PRESSURE TRANSIENT WELL TEST ANALYSIS IN THE ARBUCKLE, WELLINGTON

Step-Rate Test, Interference Test, and DST Analysis

By

Mina Fazelalavi

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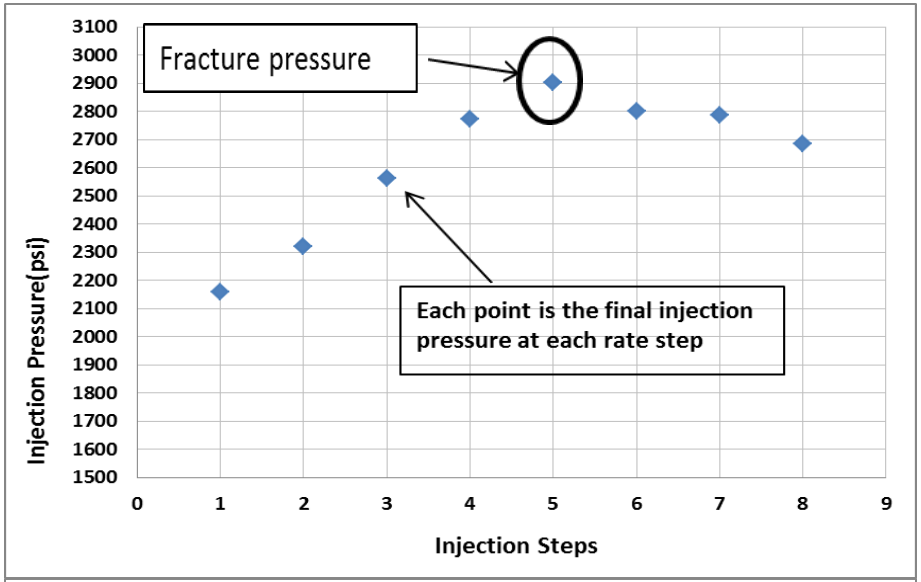
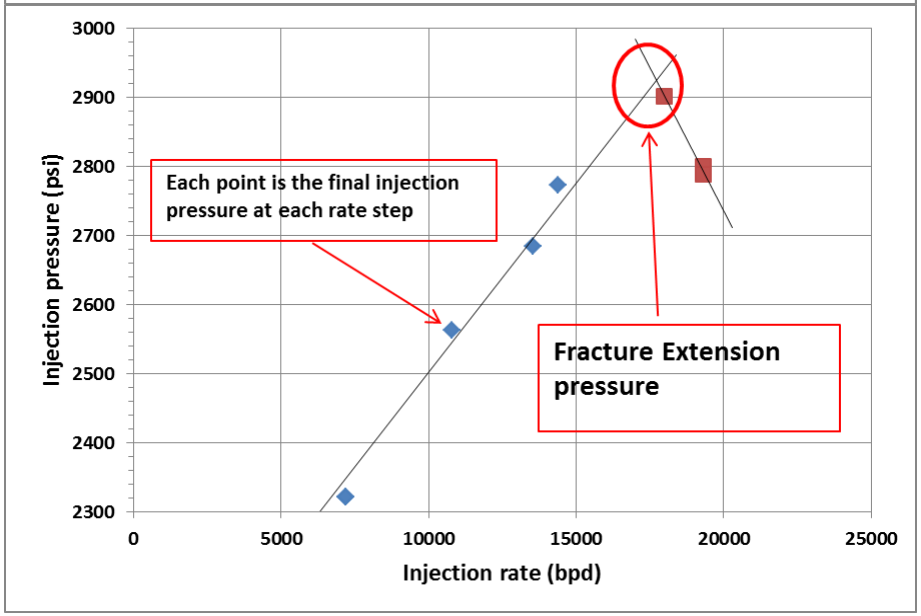
Step-Rate Test, Interference Test Results, and DST Results in Wellington

- Step-rate test was modeled by FEKETE
  - Fracture and closure pressures were calculated
  - Permeability and skin were calculated
- Interference test was modeled by FEKETE
  - Composite model was considered for this test due to change in permeability and flow capacity at some distance from the wellbore
  - Two permeabilities were calculated for two radii (regions) from 1-32
- DSTs in 1-32 and 1-28 were analyzed by FEKETE

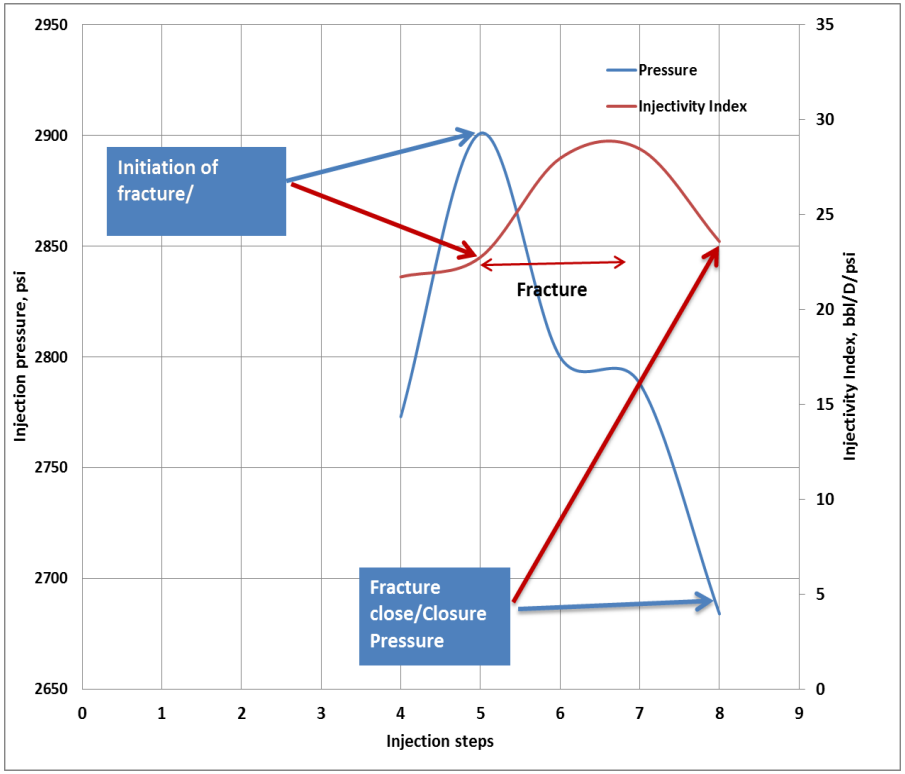
Fracture/Breakdown Pressure

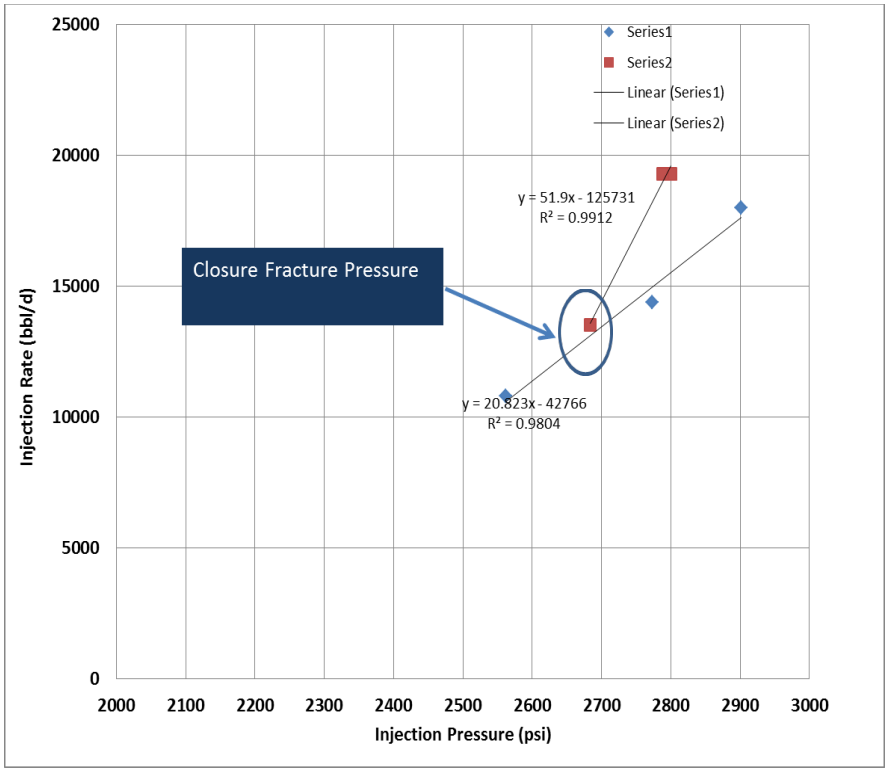
- Injection step 5 from the first and second plots show fracture occurred
- Fracture pressure/ breakdown pressure is about 2,900 psi from both plots
- Breakdown fracture gradient is 0.58 psi/ft in the Arbuckle using the gauge depth at 5,025 ft





Closure Pressure/Minimum Stress

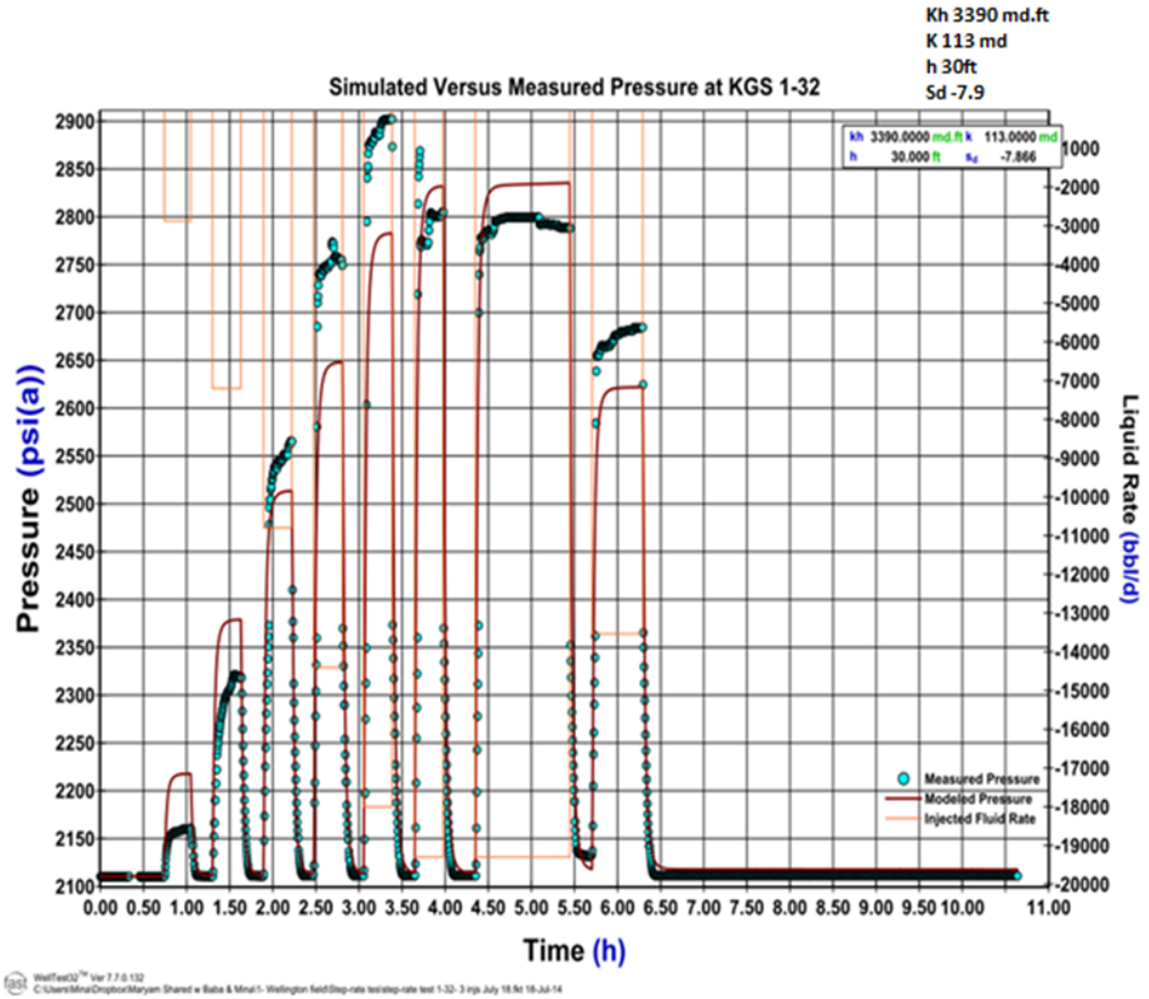




- Fracture occurred on rate step 5 and remains open during steps 5 and 6 until injectivity index starts dropping
- Fracture closes where injectivity index is back to its value before initiation of fracture
- Closure pressure or minimum stress is slightly less than 2,666 psi and its gradient is 0.55 psi/ft
- One or two more rate steps at lower rates could give more accurate closure pressure

Step-Rate Test in 1-32
Gauge Depth at 5,025 ft, Test Interval: 4,995–5,020

- Step-rate test in 1-32 was analyzed and modeled by FEKETE
- All injection steps were selected in this model; therefore, the model tries to match the pressures from all steps at the same time with a single skin
- Each step has a different skin; therefore, accurate match is not possible with a single skin
- There is good agreement between the modeled pressure (in red) and measured pressure (in blue)



Step-Rate Test Results in 1-32
Permeability and Skin

- Calculated permeability from step-rate test is 113 mD for 30 ft interval that has vertical communication based on Lorenz plot

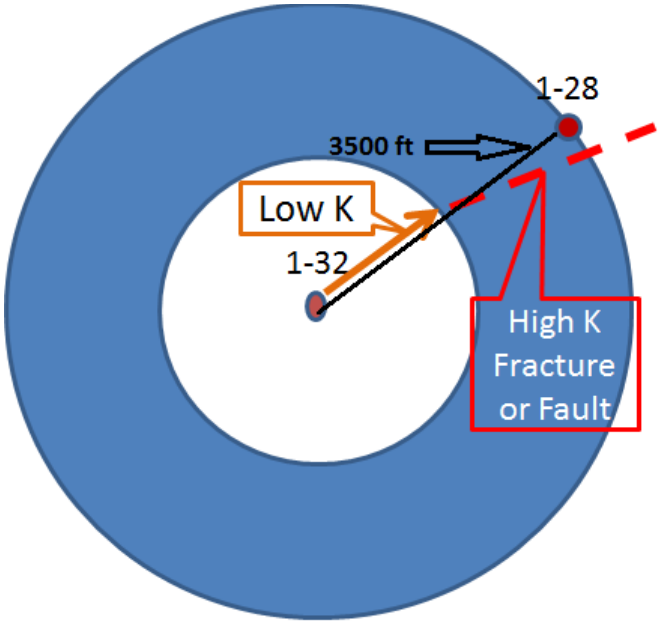
- There are vertical barriers above and below this interval. 25 ft of this interval is perforated. This permeability is close to log-derived average permeability (74mD) for the same interval

- Skin from injection step 7 is -7.6. This skin was used in the analysis

Interference Test—Well 1-28 Was the Observation Well

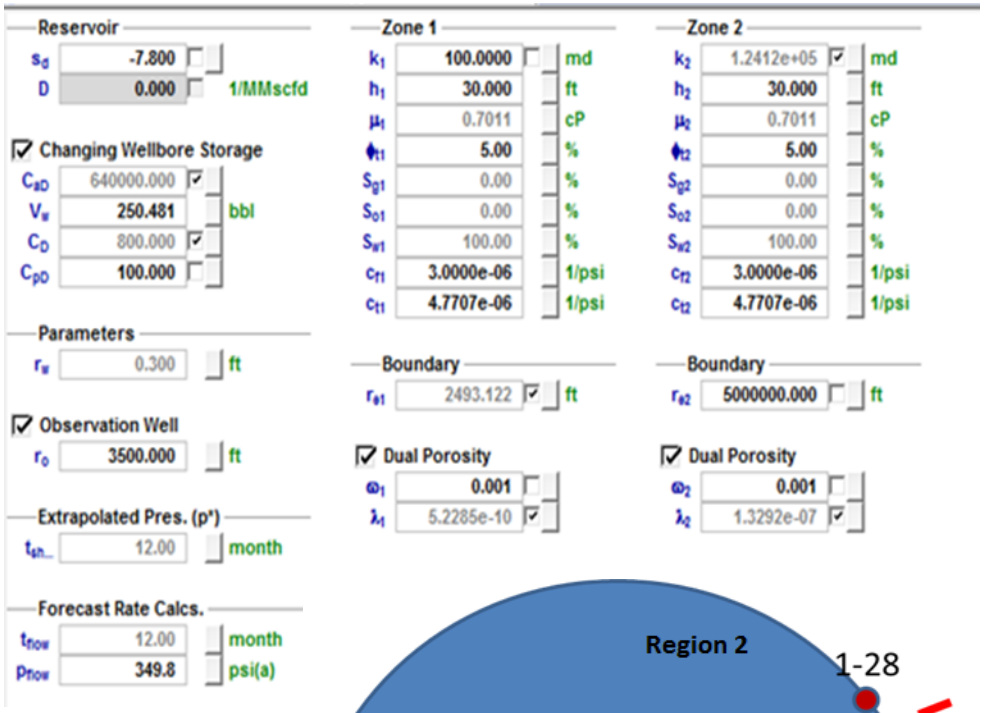
- Well 1-32 was the injection well and 1-28 was the observation well

- Distance between 1-32 and 1-28 is 3,500 ft



Results of Pressure Transient Analysis of the Observation Well (1-28)

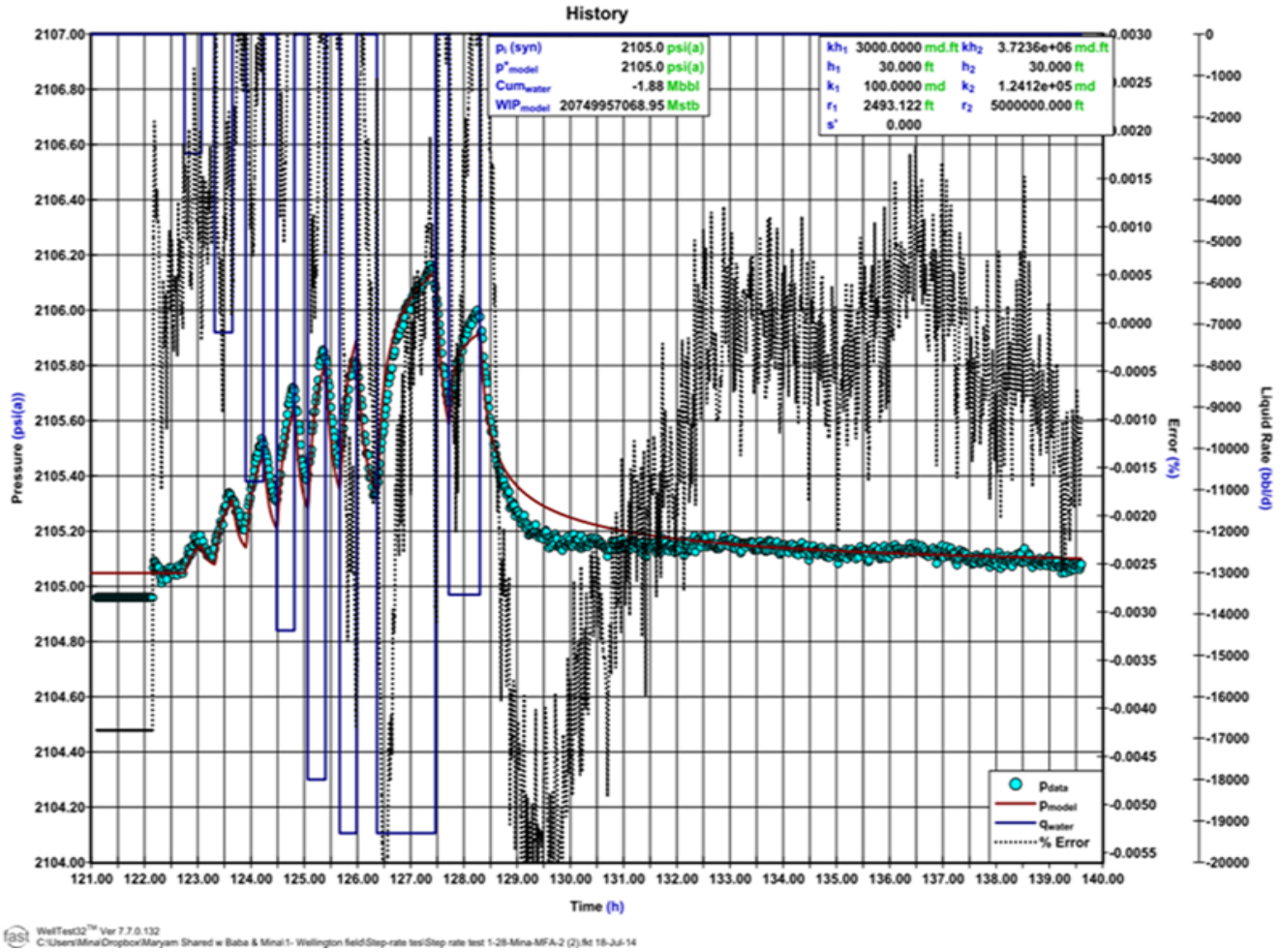
- Pressure transient data of 1-28 was modeled using composite model with dual porosity-permeability (zone/region 1&2)
- Based on this model, permeability in the vicinity of well 1-32 to a radius of 2,493 ft (region 1) has a lower value (100 mD) for 30 ft interval that is in vertical communication
- Permeability is 124 D from radius of 2,493 ft to the vicinity of 1-28
- Permeability for region 1 is close to the log-derived average permeability (74mD)
- Bigger permeability for the farther radius could be associated with fracture or fault between the two wells



Composite model and parameters

Modeled Pressure versus Measured Pressure in the Observation Well (1-28)

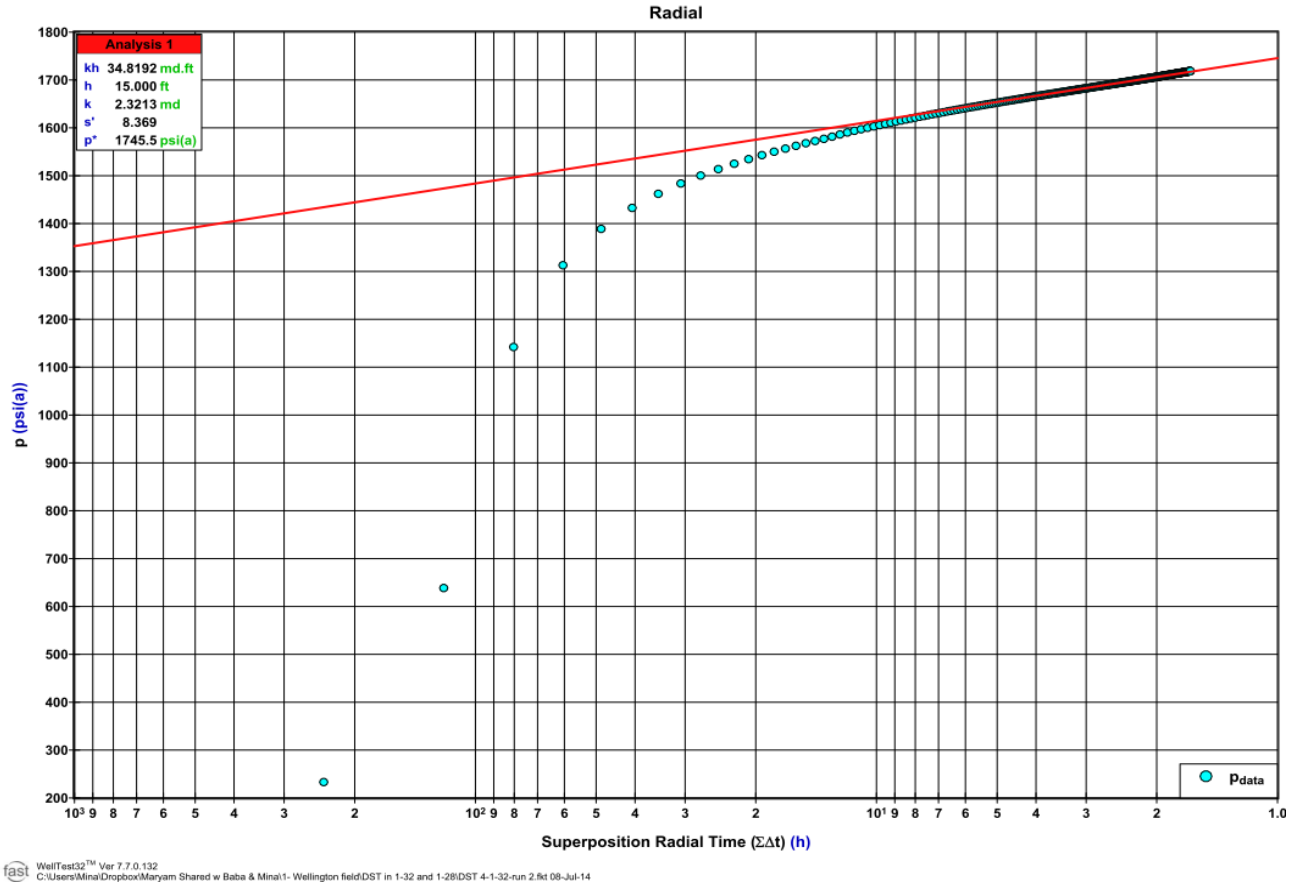
- Composite model resulted in a better match between modeled pressure and measured pressure
- Modeled pressure is in red and measured pressure is in blue



DSTs Validity in 1-32

- DST 1 and 4 are only suitable for analysis
- DST 2 and 3 are not suitable for analysis:
  - DST 2: Flowing pressure is equal to shut-in pressure; therefore, there is no build-up to analyze, but temperature and pressure are useful
  - DST 3: DST flowing pressure is equal to shut-in pressure; therefore, there is no build up to analyze

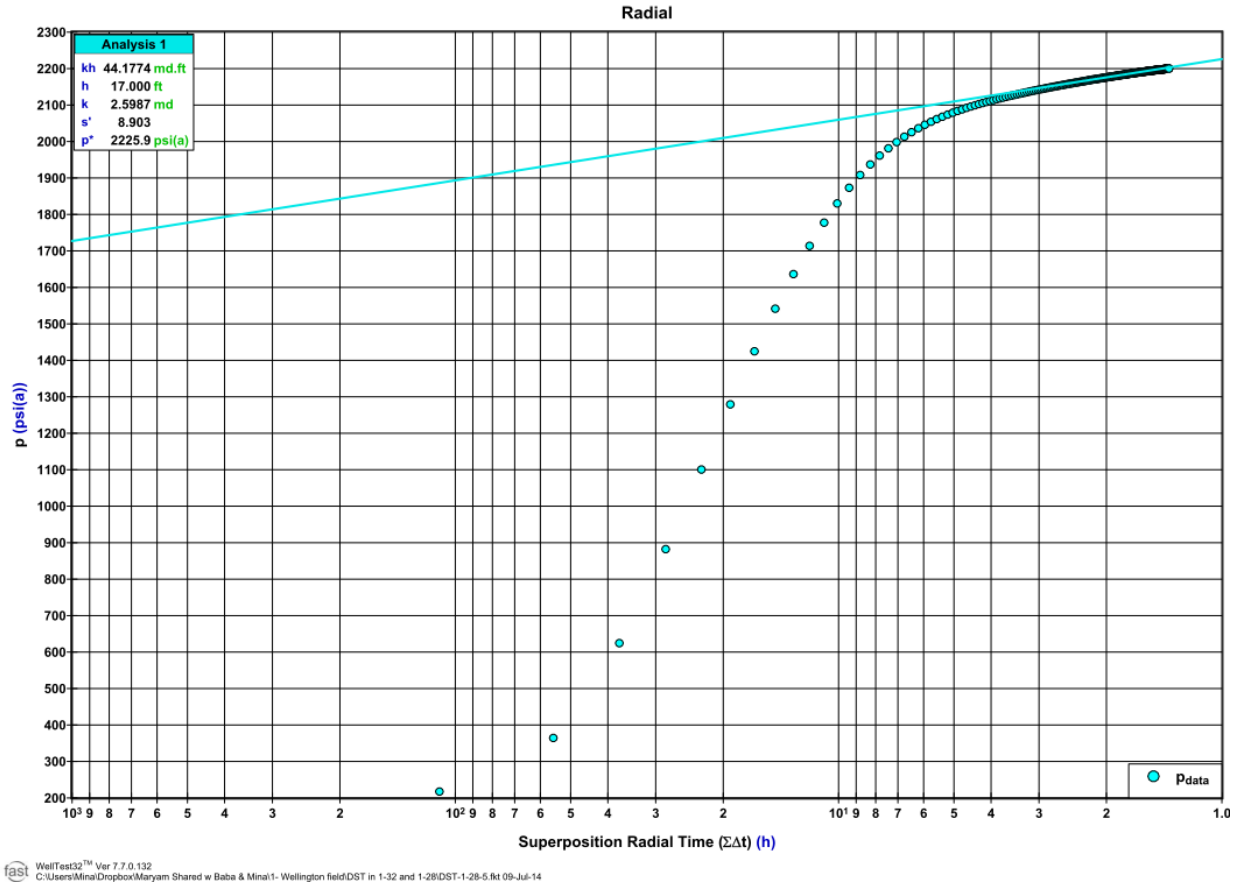
DST 4 in 1-32
Interval: 4,175–4,190 ft



DSTs Validity in 1-28

- Only DST 1 is suitable for analysis.
- DSTs 2, 3, and 4 are not suitable for analysis:
  - DST 2: Flow period is short and doesn't have transient period. Pressure from this test is useful.
  - DST 3: Like DST 2, has a short transient time. Pressure from this test is useful.
  - DST 4: Not suitable for the same reasons as 2 and 3.

DST 1 in 1-28
Interval: 5,133–5,250 ft



Results

Well 1-32				
DST Interval	K from DST	Log connectivity	Average Log derived K90	Average Core K90
ft	mD	ft	mD	mD
4175-4190	2.32	4175-4090	4.61	4.59

Well 1-28				
DST Interval	K from DST	Log cennectivity	Average Log derived K90	Average Core K90
ft	mD	ft	mD	mD
5133-5250	2.60 mD	5133-5160	2.17 (5133-5160)	NA

Step-Rate Test results				
Interval	Gauge depth@	K from Step-rate test	Average log derived K90	Average Core K90
ft	ft	mD	mD	mD
30	4869	113	74	NA

Interference test result				
Interval	K for zone 1	K for zone 2	Ave K90 from log for zone1	Average Core K90
ft	mD	D	mD	mD
30	100	124	74	NA

Conclusion

- Permeability calculated from step-rate test and interference test are close to log-derived permeability
- Permeability calculated from DST tests in 1-32 and 1-28 are in agreements with core data
- Permeability of 124D from the interference test is associated with a radius farther away from 1-32 to the vicinity of well 1-28, which can be related to fault or fracture
- Appropriate model and correct thickness were not selected in the former analysis. Skin was large and, therefore, calculated permeability was affected by the large skin
- Results can be improved if correct model and thickness selected

Comments Regarding the Previous Step-Rate Test Analysis

- Thickness of injection zone was assumed 200 feet, which is not right. Perforated interval is 25 feet, and it is in the middle of FU 14 according to Lorenz plot. Thickness of this unit is only about 30 ft and it is bounded by almost impermeable layers, which are above and below the unit
- Calculated skin factor (s) is 200. This high s is very abnormal in carbonate reservoirs
- Since the skin is very high, to obtain pressure match, calculated permeability times thickness (kh) had been increased to 4.24E+5, which is not correct

Comments Regarding the Previous Interference Test Analysis

- Thickness of injection interval was assumed 200 ft, which is not correct. Actual thickness of the affected interval by injection is 30 ft or less as discussed
- Volume of reservoir affected by injection had been increased by a factor of 6.66. Therefore, pressure signal at well 1-28 is reduced by a factor of 6.66. To compensate for this reduction, higher permeability had been calculated