Bi-Wing Fracture

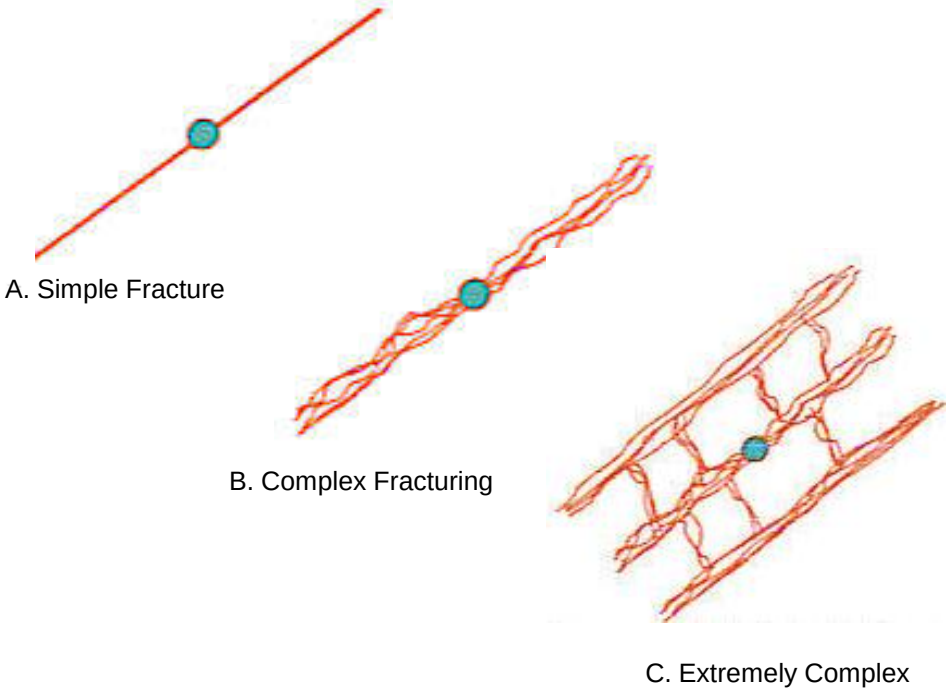


Figure 3 Examples of increasing fracture complexity from simple (most common) to extremely complex (relatively rare).

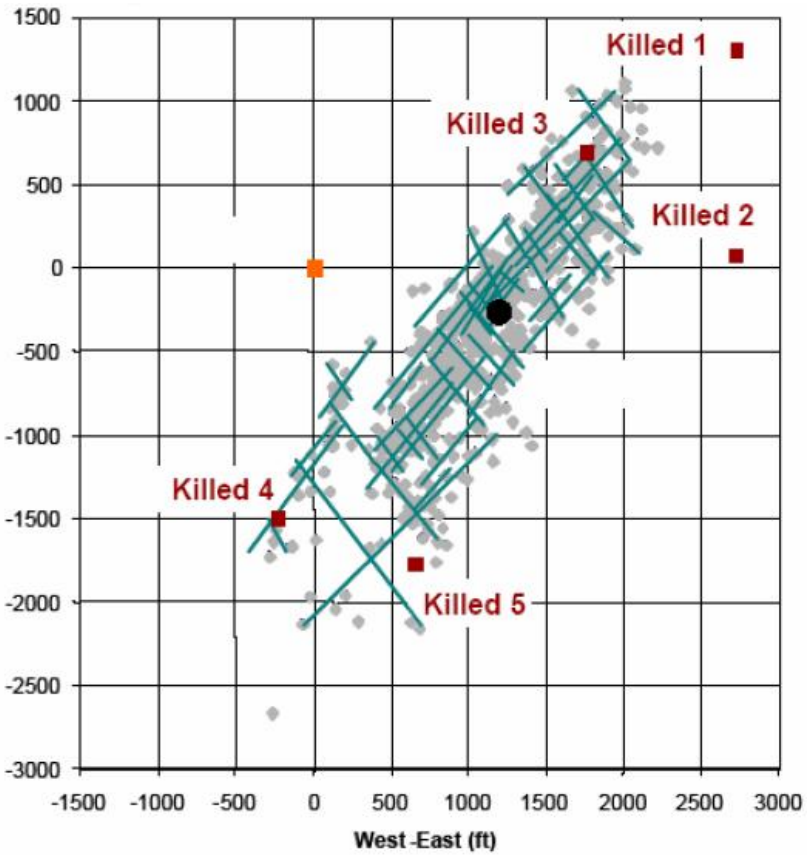
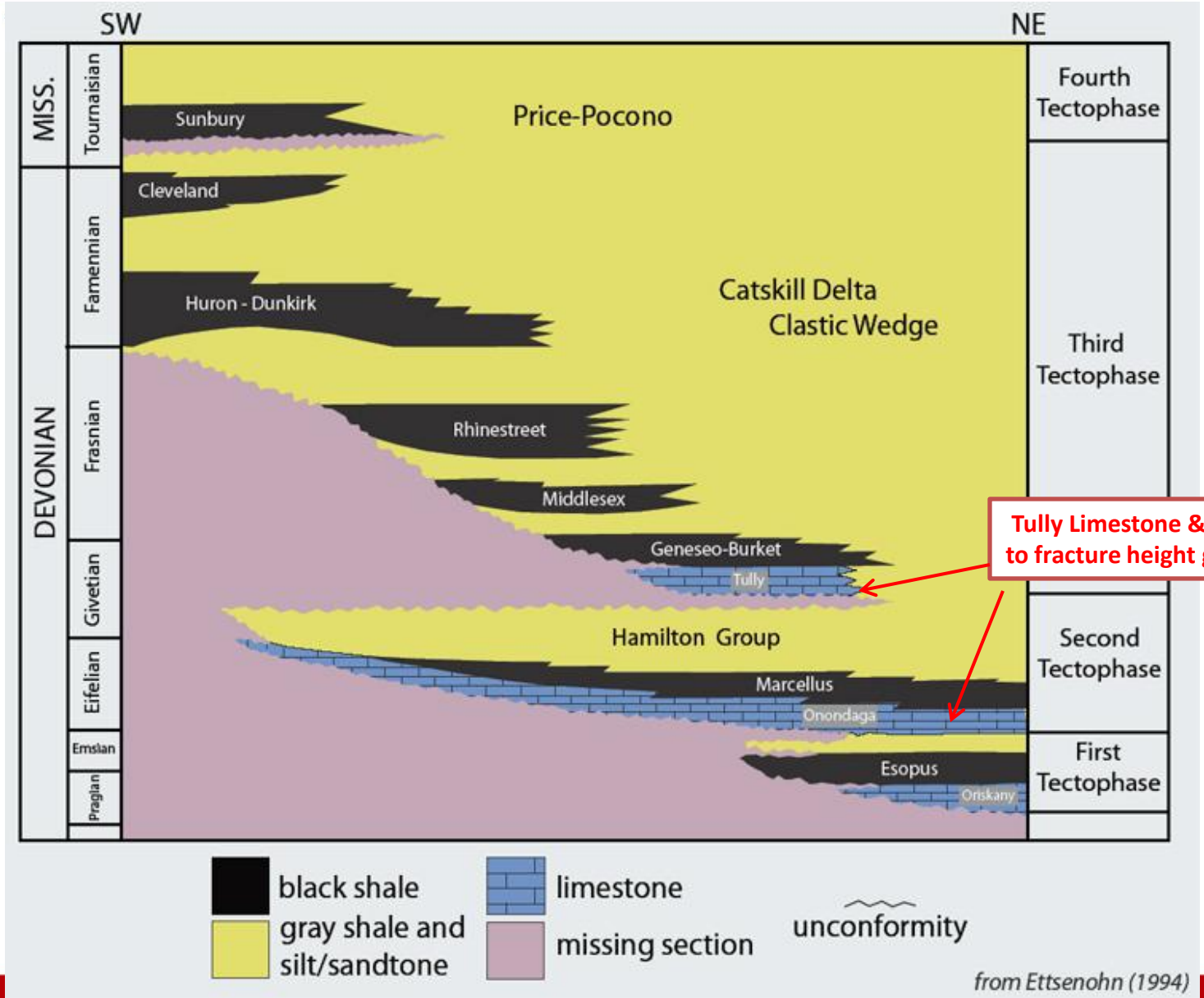


Figure 4 Example of fracture treatment map in Vertical well from core area of Barnett.

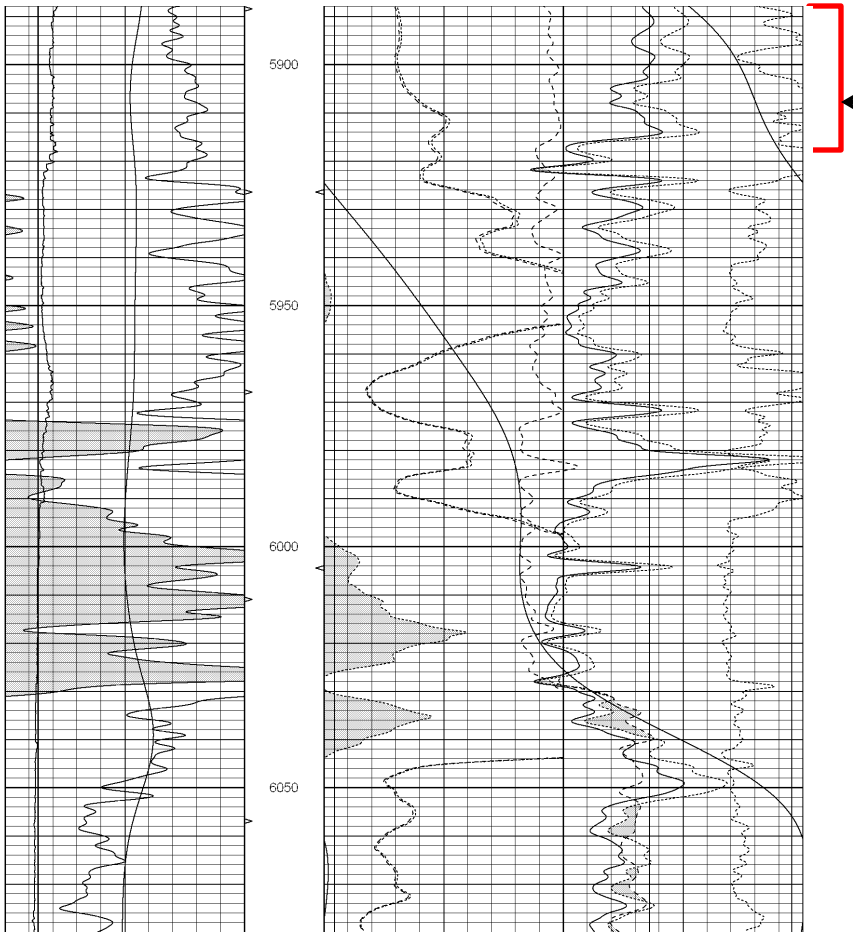
Reference - SPE 90051, "Optimizing Horizontal Completion Techniques in the Barnett Shale Using Microseismic Fracture Mapping", Fisher, Davidson, Wright, Dunn, Heinze, Harris, 2004

Stratigraphic Column – Barriers to Frac Height Growth



Tully Limestone & Onondaga – Barriers to fracture height growth

Log Section – Well Design Considerations



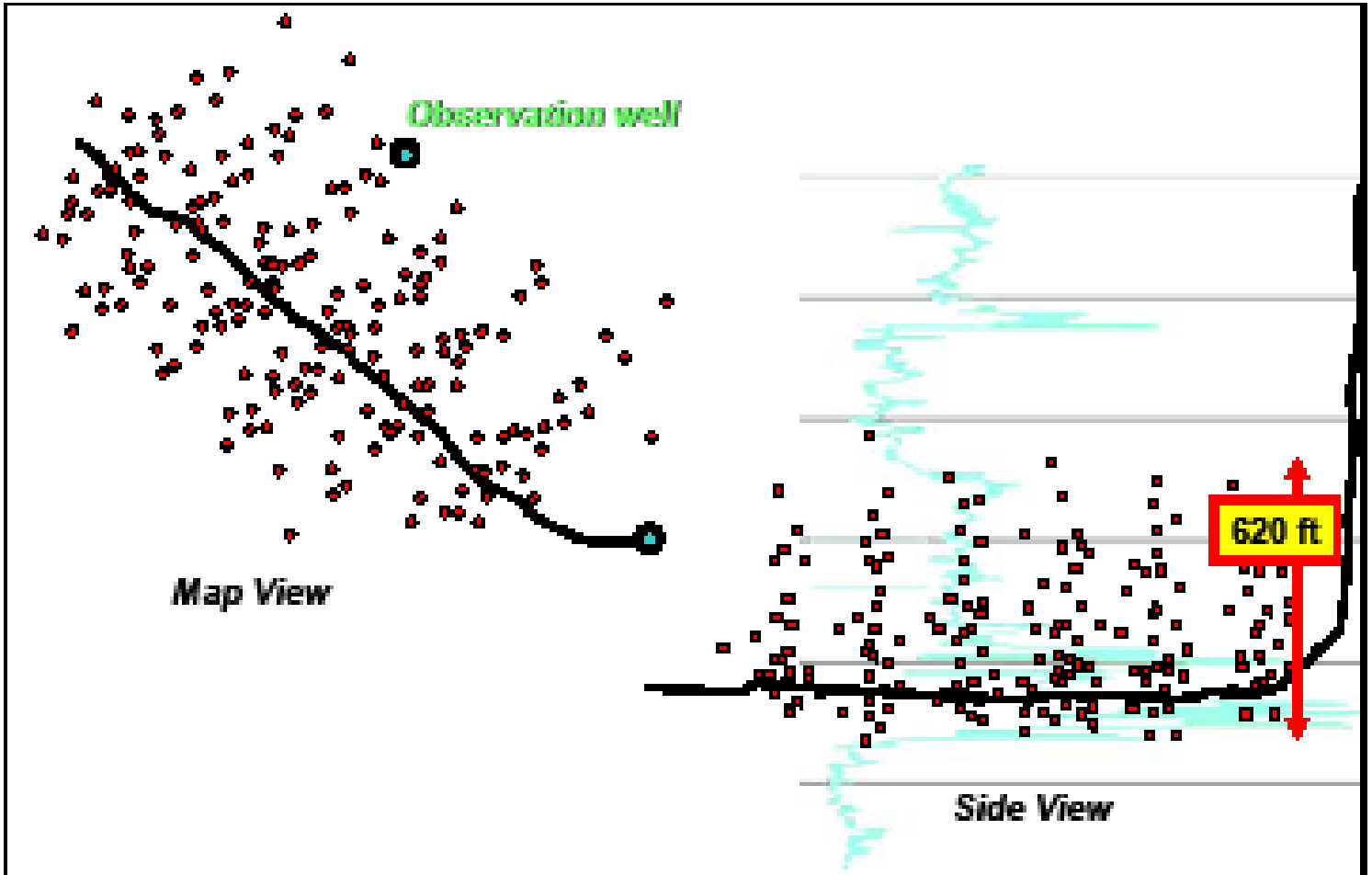
Base of Hamilton Group – typically see good gas show

Competent Rock - good landing area for horizontal and frac initiation

Ductile Rock – Problems for horizontal drills and fracs

Ononadaga

Microseismic Data
Six Stage Frac – Height & Length



*Pinnacle Technologies

Frac Water Reuse in High Volume High Rate Shale Fracturing:

Technology

Challenges

Practical Solutions

Why Reuse Frac Water ?

STREAM WATCH

[*In the Sept. 2009 issue, John Randolph in his page 2 article "The Threats Posed by Marcellus Drilling" identified "the single largest threat to Pennsylvania (also new York, West Virginia, and Ohio) wild-trout streams since the coal/steel era of the Industrial Revolution." After that issue went to subscribers, a "total" fish kill on 43 miles of Dunkard Creek in Pennsylvania raised the question again: "Is the Commonwealth of Pennsylvania protecting its waterways?"* THE EDITOR.]

Fracking our Rivers

Investigating the causes of the Dunkard Creek fish kill

DEBORAH WEISBERG

ON CHRISTMAS DAY 2007, George Watson returned home from a family dinner to find one of his prized Black Angus cows dead alongside Hargus Creek, a stream that runs through his southwestern Pennsylvania farm.

Over the next three months, Watson lost 16 more cattle—all of which had been bred—making it, as he said, "a double loss." Up to three in one day were found lying near the water. A series of calves died soon after birth.

"I've been raising cattle for 22 years and never had anything like that," said Watson, a Vietnam veteran, who also was having problems with discolored, sludgy well water. A local vet tested the dead cows, but failed to find anything abnormal. Looking back now, Watson wishes he'd had someone test the water in the creek.

Although natural gas wells were being developed all around him, rumors of illegal wastewater dumping in local streams, and a 43-mile fish kill on Dunkard Creek in the same Monongahela River watershed two years later, fueled his darkest fears.

"After my cows died, I suspected it was from brine and waste being dumped, although I can't prove it now," said Watson, who later leased the mineral rights on his farm to Range Resources for $3,000 an acre plus 15 percent production royalties. Drilling hadn't begun as of late last year.

Range is one of 40 companies driving the boom in hydraulic fracturing for natural gas in Pennsylvania, where 53,000 wells are turning pastures and woods into

Sixteen of George Watson's black Angus cows died mysteriously along the banks of Hargus Creek in the Monongahela River watershed. The deaths are just a glimpse of larger problems across Pennsylvania that may be the result of excessive levels of total dissolved solids (tds) in the water.

Photo | Deborah Weisberg

- Withdraw permits are variable, time consuming, and have withdraw fees associated
  - Reduce consumptive water use
- Marcellus development is occurring in an environmentally sensitive region
- Proactive compliance of January 2011 DEP Regulations
  - 500 mg/L TDS
  - 250 mg/L Chlorides
- Minimize or eliminate POTW treatment of flowback
  - Control and eliminate release to environment
  - Eliminate "metals pass-through"
- Demonstrate to the public that lower-impact development is possible

SUPERIOR WELL SERVICES

Frac Fluid Environmental Drivers and Design Issues for Reuse of Frac Water

- Potential Surface Discharge Concerns with Frac Flowback Waters from “High Volume” fracturing operations
- Surface spills and surface water contamination
- Protection of Underground sources of drinking water

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Technically Available Frac Flowback Water Remediation Technologies

- Oxidation / Ozonation
- Membrane
- AOP (Advanced Oxidation Processes)
- Concentrators
- Evaporative Crystallization
- Etc.
- FSF (Flocculation, Sedimentation, & Filtration)
- Direct Blending / Dilution
- Direct Chemical Treatment
- Filtration

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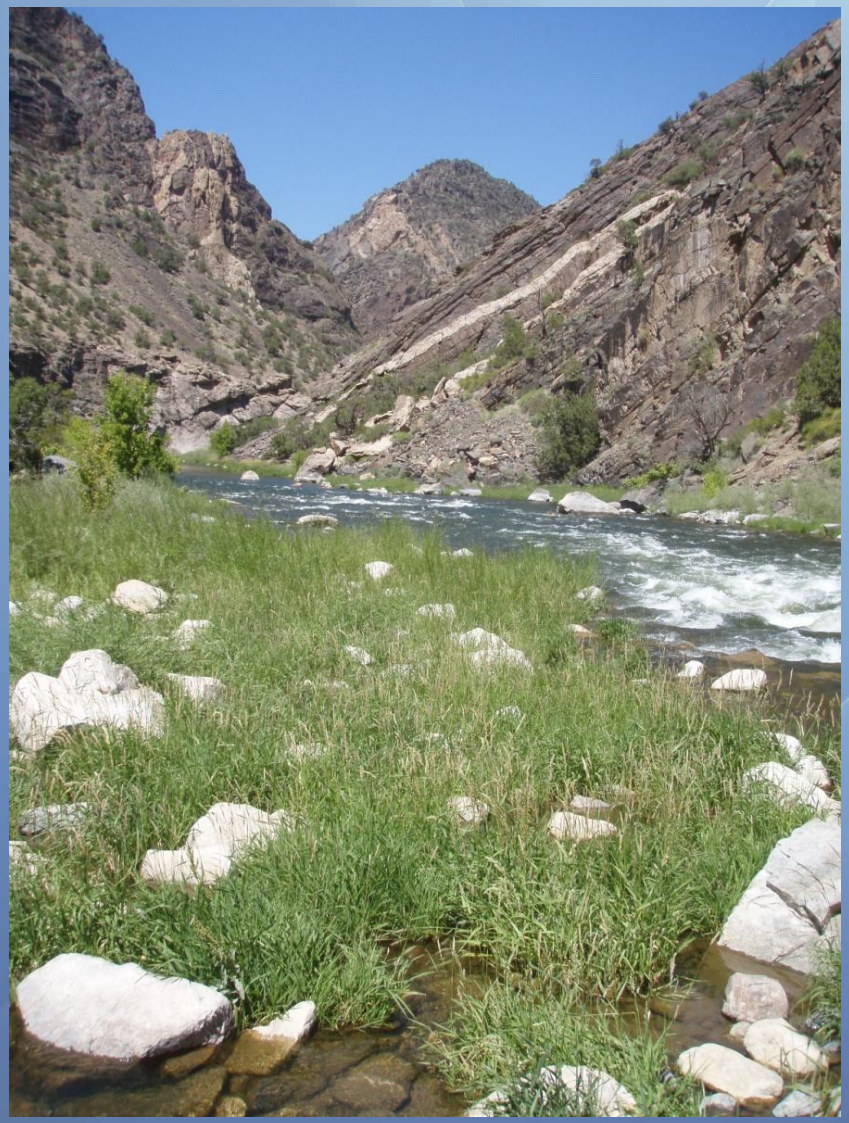
The Ideal Reuse Solution Should Be…



- Effective for Fracturing
- Safe
- Practical
- Economic
- Fit-for-Purpose
- Integrate Biological Control
- Non-Damaging to Production

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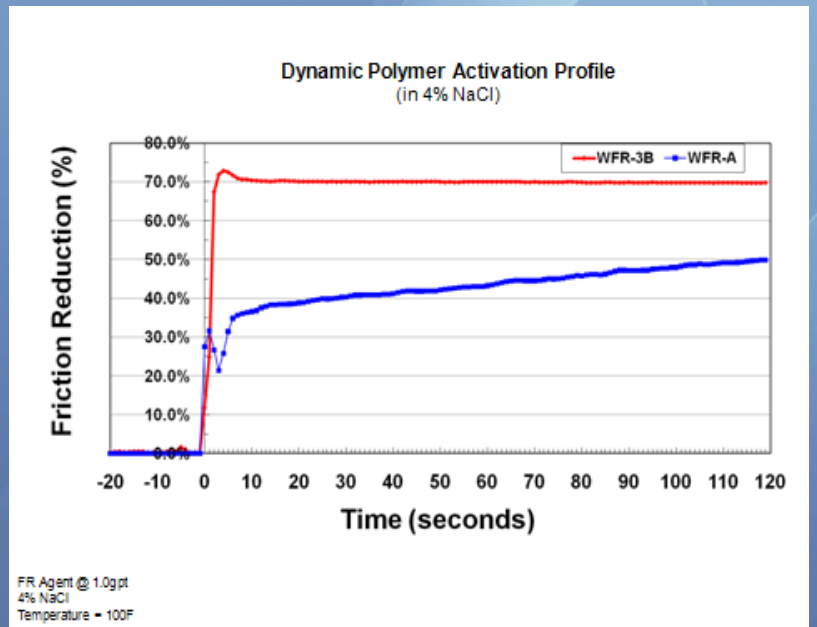
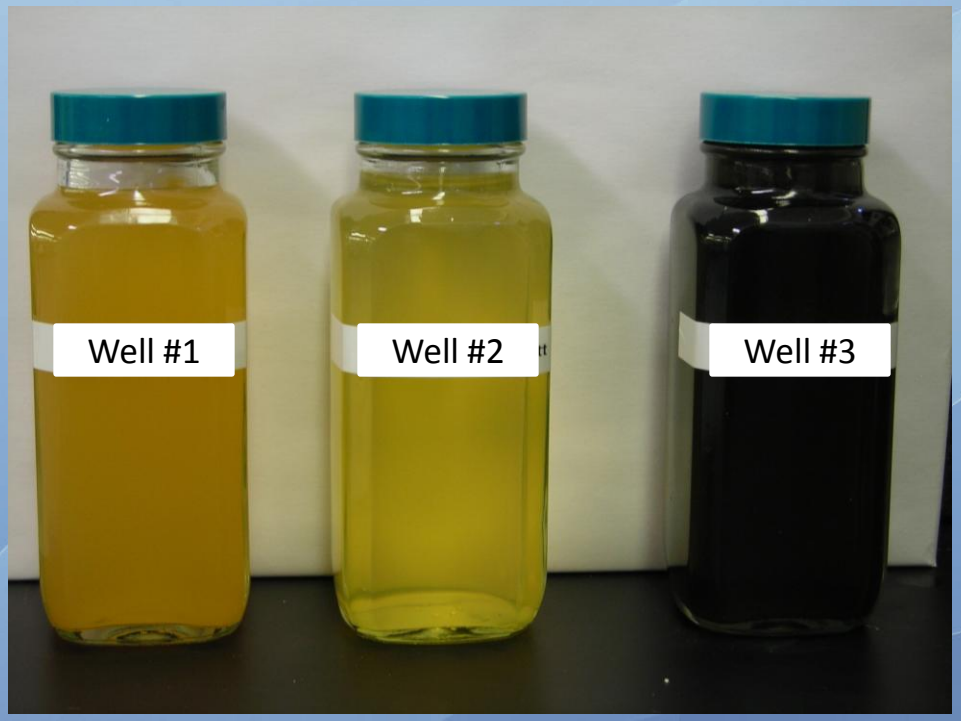
What is needed for reuse? The Right FR Chemistry

- Brine Tolerant Frac Fluid Design
- Practical and Economic





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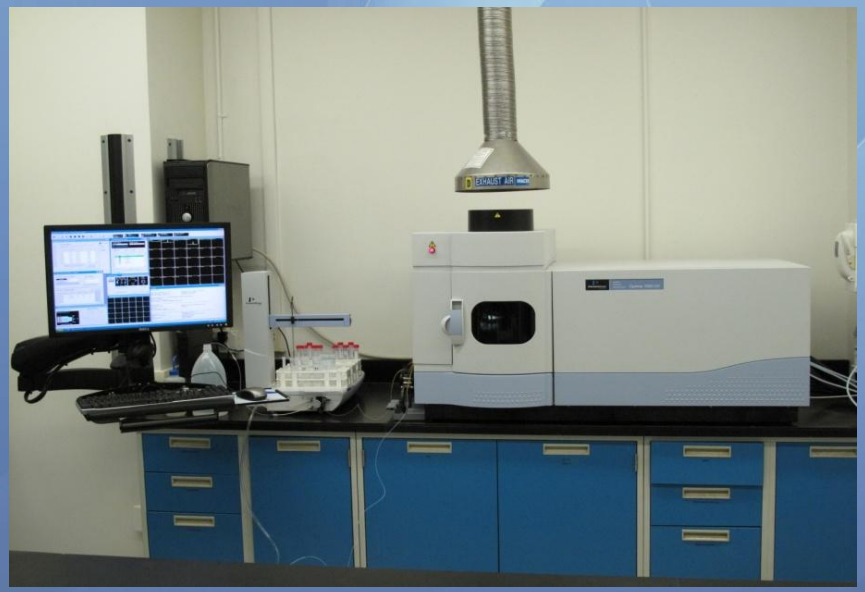
What is needed for reuse?
Lab Testing

Rapid Detailed Water Analysis & Lab Performance Testing

- Spectrophotometer, digital titrator, microbiological illuminated, TSS, scale calculations
- ICP (Inductive Coupled Plasma) analysis
- FR performance on “as is” and remediated (if needed) water for reuse
- Geochemical modeling determinations
- Chemical loading compatibility and performance recommendations

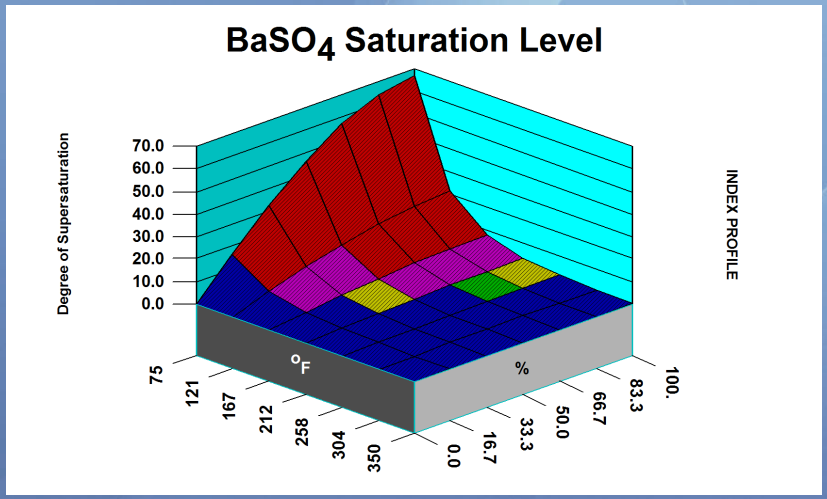


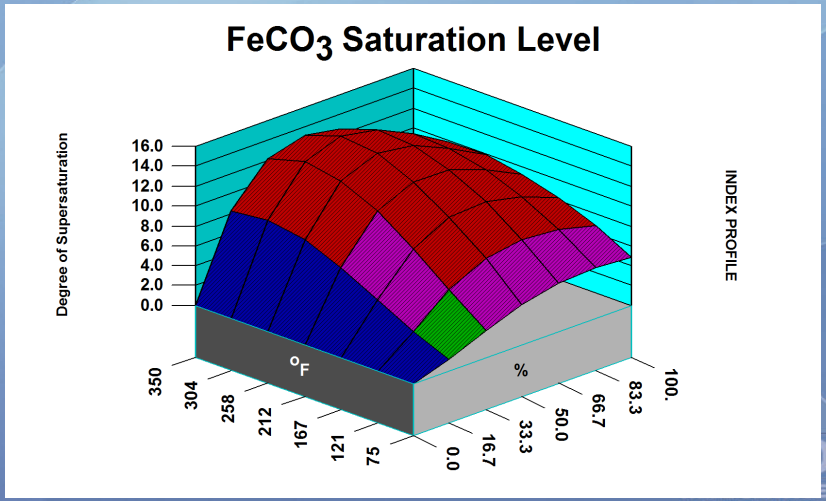
What is needed for reuse?

Geochemical Controls

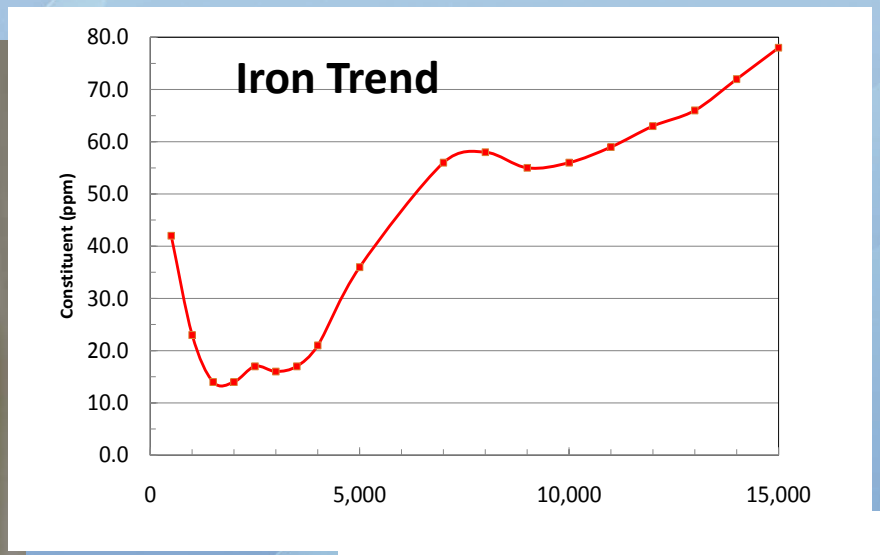
- Sophisticated Geochemical Scale Modeling Simulator
- Specific to Downhole Conditions

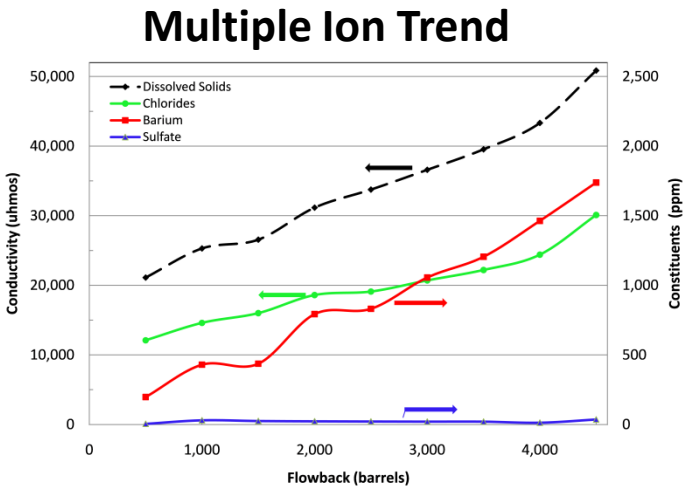
DownHole SAT Rx
INJECTION WATER CHEMISTRY INPUT





What is needed for reuse?
Chemical Flowback Analyses

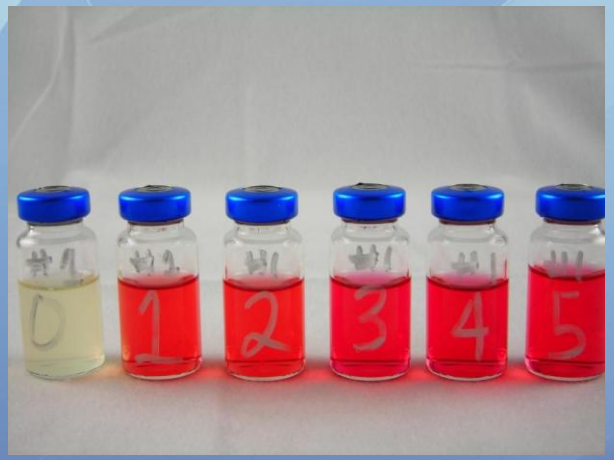




What is needed for reuse?

Biomass Control

- Comprehensive Microbiological Control
- Serial Dilution Studies
- Biocide efficacy Studies



What can go Wrong ?

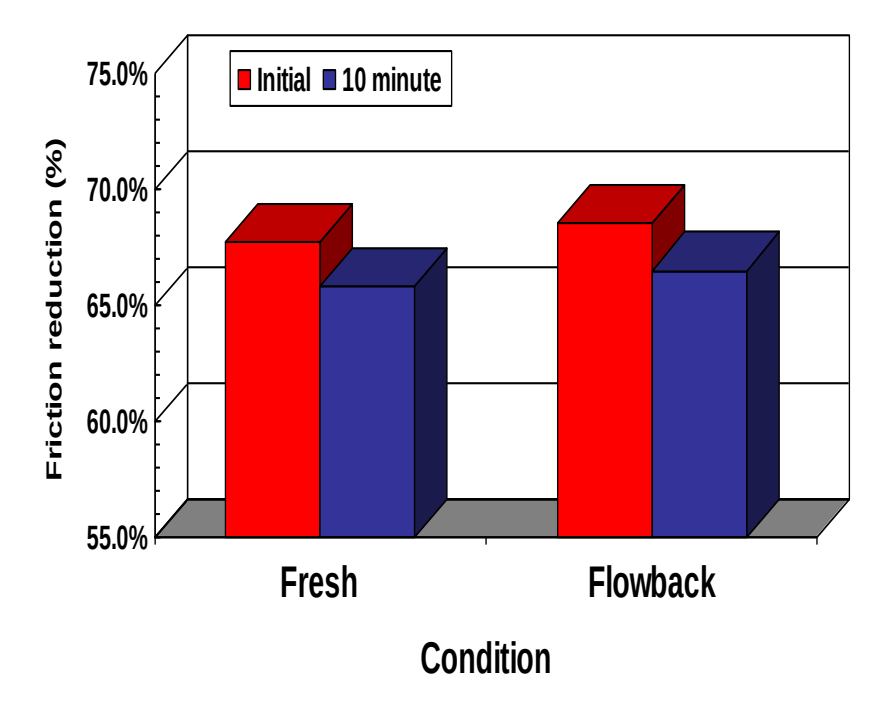
Choosing the wrong FR chemicals and loading dependant on reuse water quality

FR for Reuse

Designed to be used on Flowback Waters
FR results similar to fresh water

WATER ANALYSIS DATA ON FLOW BACK

pH	6.9
TDS Total Dissolved Solids as mg/l	56,600
Ferrous Iron (mg/L as Fe)	14
Total Iron (mg/L as Fe)	41
Total Alkalinity (mg/L as $CaCO_3$)	330
Calcium Hardness (mg/L as Ca^{2+})	984
Magnesium Hardness (mg/L as Mg^{2+})	76
Total Hardness (mg/L as $CaCO_3$)	3,250
Chlorides (mg/L as Cl^-)	20,650
Sulfate (mg/L as SO_4^{2-})	21
Total Suspended Solids (mg/L)	60
LSI	0.93
Calcium Sulfate Scaling Potential	negative



Chemical Loading for Reuse

STFR	1.0 gpt
Biocide	0.1 gpt
Iron Control	0.1 gpt
Scale Control	0.2 gpt

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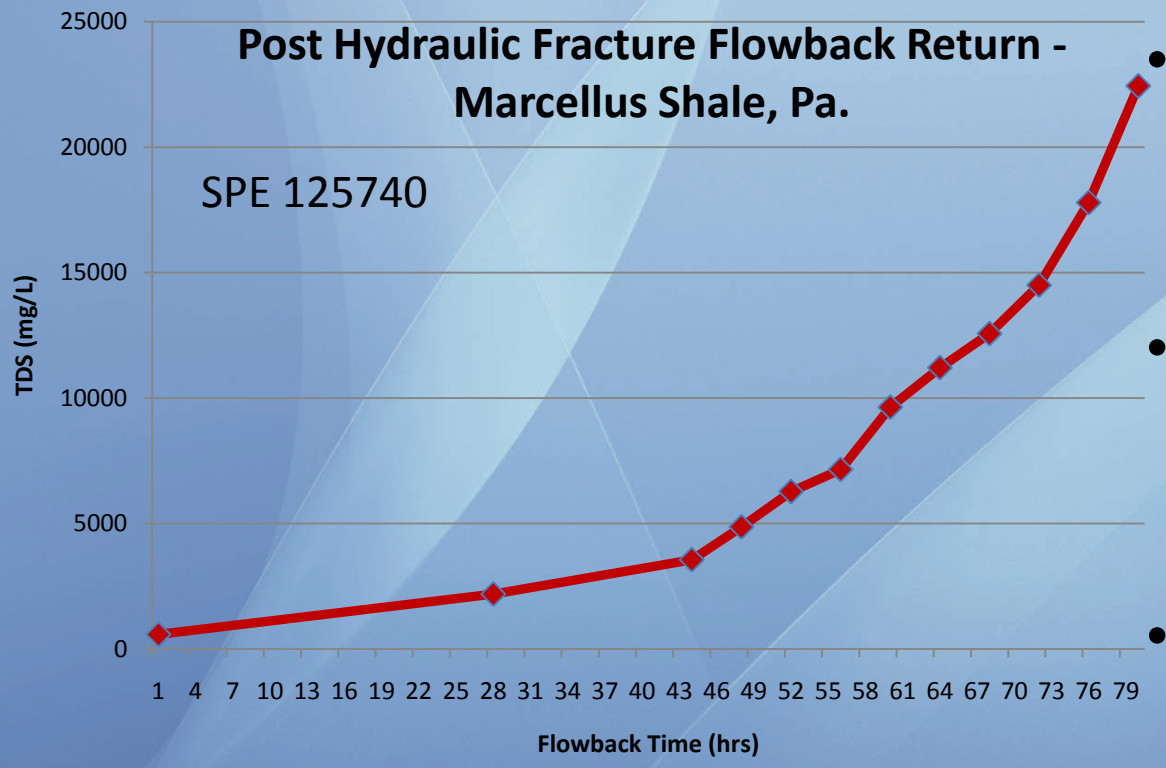
TDS / Salt Trends In Flowback

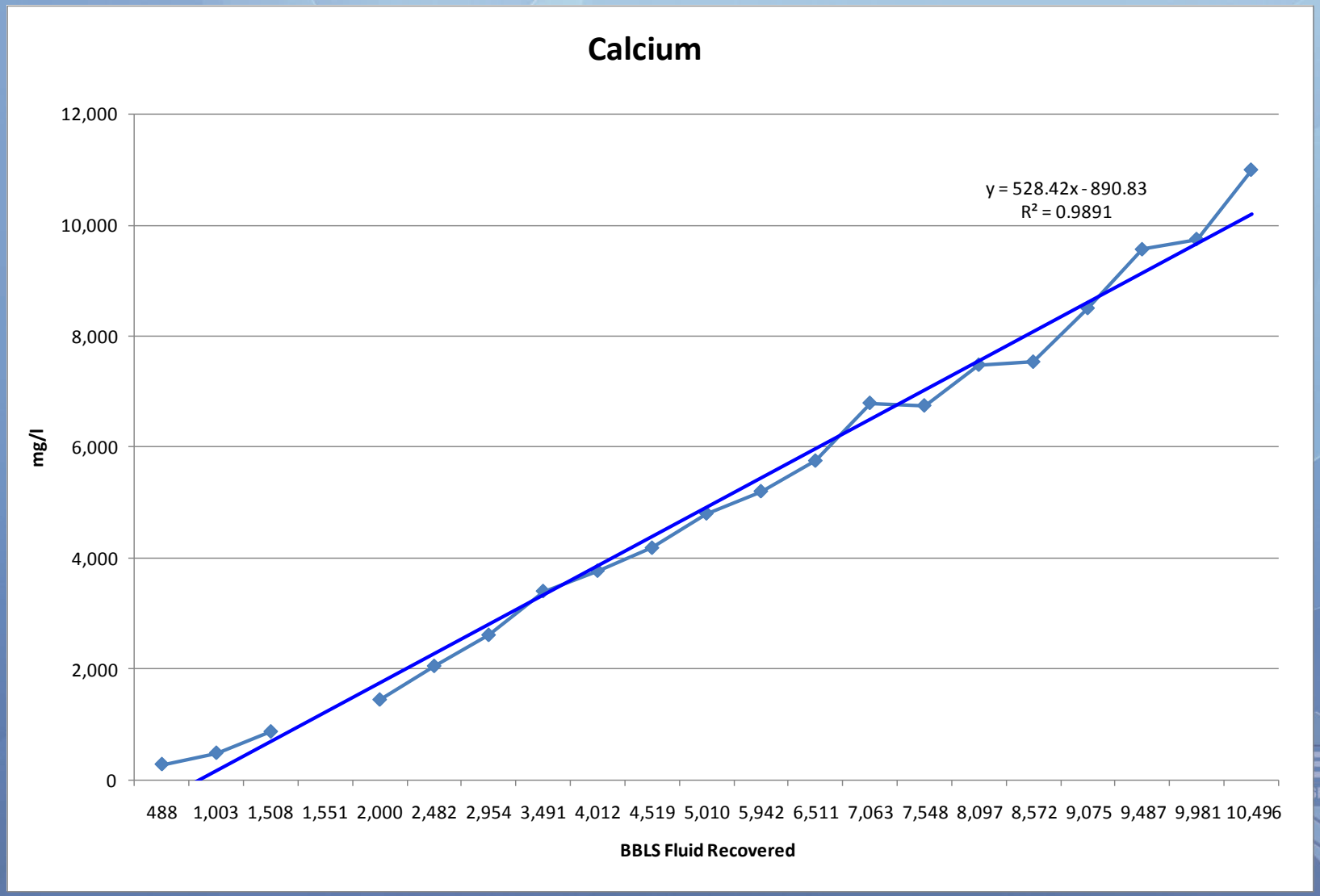


- TDS Levels Increase with time.
- Volume decreases with time.
- Ave Approx 50,000 mg/L
- Limit for Drinking Water is 500 mg/L

Some POTWs limited to 1% of total daily flow based on total dissolved solids (TDS) load.

Case History - Flowback Calcium

(Ca^{2+}collected every 500 bbls over 27 days)



Closed-Loop Reuse of Flowback Water

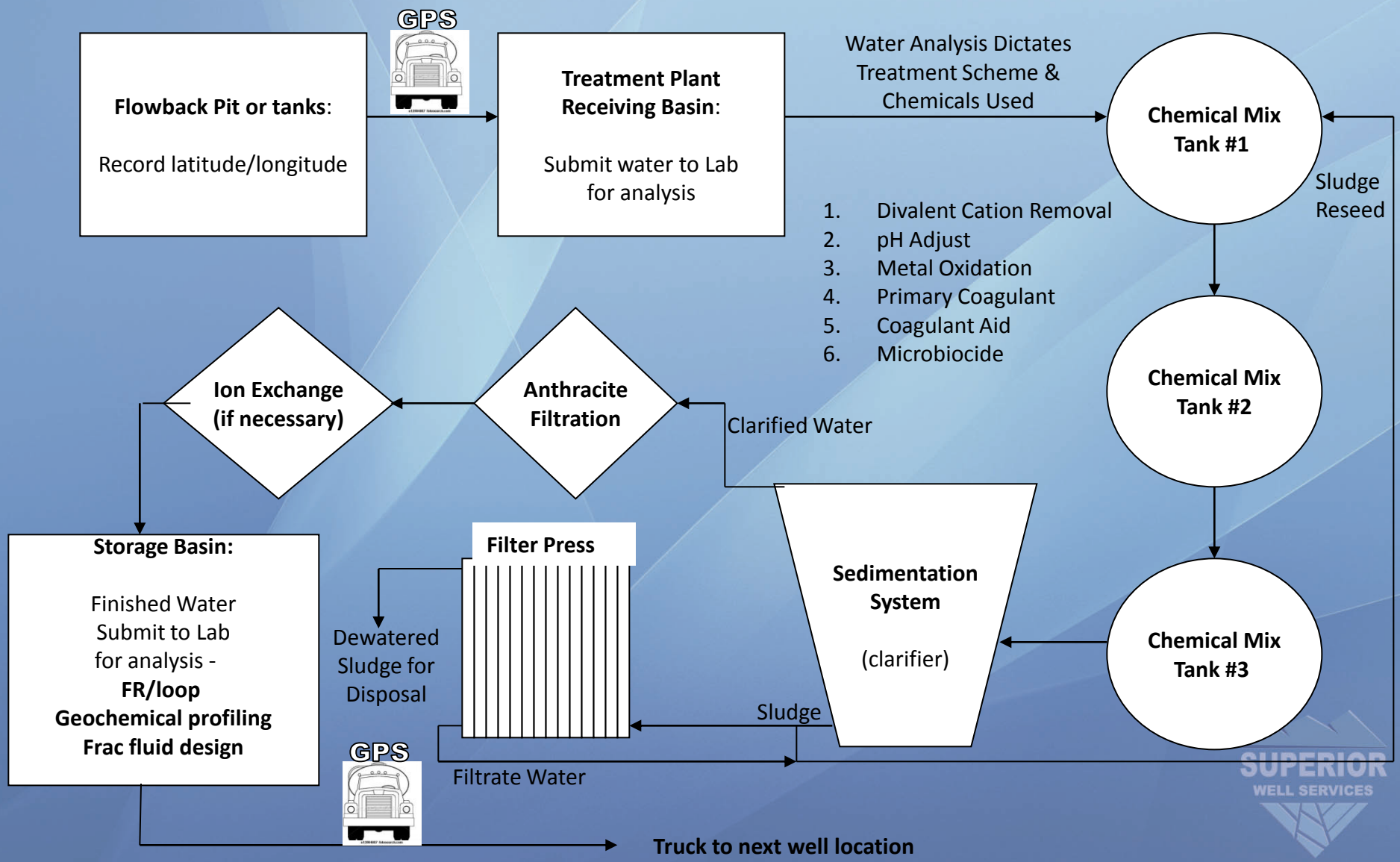
4. Analyze and Treat Flow Back

Stationary or mobile remediation

6. Determine Chemical Loading for Frac Fluids.

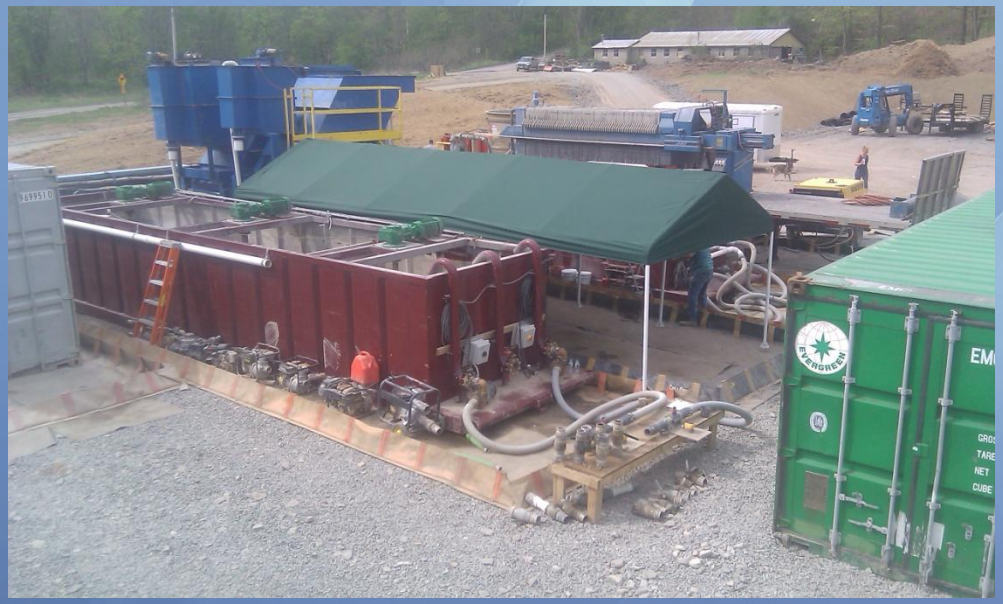
7. Reuse Treated Flow Back Water

Example FSF Treatment Process



Mobil remediation of frac flowback water for reuse

- Existing technology – Available
- Transportation savings



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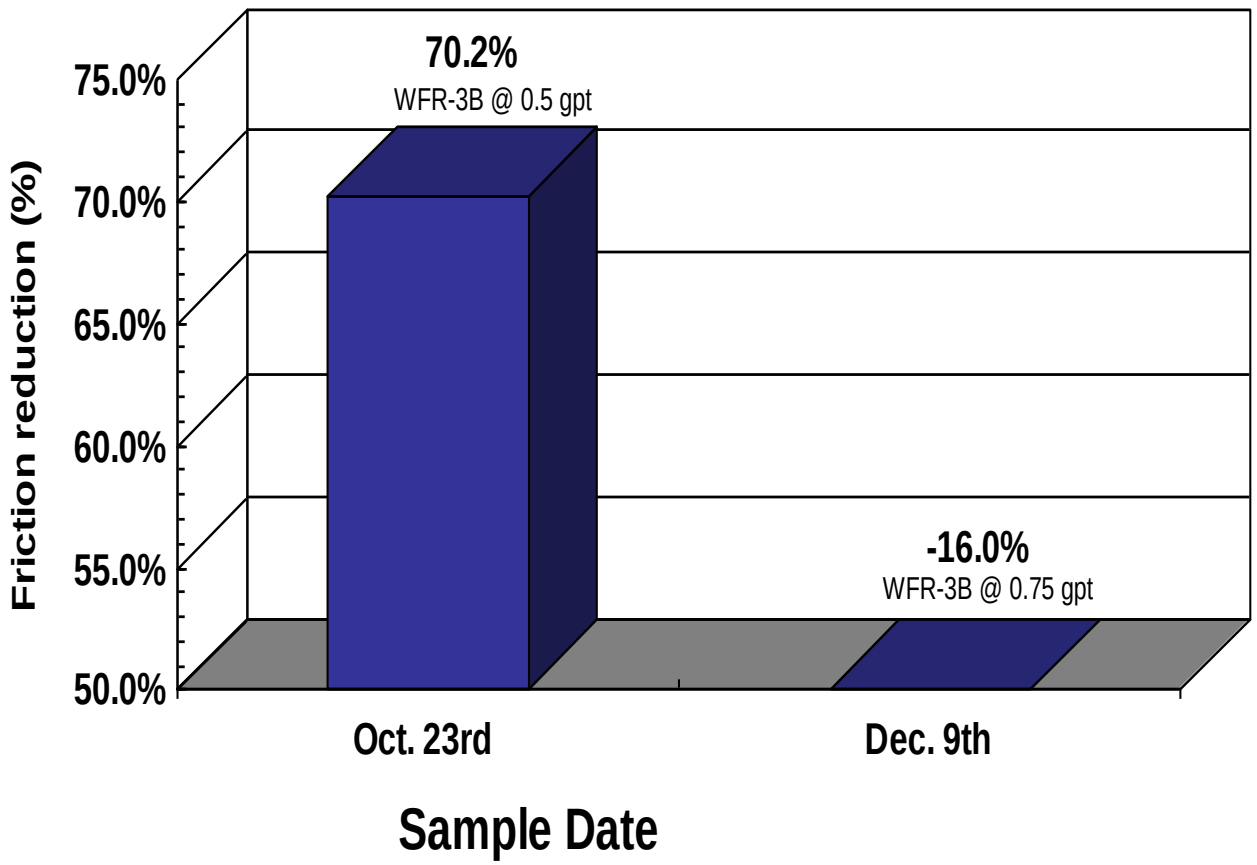
Stationary Water Remediation for Reuse Rather than Release

- Requires
  - Flowback Retrieval
  - Analysis
- Direct Flowback Blending
- Good Alternative to conventional POTW Disposal
- Can handle large volumes

SUPERIOR WELL SERVICES

Importance of Pre-Job Lab Testing
Case History Example



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Treatment Case History
A 100% Reuse Example

Treatment Removal (%)	
Constituent	**Removal (%)**
Barium	99.6%
Strontium	70% *
Calcium	34% *
Magnesium	84% *
Iron	100%

* Addition ion reduction > 99% if deemed necessary

Microbiological count reduced to < 10^3 cfu/ml

TSS reduced to < 50 mg/L

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A Near Zero Risk Operational Practice for Mitigating Chemical and Reuse Fluid Releases on Location

- Chemical Floats and Transports with Containment
- Manifolding system Containment
- Coverage of all Potential Leak Sites

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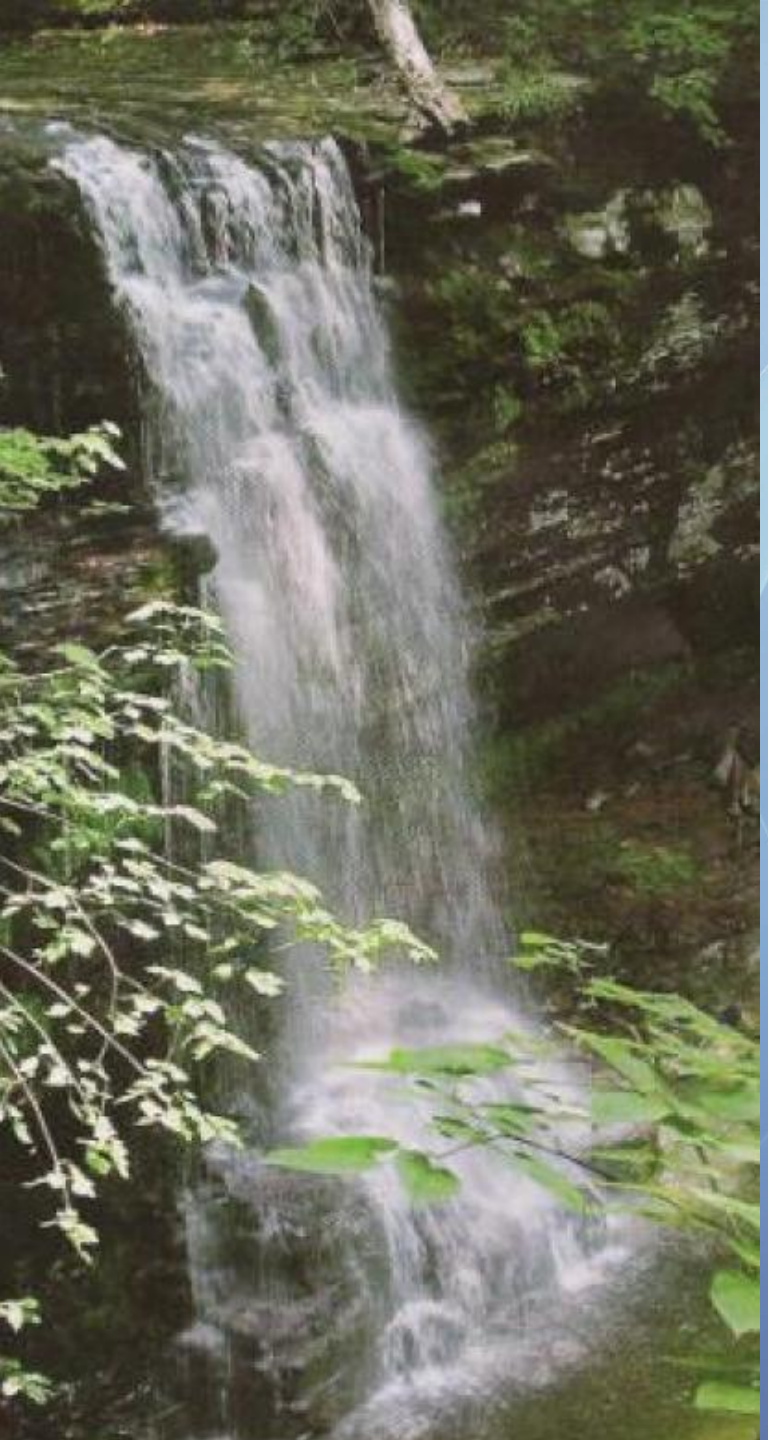

The Way Forward

"Can we do this right? Sure we can. We have the knowledge, the expertise, the technology, the historical perspective, and the conscience for it."

The Hemlock, Vol. 2, Issue 6 (March 2009).

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Frac Fluid Dosage Calculator

Microsoft Excel - Dosage calcs GammaFRac.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Primary Water Analysis Results**												
2													
3	ID #:											**LSI Calculator**	
4	Sample ID:												
5	Sample Date:												
6	**Anions**										Lease:		
7	P Alkalinity (mg/L as $CaCO_3$)	0									Sample ID:		
8	M Alkalinity (mg/L as $CaCO_3$)	30									Sample Date:		
9	Chloride (mg/L as Cl^-)	5									Temperature (°C):	40.0	40.0
10	Sulfate (mg/L as SO_4^{2-})	20									Conductivity (ms)	0.13	
11											TDS (mg/l)	87	
12											pH	7.30	
13	**Cations**										Mg as CaCO3	10	
14	Barium (mg/L as Ba)	0									Ca as CaCO3	10	
15	Calcium (mg/L as Ca^{2+})	48		**Iron Fouling Potential**				(as Fe)			Hardness (ppm $CaCO_3$)	20	
16	Magnesium (mg/L as Mg^{2+})	25					**Iron**	**Low**	**High**		Alkalinity (ppm $CaCO_3$)	30	
17	Total Hardness (mg/L as $CaCO_3$)	73		**ICP 1000 Dase Rate**			Extremely High	200.1			Chloride (ppm)	5	
18	Iron, Ferrous (mg/L as Fe)	4		0.04	gpt*		Very High	100.1	200		Sulfate (ppm)	32	
19	Iron, Total (mg/L as Fe)	20					High	50.1	100		Temp. [B]	*1.81*	*#VALUE!*
20				* gallons ICP1000 per 1000 gallons of treated wate			Moderately High	20.1	50		TDS [A]	*0.09*	*#VALUE!*
21	**Miscellaneous**						Moderate	3.0	20		Hard [C]	*0.60*	*#VALUE!*
22	pH	7.30					Low	0.0	3		Alk [D]	*1.48*	*#VALUE!*
23											Factor[temp+TDS]	1.90	#VALUE!
24	Total Suspended Solids (mg/L)			**Microbiological Fouling Potential**							Factor[hard+alk]	2.08	#VALUE!
25	Specific Gravity (g/ml)										Calc. pH_s	9.13	
26	Conductivity (micromhos)			Free ATP (RLU)	50	← Enter Free ATP Here					LSI	-1.83	
27	Δ ATP (rlu) – Microbiological Content			Total ATP (RLU)	1500	← Enter Total ATP Here					Langelier Potential	Corrosive	
28				Δ ATP(RLU)	1450						Scaling	Negative	
29	Iron Fouling Potential	**Moderately High**											
30	Microbiological Content	low		Microbiological Content		Very High						*Temperature calculator:*	
31	Langelier Saturation Index (LSI)	-1.83		KR-153SL Dose Rate	0.25	gpt*						[°F]: 104.0	
32	Langelier Potential	Corrosive										[°C]: 40.0	

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KR-153SL Dosage Calculator | ICP-1000 Dosage Calculator | Sheet3

Ready

THANK YOU FOR YOUR ATTENTION

QUESTIONS??

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