SPE 170923
Granite Wash Optimization – Validating Completion and Production Techniques

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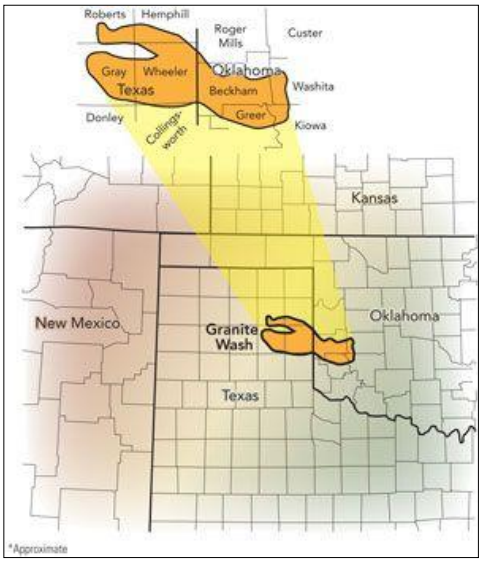
Agenda

- Area overview
- Tracer overview
- Monitoring goals
- Openhole completion test
- Stacked lateral test
- Offset well review
- Conclusions

Introduction

- Granite Wash
  - Texas Panhandle play extending into west Oklahoma
  - Multiple zones
  - Late 80's, early 90's saw large vertical development
  - Currently—multilateral horizontal wells
- Project Scope
  - 200+ horizontal wells



Standard Operating Process

- Well is prepared 2-3 weeks prior to stimulation operations.
- The well is evaluated for level of Chemical Frac Tracer involvement.
- During operations CFT is pumped in scheduled stages.
- During drillout and flowback operations fluid's are sampled on a scheduled basis.
- Long term sample schedule is determined by wells response and nearby offset activity.

Tracer Overview

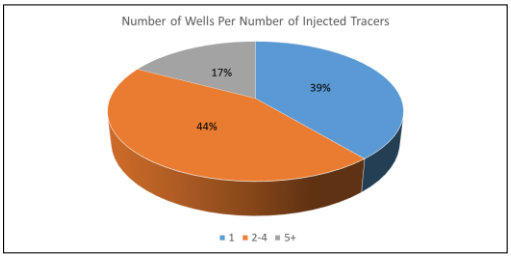
- Fluid tracing involves pumping unique water-based tracers in the pad and proppant-laden fluid of a stimulated stage.
- After fracture operations are completed, water samples from the flowback stream are then caught and analyzed with gas chromatography.
- Tracers are referred to as Chemical Fluid Tracers (CFT)

Sample Well Report

Key		Cum Vol*	Sample Date	Sample Type	Chemical Frac Tracer Concentration, ppb												
				Traced Segment	12	11	10	9	8	7	6	5	4	3	2	1	
				Stim Date	10/7/11	10/7/11	10/7/11	10/7/11	10/7/11	10/7/11	10/7/11	10/7/11	10/7/11	10/7/11	10/7/11	10/7/11	Totals
				Traced Fluid vol (Gal)	286,902	390,654	403,293	386,406	404,179	368,424	400,680	401,268	402,108	408,602	415,002	420,336	4,687,854
				CFT Injected (g)	1,134	1,134	1,134	698	1,068	1,134	1,112	1,134	1,134	1,003	785	1,003	12,470
				% Injected	9.1%	9.1%	9.1%	5.6%	8.6%	9.1%	8.9%	9.1%	9.1%	8.0%	6.3%	8.0%	
>200	1		10/8/11 3:33	Water (Pre-Frac)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	1.2
150 to 200	2		10/10/11 12:00	Water (Pre-Frac)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	1.2
100 to 150	3	599	10/13/11 1:00	Water (Produced)	206.6	23.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	231.1
70 to 100	4	1319	10/13/11 5:00	Water (Produced)	251.1	35.2	67.2	15.6	29.3	29.3	21.1	2.9	1.1	1.1	1.7	0.8	456.5
50 to 70	5	5783	10/14/11 9:00	Water (Produced)	203.9	52.9	91.5	19.4	41.9	48.2	36.6	4.9	1.0	1.1	1.0	0.7	502.9
35 to 50	6	9533	10/14/11 13:00	Water (Produced)	74.2	38.6	58.5	12.7	33.7	40.9	34.8	17.9	11.1	22.0	9.9	38.1	392.4
25 to 35	7	15705	10/15/11 9:00	Water (Produced)	66.7	43.5	62.6	15.5	40.3	39.5	36.5	14.4	26.5	21.2	12.6	28.6	408.0
17 to 25	8	22949	10/22/11 9:00	Water (Produced)	31.6	32.2	28.1	6.3	0.0	0.0	25.5	0.0	34.9	0.0	0.0	28.9	187.5
12 to 17	9	24872	10/23/11 9:00	Water (Produced)	30.3	31.6	27.4	6.0	25.5	23.3	24.9	30.8	33.3	22.5	16.9	27.4	299.9
8 to 12	10	26721	10/24/11 9:00	Water (Produced)	27.8	36.8	30.3	7.7	25.3	21.5	23.0	30.9	32.6	20.2	15.0	23.6	294.8
5 to 8	11	29363	10/25/11 21:00	Water (Produced)	28.6	46.1	33.1	9.5	24.5	19.9	22.6	31.4	26.2	17.8	11.8	19.3	290.8
3 to 5	12	32661	10/27/11 21:00	Water (Produced)	20.9	34.8	29.6	10.9	18.9	16.1	20.6	22.6	27.2	17.1	12.9	20.5	252.2
2 to 3	13	35728	10/29/11 21:00	Water (Produced)	15.5	30.5	28.9	12.6	16.3	12.8	17.7	22.3	23.6	13.6	9.7	13.6	217.2
1 to 2	14	38587	10/31/11 21:00	Water (Produced)	15.1	29.9	27.6	12.4	15.7	12.1	17.7	21.7	22.6	13.8	9.2	13.5	211.3
0.05 to 1	15	42529	11/3/11 21:00	Water (Produced)	15.1	29.5	28.2	12.9	16.0	12.3	17.7	22.4	23.4	13.2	9.3	13.1	213.1
	16	45098	11/6/11 0:00	Water (Produced)	12.8	23.8	23.6	10.9	14.1	11.5	16.1	18.6	19.5	12.4	9.0	13.0	185.2
	17	49498	11/10/11 0:00	Water (Produced)	11.1	21.1	21.5	10.6	13.3	11.1	15.9	18.3	18.7	11.0	8.3	11.7	172.7
	18	80848	11/11/11 21:00	Water (Produced)	10.7	19.3	18.0	8.9	10.8	9.2	12.4	15.9	15.3	10.6	5.6	9.1	145.7
	19	59305	11/21/11 0:00	Water (Produced)	7.6	17.0	15.0	8.5	10.6	9.4	9.3	14.3	14.5	8.2	4.5	6.2	125.0

Monitoring Program

- Over 50% of wells monitored use multiple CFT's
- Toe only logic
- Recycled water
  - Flowback water is piped to pits and treated
  - Use 60-80% recycled water each frac



Fracturing Fluid Recycling

- Small amounts of tracer in the recycled frac fluid are accounted for in pre-frac sampling

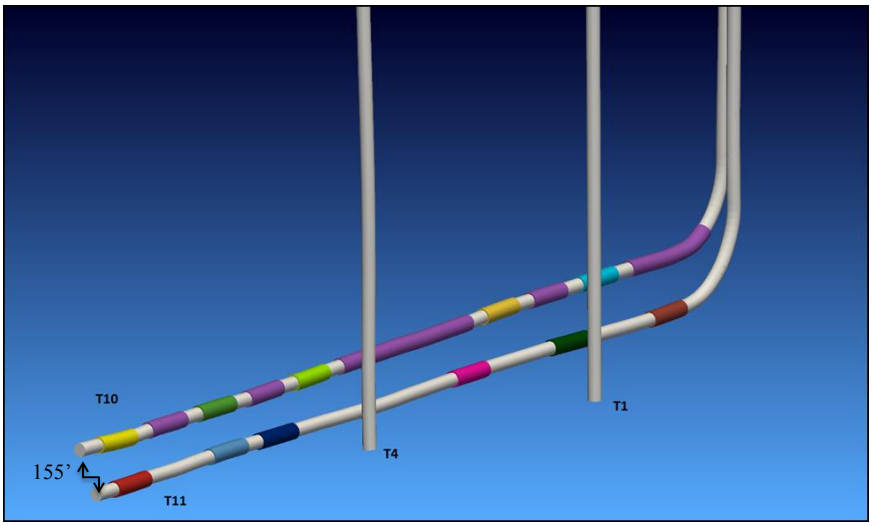
				Traced Segment	11	5	1	
				Stim Date	4/20/14	4/20/14	4/20/14	Totals
				Traced Fluid vol (Gal)	546,756	565,320	440,496	1,552,572
				CFT Injected (g)	1,563	1,610	1,255	4,428
				% Injected	35.3%	36.4%	28.3%	
Key		Cum Vol*	Sample Date	Sample Type	CFT 2400	CFT 2000	CFT 1500	CFT Total ppb
>200	1		4/20/14 6:00	Water (Pre-Frac)	2.0	2.4	1.4	5.9
150 to 200	2		4/20/14 6:01	Water (Pre-Frac)	1.9	2.3	1.4	5.6
100 to 150	3	377	4/23/14 21:00	Water (Produced)	22.6	95.1	1.6	119.2
70 to 100	4	3517	4/24/14 9:00	Water (Produced)	19.6	92.4	9.4	121.4
50 to 70	5	7281	4/24/14 21:00	Water (Produced)	7.4	70.4	30.0	107.8
35 to 50	6	15361	4/25/14 21:00	Water (Produced)	4.7	63.1	12.3	80.1
25 to 35	7	not given	4/26/14 21:00	Water (Produced)	2.0	8.2	0.8	11.0
17 to 25	8	not given	4/27/14 21:00	Water (Produced)	28.0	3.3	1.0	32.4
12 to 17	9	not given	4/29/14 21:00	Water (Produced)	6.2	12.8	7.7	26.7
8 to 12	10	not given	5/1/14 21:00	Water (Produced)	7.9	15.2	14.6	37.7
5 to 8	11	not given	5/3/14 21:00	Water (Produced)	8.2	15.1	16.6	39.9
3 to 5	12	not given	5/5/14 21:00	Water (Produced)	9.3	13.1	17.6	40.1
2 to 3	13	not given	5/7/14 21:00	Water (Produced)	9.9	12.6	17.0	39.6
1 to 2	14	not given	5/10/14 22:30	Water (Produced)	11.9	13.6	19.1	44.5
0.05 to 1	15	not given	5/14/14 10:15	Water (Produced)	10.7	12.0	15.9	38.6
	16	not given	5/18/14 22:30	Water (Produced)	10.5	11.4	14.7	36.5
		Avg BPD		Time Weighted Avg, ppb	10.12	17.36	14.35	41.82
				% total ppb from Stage	24.2%	41.5%	34.3%	100.0%
				% total ppb @ last sample	28.8%	31.1%	40.1%	

Z5H Example –Diagnostics

- Three CFT's injected equally across three sections of the lateral
- Stimulation treatment tested for even load recovery across the lateral
- Overall load fluid recovery was fairly even across the lateral
  - With other wells, early heel domination is seen

				Chemical Frac Tracer, ppb			
			Traced Segment	36-31	30-22	18-9	
			Stim Date	11/8/13	11/6/13	11/4/13	Totals
			Traced Fluid vol (Gal)	608,004	1,978,422	3,235,636	5,822,062
			CFT Injected (g)	1,788	5,709	9,318	16,815
			% Injected	10.6%	34.0%	55.4%	
Key		Cum Vol*	Sample Date	Sample Type	CFT 1100	CFT 1200	CFT 1000	CFT Total ppb
>200	1		11/4/13 7:00	Water (Pre-Frac)	10.0	14.5	23.9	48.4
150 to 200	2		11/8/13 10:00	Water (Pre-Frac)	0.0	0.0	0.0	0.0
100 to 150	3	560	11/9/13 0:01	Water (Produced)	395.3	297.5	20.1	712.8
70 to 100	4	3065	11/9/13 12:00	Water (Produced)	235.0	323.6	38.8	597.4
50 to 70	5	4075	11/10/13 0:01	Water (Produced)	110.5	290.0	72.4	472.9
35 to 50	6	5750	11/10/13 12:00	Water (Produced)	109.0	283.8	68.8	461.6
25 to 35	7	8105	11/11/13 0:01	Water (Produced)	11.4	66.7	247.5	325.5
17 to 25	8	9720	11/12/13 12:00	Water (Produced)	14.5	70.2	263.6	348.3
12 to 17	9	11235	11/13/13 6:00	Water (Produced)	18.8	73.3	272.6	364.7
8 to 12	10	13720	11/15/13 6:00	Water (Produced)	36.6	104.6	222.0	363.2
5 to 8	11	18885	11/17/13 6:00	Water (Produced)	41.0	129.7	193.3	364.0
3 to 5	12	25280	11/19/13 6:00	Water (Produced)	32.1	113.0	148.5	293.6
2 to 3	13	31625	11/21/13 6:00	Water (Produced)	29.8	102.7	132.9	265.3
1 to 2	14	37195	11/23/13 6:00	Water (Produced)	37.9	126.0	176.1	340.0
0.05 to 1	15	42365	11/25/13 6:00	Water (Produced)	24.8	81.1	118.3	224.2
	16	47025	11/27/13 6:00	Water (Produced)	21.7	69.8	99.9	191.4
	17	51465	11/29/13 6:00	Water (Produced)	21.1	68.2	97.1	186.4
	18	64091	12/22/13 0:00	Water (Produced)	11.3	33.1	50.1	94.6
	19	77663	1/17/14 0:00	Water (Produced)	8.2	25.1	37.2	70.5
	20	96455	2/22/14 0:00	Water (Produced)	7.3	22.8	31.8	61.9
		918		Avg ppb	64.79	126.73	127.27	318.79
		Avg BPD		% total ppb from Stage	20.3%	39.8%	39.9%	100.0%

T10H and T11H Stacked Lateral Test



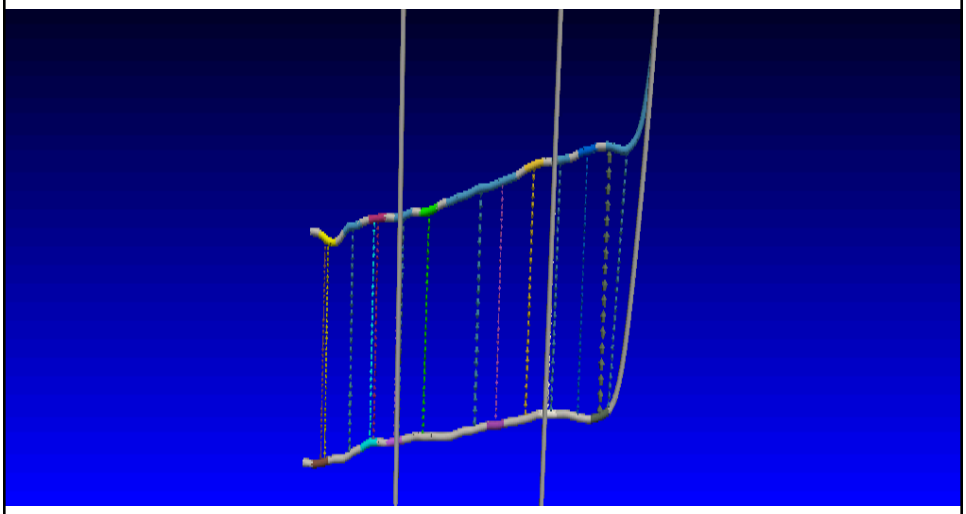
T10H and T11H Stacked Lateral Test

- Project Scope: Evaluating barriers between horizontal bedding planes and target formations.
- Both wells traced, and sampled
  - Offset verticals considered and sampled as well

		T11H						
	Traced Segment	12	10	8	4	3	1	
	Stim Date	5/13/11	5/12/11	5/11/11	4/14/11	4/12/11	4/12/11	Totals
	Traced Fluid vol (Gal)	6,269,752	1,614,900	1,614,900	1,571,434	1,628,848	1,602,598	14,302,432
	CFT Injected (g)	17,654	4,352	4,352	4,352	4,387	4,352	39,448
	% Injected	44.8%	11.0%	11.0%	11.0%	11.1%	11.0%	
Sample Date	Sample Type	CFT 1000	CFT 2400	CFT 2500	CFT 2200	CFT 2100	CFT 2000	CFT Total ppb
4/13/11 20:00	Water (Pre-Frac)	0.0	0.4	0.0	0.0	0.0	0.0	0.4
4/16/11 0:01	Water (Pre-Frac)	6.5	1.8	0.0	1.1	1.7	1.7	12.7
4/19/11 15:00	Water (Produced)	4.1	0.5	0.0	0.8	1.7	0.8	7.9
4/19/11 19:00	Water (Produced)	5.7	0.4	0.0	1.6	1.3	1.2	10.2
4/20/11 11:00	Water (Produced)	0.0	0.0	0.0	0.0	0.0	0.2	0.2
5/11/11 8:00	Water (Pre-Frac)	0.0	0.9	0.0	0.0	0.1	0.9	2.7
5/14/11 0:01	Water (Produced)	105.1	1.3	0.0	1.5	3.2	1.8	116.8
5/14/11 6:00	Water (Produced)	3.1	0.9	0.0	0.0	0.9	0.8	5.7
5/21/11 14:00	Water (Produced)	4.3	0.6	3.2	0.4	0.9	0.5	9.9
5/22/11 22:00	Water (Produced)	2.4	0.6	3.3	0.3	1.0	0.3	7.9
5/23/11 18:00	Water (Produced)	4.3	0.7	2.8	0.4	1.0	0.5	9.6
5/24/11 18:00	Water (Produced)	4.0	0.6	1.7	0.4	0.9	0.5	8.2
5/27/11 6:00	Water (Produced)	3.6	0.6	1.5	0.4	0.9	0.5	7.4
5/28/11 5:12	Water (Produced)	6.2	0.7	2.7	0.3	1.0	0.8	11.7
	Time Weighted Avg, ppb	8.5	0.8	8.6	1.7	1.6	1.0	22.2
	% total ppb from Stage	38.3%	3.7%	38.9%	7.7%	7.0%	4.4%	100.0%

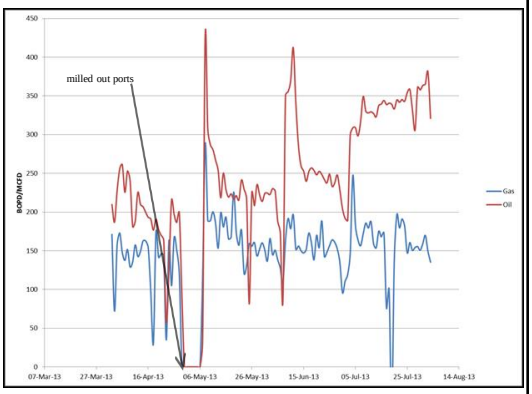
		Offset Chemical Frac Tracer Concentration, ppb												
		T 10H						T 11H						
	Traced Segment	12,10,8,6,4,2 ; 1	11; 12	9; 2	5; 10	3; 3	1; 4	12; 11	10; 8	8; 9	4; 7	3; 6	1; 5	
	Stim Date	5/12/11	5/12/11	5/11/11	4/15/11	4/14/11	4/13/11	5/13/11	5/12/11	5/11/11	4/14/11	4/12/11	4/12/11	Totals
	Traced Fluid vol (Gal)	5,185,000	1,628,596	1,614,900	1,483,066	1,642,569	1,282,642	6,269,752	1,614,900	1,614,900	1,571,434	1,628,848	1,602,598	27,139,205
	CFT Injected (g)	15,164	4,395	4,352	4,330	4,352	3,545	17,654	4,352	4,352	4,352	4,387	4,352	75586
	% Injected	20.1%	5.8%	5.8%	5.7%	5.8%	4.7%	23.4%	5.8%	5.8%	5.8%	5.8%	5.8%	
Sample Date	Sample Type	CFT 1100	CFT 1300	CFT 1200	CFT 1600	CFT 1700	CFT 1900	CFT 1000	CFT 2400	CFT 2500	CFT 2200	CFT 2100	CFT 2000	CFT Total ppb
9/30/11 0:00	Water (Produced)	15.1	0.0	1.5	3.9	4.2	0.0	7.2	0.0	8.0	42.5	40.3	0.0	122.6
	Time Weighted Avg, ppb	15.1	0.0	1.5	3.9	4.2	0.0	7.2	0.0	8.0	42.5	40.3	0.0	122.6
	% total ppb from Stage	12.3%	0.0%	1.2%	3.2%	3.4%	0.0%	5.8%	0.0%	6.5%	34.7%	32.9%	0.0%	100.0%
	% total ppb @ last sample	12.3%	0.0%	1.2%	3.2%	3.4%	0.0%	5.8%	0.0%	6.5%	34.7%	32.9%	0.0%	100.0%
	IVC	7.0	0.0	0.7	1.8	1.9	0.0	3.3	0.0	3.7	19.8	18.7	0.0	57.0
	% Contrib	12.3%	0.0%	1.2%	3.2%	3.4%	0.0%	5.8%	0.0%	6.5%	34.7%	32.9%	0.0%	100.0%

T10H and T11H Stacked Lateral Test



P4H Example – Tracer Longevity and Intervention Benefits

- Open hole completion
  - Standard for this particular formation
- Originally no seats were milled
  - Decision was made to mill seats based on low tracer recovery from toe stages
- Post intervention increase in production of oil and gas



New Wells to Existing Offsets

- K1H is stimulated 6 months prior to the T3H
- The offset well communication level was unknown for the area
- Recovered tracer from the K1H well does not show traced communication from the T3H stimulation treatment

		Chemical Frac Tracer Concentration, ppb					
	Traced Segment	16	13	9	5	1	
	Stim Date	5/19/13	5/19/13	5/18/13	5/18/13	5/18/13	Totals
	Traced Fluid vol (Gal)	72,853	71,299	73,736	23,280	72,151	313,319
	CFT Injected (g)	213	213	213	83	225	947
	% Injected	22.5%	22.5%	22.5%	8.8%	23.8%	
Sample Date	Sample Type	CFT 1000	CFT 1100	CFT 1200	CFT 1300	CFT 1700	CFT Total ppb
5/18/13 12:58	Water (Pre-Frac)	0.0	0.0	0.0	0.0	0.0	0.0
5/19/13 20:45	Water (Pre-Frac)	0.0	0.0	0.0	0.0	0.0	0.0
5/20/13 17:00	Water (Produced)	172.0	17.4	0.0	0.0	0.0	189.3
5/22/13 17:00	Water (Produced)	19.0	24.2	28.9	9.8	2.6	84.4
5/23/13 5:00	Water (Produced)	19.7	24.0	28.9	10.1	2.6	85.3
5/25/13 17:00	Water (Produced)	19.0	23.7	28.4	9.7	2.6	83.5
5/26/13 17:00	Water (Produced)	19.2	25.0	30.3	10.3	2.6	87.4
5/27/13 17:00	Water (Produced)	19.6	24.9	29.7	10.0	2.7	86.8
5/28/13 17:00	Water (Produced)	20.6	27.5	32.3	9.2	2.4	92.0
5/30/13 17:00	Water (Produced)	22.2	28.8	34.6	10.5	2.6	98.7
6/1/13 17:00	Water (Produced)	31.8	27.5	33.6	7.7	2.3	102.8
6/3/13 17:00	Water (Produced)	30.1	25.1	29.6	5.5	2.0	92.4
6/6/13 17:00	Water (Produced)	17.7	17.4	20.3	5.9	2.0	61.3
6/9/13 17:00	Water (Produced)	9.2	11.3	11.4	2.6	19.5	54.1
6/11/13 5:00	Water (Produced)	9.4	12.1	13.2	3.4	20.3	58.4
6/14/13 5:00	Water (Produced)	8.1	9.4	10.4	3.2	16.8	47.9
10/17/13 10:00	Water (Produced)	0.8	0.8	1.9	0.7	3.2	7.5
10/21/13 8:00	Water (Produced)	0.8	0.7	1.8	0.8	3.1	7.2
11/14/13 13:00	Water (Produced)	0.8	0.0	1.2	0.4	2.3	4.7
12/15/13 11:00	Water (Produced)	1.1	0.4	0.8	0.5	2.2	5.0
	Avg ppb	23.40	16.67	18.75	5.46	5.09	69.37
	% total ppb from Stage	33.7%	24.0%	27.0%	7.9%	7.3%	100.0%
	% total ppb @ last sample	22.5%	7.4%	16.2%	9.5%	44.5%	
	Mass Balance Recov'd (g)	59.3	59.3	71.8	18.5	33.4	242.4
	% of Total Recovery	24.5%	24.5%	29.6%	7.6%	13.8%	100.0%

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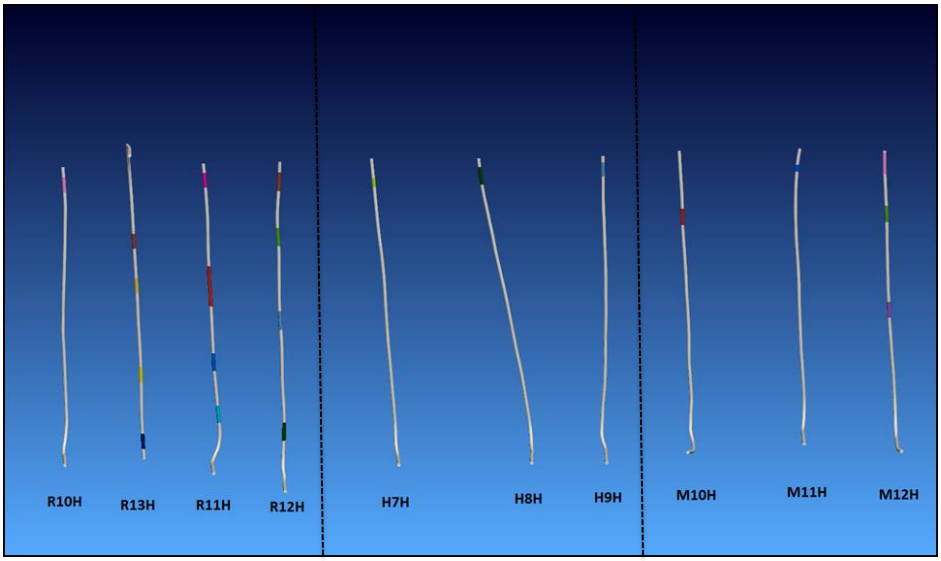
Communication Test: 10 Well Project



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Communication Test: 10 Well Project

- Fracced using three stimulation fleets simultaneously across three sections.
- Wells stimulated first receive less communication from the latter wells.
- Table below grades into tiers of exposure.

Average PPB Communication Summary				Sampled Wells 10 Well Tracing Project										# Wells receiving CFT
Traced Well	Traced Segment	Stim Date	CFT	R10H	R13H	R11H	R12H	H7H	H8H	H9H	M10H	M11H	M12H	
R10H	1	8/23/2012	1400	2.6										0
R13H	1	8/27/2012	1700		28.0									0
	4	8/27/2012	2200		30.0									0
	8	8/29/2012	1900		19.0									0
	10	8/30/2012	1200		56.0									0
R11H	1	8/30/2012	2500		5.0	48.0	1.3						26.6	3
	4	9/1/2012	2000			36.0	0.4							1
	8	9/2/2012	1500			35.0	0.3							1
	10	9/2/2012	1300		2.5	63.0	1.8							2
R12H	1	11/14/2012	1000				40.0							0
	3	11/14/2012	1700				58.0							0
	6	11/15/2012	2100		4.3		33.0							1
	10	11/16/2012	2400				70.0							0
H7H	1	9/3/2012	1600			20.2		65.0	4.0					2
H8H	1	9/5/2012	2400					12.6	33.0					1
H9H	1	9/5/2012	2100					6.4	4.0	7.5	7.0			3
M10H	3	9/7/2012	2000							8.7	11.0	3.3	3.7	3
M11H	1	9/8/2012	1500								9.2	31.0	6.2	2
M12H	1	9/11/2012	1400								9.2	9.0	12.0	2
	3	9/11/2012	1700								3.5	10.0	39.0	2
	7	9/12/2012	1100								2.0	11.0	22.0	2

Tier 1	>20 ppb
Tier 2	10-20 ppb
Tier 3	1-10 ppb
Traced well	

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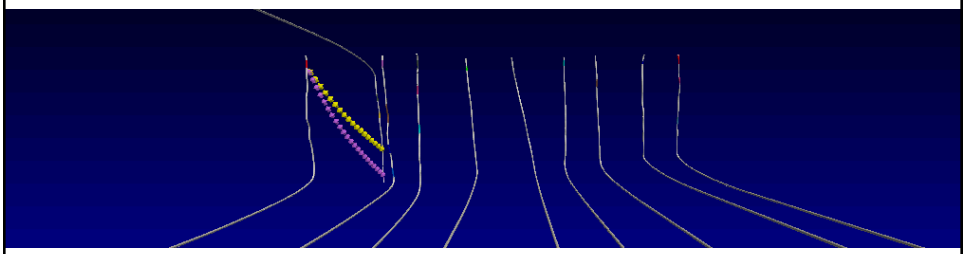
Overall Communication: 10 Well Project



3D Animation of early communication matrix

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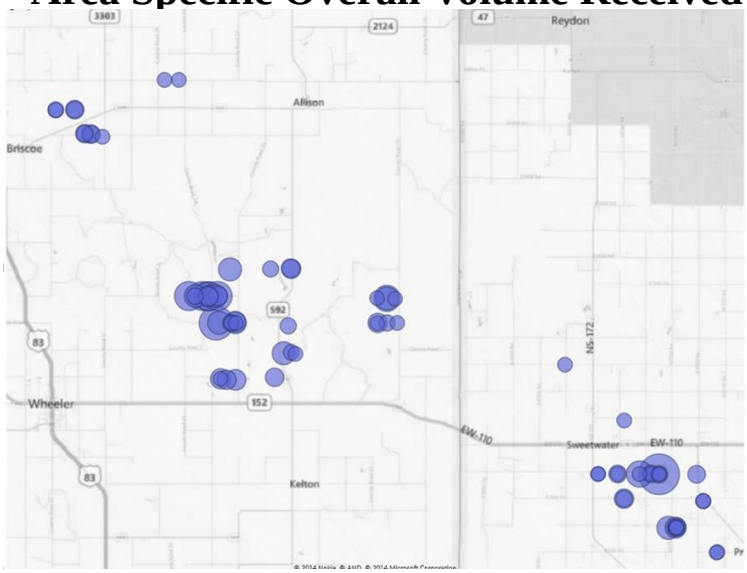
Area Specific Overall Volume Received



Conclusions

- Recycled water can be utilized, as background tracer data can be confirmed prior to use.
- New completion techniques can be tested for well response and even flow regimes.
- Interwell communication can be evaluated with mature wells and fresh offset infill wells.
- Boundary formation efficacy can be tested with stacked laterals
- Initial flowback can give guidance on the next step required for the health of the well.
- Non-productive portions of the lateral can be quickly identified and remediation can be performed to maintain healthy production.

Acknowledgements / Thank You / Questions

The authors gratefully acknowledge the assistance and support of Linn Energy in preparing and presenting this paper.