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TECHNICAL SERVICES REPORT HOU-020063
ROCK MECHANICS LABORATORY

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SUMMARY

This report reviews the results of acoustic velocity, dynamic elastic parameters, unconfined compressive strength and backpressure analysis for limestone formation of the Eastern Hillsboro FAMW-1 well, Integrity Well & Pump Company, Palm Beach County water utilities department.

The results from acoustic velocities along with porosity and bulk density indicate that the samples can be categorized into two groups. The first group (samples #8 and #9) is well-consolidated limestone with high compressional-wave (Vp) velocity (~16500 ft/s) and high shear-wave (Vs) velocity (~9100 ft/s), high values of dynamic elastic parameters (Young's modulus, bulk modulus, shear modulus), high bulk density (~2.36 gm/cc), and low porosity (~13%). The second group is soft limestone with low Vp of around 6000 ft/s, low Vs of around 3500 ft/s, low values of dynamic elastic parameter, low bulk density of ~1.62 gm/cc and high porosity of ~40%.

Four 4-inch diameter cores and three 1.5-inch diameter samples were tested under unconfined condition and the corresponding uniaxial compressive strengths (UCS) were determined on dry core. The samples with high acoustic velocities are stronger with UCS values over 2700 psi than those with low acoustic velocities, which have UCS ranging from 400 to 1000 psi. UCS shows good correlation with dynamic Young's modulus (**Figure 1**) and hence UCS of samples that do not have enough material for compressive test was interpolated from the measurements of Young's modulus of samples with known UCS. Although not tested, the UCS of the core is expected to decrease in fresh water. The softer samples are more sensitive to fresh water. The results of acoustic velocity, dynamic elastic parameters, and UCS are listed in **Table1**. Stress-strain curves for the unconfined compressive test are shown in **Figures 2** to **8**.

The bottom hole water pressure analysis was performed for water well operation assuming constant-pressure outer boundary and steady-state flow conditions. Well pressure (bottom hole pressure) was analyzed first using arithmetic average (700 mD measured with air) for formation permeability. The well pressures were calculated for several flow rates (i.e., pumping rates) assuming 1- and 2-mile drainage radius. The well pressures were also calculated assuming formation permeabilities of 300 mD and 500 mD. The analysis indicates that about 2800 to 3000 gallon/min of water can be pumped with formation permeability of 700 mD, while maintaining well pressure equivalent to the water column that is equal to the reservoir thickness. However, in order to maintain the same well pressure, the flow rate should be decreased with decreasing formation permeability. The analysis for well pressure is summarized in **Tables 2** to **4** assuming different formation permeabilities and drainage radii.

INTRODUCTION

The Rock Mechanics Laboratory (RML) at Core Laboratories' Advanced Technology Center (ATC) provides rock and soil mechanics measurements and analysis services for client companies using cores from Core Laboratories worldwide operations. The Rock Mechanics Laboratory also analyzes, calibrates and interprets logs for client companies.

The current RML provides data and analysis for hydraulic and acid fracturing designs, borehole stability analysis and reservoir engineering applications. The laboratory services performed include determining sonic and static values for Young's modulus, Poisson's ratio, compressive strength, formation stresses, rock cohesion strength, pore volume compressibility and fracture azimuth from cores. The data and analysis performed are used to help achieve optimized hydraulic and acid fracture designs but are also used for sand control, borehole stability and reservoir engineering applications (i.e., determining reservoir size or water or waste fluid injection). Sonic velocity data is also supplied to customers for seismic 3D surveys and cross well topography studies.

The RML has four major facilities for measuring both static and sonic geomechanical properties. The primary rock mechanics equipment consists of a computer controlled 400,000-lbf-load frame with associated triaxial cells for confining pressure up to 10,000 psi. A 100,000-lbf-load frame with a triaxial cell for confining pressure up to 10,000 psi is dedicated to testing soils and weakly consolidated cores. The 100,000-lbf-load frame is designed to exert only low stresses on frozen or weakly consolidated samples after applying confining pressure to the samples. Sonic velocities can also be measured in a dedicated facility for hydrostatic pressure up to 15,000 psi. The fourth facility consists of equipment dedicated to measuring pore volume compressibility (PVC) for reservoir engineering applications. All equipment used in the acoustic velocity test is calibrated to an accuracy of 1%.

DESCRIPTION OF TEST METHODS

There are two laboratory methods for determining Young's modulus and Poisson's ratio:

- Dynamic method using ultrasonic velocity measurements on cores.
- Static method using stress-strain relations from uniaxial or triaxial tests on cores.

The preferred method is to perform static triaxial tests on cores with in-situ stress conditions since this method provides the most accurate and reliable data. The ultrasonic tests work on the same principal first studied by Young (circa 1600):

sound wave velocities propagating in solids are related to Young's modulus, Poisson's ratio, and density. Both compressional and shear wave velocities must be measured to calculate dynamic elastic moduli. As a general rule, the dynamic techniques are inaccurate because of poroelastic influences on sonic wave propagation. Dynamic values for Young's modulus can be a factor of 2 to 20 times higher than static values. Consequently all dynamic test results, including dipole sonic logs, must be calibrated to provide reasonable estimates of static values needed for hydraulic fracture design, wellbore stability analysis, subsidence studies, and prediction of reservoir behavior.

Static values of Young's modulus and Poisson's ratio are measured on cores with diameters of 1.5 inches and lengths of about 3 inches. The preferred technique is to directly measure the change of core dimensions as a function of applied stress in a triaxial test. In triaxial test, the sample length changes are accurately measured during application of differential stress by using two internal Linear Variable Displacement Transducers (LVDT) calibrated to an accuracy of 0.0004 inch. Radial LVDT is mounted around the lateral surface of the sample and measures changes in sample circumference and hence diameter during the deformation. The applied axial stress is calculated based on the measurements of applied load using a calibrated force gauge.

Young's Modulus and Poisson's Ratio

Young's modulus, Poisson's ratio and compressive strength are measured directly in the laboratory by uniaxial and triaxial tests or calculated indirectly from ultrasonic velocities. Young's modulus is the slope of a line when axial stress is plotted against axial strain. The typical accuracy of the static technique to determine Young's modulus is about 1 %. During the test, confining pressure and axial stress are controlled by computer.

Another important property of linear-elastic material is the ability to expand in a lateral direction when the load is applied on the material in a vertical direction. This ability to expand laterally is expressed by Poisson's ratio, which is defined by the ratio of lateral expansion to vertical contraction. Poisson's ratio for linear-elastic materials can vary from 0 to a maximum of 0.5. The maximum value of 0.5 is a theoretical limit because all materials with values greater than 0.5 would actually increase in volume when compressed. Expansion of materials during compression rarely happens in practice and violates a law of thermodynamics.

Most rocks have Poisson's ratio between 0.05 and 0.48. Hard sandstone has typical values between 0.1 and 0.3. Soft sandstone has typical values of 0.30 to 0.48. Limestones have typical values between 0.15 and 0.35. Poisson's ratio is a critical parameter in determining formation stress and consequently influences fracture height and width calculations and designs and wellbore stability calculations. When encountering low values for Poisson's ratio, subsurface engineers should exercise caution. With low values of Poisson's ratio, the fracture can grow out of the producing zone and sometimes give unconfined fracture height growth.

Acoustic Velocities and Dynamic Elastic Parameters

The pulse transmission technique of velocity measurements was used with 1MHz frequency for P- and S-waves. The accuracy of velocity measurements is about 1%. Dynamic elastic parameters (bulk modulus, Young's modulus, shear modulus, and Poisson's ratio) are calculated using P- and S-wave velocities (Vp and Vs, respectively) and bulk density based on linear elastic theory.

Uniaxial Mechanical Properties Testing Procedures

Four 4-inch diameter cores and three 1.5-inch diameter samples were deformed under unconfined condition and uniaxial compressive strengths (UCS) were determined. Procedures for triaxial (uniaxial) test are summarized in the following:

- A cylindrical sample of 1.5- or 4-inch diameter is cut from the sample core. The length to diameter ratio of 2:1 is recommended to obtain representative property of the sample. Sample length, diameter and mass are measured and recorded.
- The sample is inserted into a rubber jacket and radial LVDT is placed around the lateral surface of the sample.
- The sample is mounted between pistons with ports on the contacting surfaces for controlling pore pressure.
- The entire assembly is mounted in a pressure vessel that allows application of confining pressure and axial stress. The top piston extends through the top of the pressure vessel enabling the application of axial load.
- The pressure vessel is then loaded into a computer controlled load frame where another LVDT is attached for axial strain measurements.
- Inspect the pressure system for any leak. Then confining and axial pressures are increased at the same rate to the desired hydrostatic testing pressure. (This step is not applicable to the uniaxial test.)
- Logging of data is begun and the axial load is increased at a constant rate while confining pressure is held constant. (For the uniaxial test, the confining pressure is zero.)
- Stop all data recording upon attaining desired level of axial stress or after sample fails and reduce the axial stress to the hydrostatic condition. Reduce axial and confining pressures to zero at the same time.

Uniaxial Data Analysis

Deviatory stresses are plotted against both axial strain ε_L (= $\Delta L/L_o$) and radial strain ε_R (= $\Delta R/R_o$). Deviatory stress (σ_d) is defined as the difference between the total axial stress and the confining pressure. Since all tests were conducted under compressive stresses, compressive stress and contraction (shortening) are considered positive. Accordingly, positive axial strain indicates shortening of sample and negative radial strain indicates increase in sample diameter during deformation.

Static Young's modulus is determined by taking the slope of linear elastic part of the curve plotted on σ_d vs. ε_L space. Static Poisson's ratio (= $-\Delta\varepsilon_R/\Delta\varepsilon_L$) is also determined in a similar way by taking the slope of linear part of the ε_R vs. ε_L curve.

Well Pressure (Bottom Hole Pressure) Analysis

The bottom hole pressure analysis was performed for water well operation assuming constant-pressure outer boundary and steady-state flow conditions. Darcy's law in the form of radial flow equation with zero skin effect was used for analysis.

The bottom hole pressure (P_{wf}) was calculated assuming viscosity of water (μ) of 1 centi-poise, well radius (r_w) of 1 ft, and reservoir thickness (h) of 400 ft. The reservoir pressure (P_e) of 621 psi measured in the field (35' of water above ground) was used as the constant pressure at the outer boundary (r_e). The bottom hole pressure was calculated for a drainage radius (r_e) of 1- and 2-mile. Minimum pump outlet pressure was calculated by adding 1000' of water pressure to the bottom hole pressure.

For uniform flow along continuous parallel layers, the effective permeability of these layers can be represented by arithmetic average of all layers combined with thickness of each layer. Therefore, the bottom hole pressure was calculated first using arithmetic average (700 mD) of air permeability measured for the core samples as a formation permeability. To evaluate the effect of formation permeability on the bottom hole pressure, variation of the bottom hole pressure was calculated using the formation permeability of 300 mD and 500 mD. The bottom hole pressure was also evaluated for different flow rates (q).

TEST RESULTS

Acoustic Velocities and Uniaxial Compressive Strength

While the mechanical properties of rocks can be estimated from downhole measurements through wireline logging of acoustic velocities and rock density (i.e., dynamic measurements), it is known that the dynamic moduli are higher than the values measured directly in the laboratory from uniaxial or triaxial tests (i.e., static measurements). Static measurements on cores are much more indicative of the mechanical properties of the reservoir rocks than the dynamic results, however, the wireline logging covers much more of the reservoir than static core measurements due to the limitation placed by availability of recovered core materials. Since there is a significant difference between static and dynamic values, it is important to calibrate dynamically derived mechanical properties to the statically measured values which better represent the in-situ reservoir rocks.

The results of compressional-wave (Vp) and shear-wave (Vs) velocities indicate that the samples can be classified into two distinctive groups. The first group (samples 8 and 9) is well-consolidated limestone with high Vp (~16500 ft/s) and high Vs velocity (~9100 ft/s) and correspondingly high values of dynamic elastic parameters (Young's modulus, bulk modulus, shear modulus). These samples also show high bulk density (~2.36 gm/cc) and low porosity (~13%). The second group is soft limestone with low Vp of around 6000 ft/s and low Vs of around 3500 ft/s and hence low values of dynamic elastic parameter. These samples have relatively low bulk density of ~1.62 gm/cc and very high porosity of ~40%. The results of acoustic velocity and dynamic elastic parameters are listed in **Table1**.

The results of unconfined compressive tests indicate that the samples with high acoustic velocities are stronger with unconfined strength (UCS) over 2700 psi than those with low acoustic velocities, which have UCS ranging from 409 psi (sample #4) to 1028 psi (sample #3). The UCS shows good correlation with dynamic Young's modulus (**Figure 1**) and hence UCS of samples that do not have enough material for compressive test was interpolated from the measurements of Young's modulus of samples with known UCS. The interpolated UCS is shown in red in **Figure 1**. The results of unconfined compressive tests are listed in **Table1** along with interpolated UCS. Stress-strain curves for the unconfined compressive test are shown in **Figures 2** to **8**.

Well Pressure (Bottom Hole Pressure) Analysis

Well pressure (bottom hole pressure) was analyzed first using arithmetic average of 700 mD (measured with air) for formation permeability. The well pressures were calculated for several flow rates (pumping rates) assuming 1- and 2-mile drainage radius. The bottom hole pressure analysis indicate that 2800 to 3000 gallon/min of water can flow while maintaining height of water column equal to the reservoir thickness.

However, in order to maintain the same well pressure, the flow rate (pumping rate) should be decreased with decreasing formation permeability. The well pressures were also calculated assuming formation permeabilities of 300 mD and 500 mD. The analysis indicates that about 1200 to 1300 gallon/min and 2000 to 2150 gallon/min of water can be pumped while maintaining height of water column equal to the reservoir thickness when formation permeability reduces to 300 mD and 500 mD, respectively. The analysis of well pressures for various flow rates is summarized in **Tables 2** to **4** assuming different formation permeabilities and drainage radii.

Caveat on Bottom Hole Pressure Analysis

For the bottom hole pressure analysis, consideration for wellbore stability was not included. The uniaxial compressive tests indicate that the samples are relatively weak except the samples #8 and #9. We also encountered problem during the drilling of cores using water as drilling fluid. The samples start to disintegrate upon contact with fresh water. There may be a potential problem regarding wellbore stability while injecting fresh water into the aquifer.

It is also assumed that the skin effect is zero, which means that there is no formation damage during drilling of wellbore and production of water. In fact, formation permeability will be affected by any damage caused by drilling and migration of fine materials within the formation. This permeability decrease is partly entailed in the analysis by calculating the bottom hole pressures using different formation permeabilities.

Table 1. Results of acoustic velocity measurements, dynamic elastic parameters, and unconfined compressive strength for samples from Eastern Hillsboro FAMW-1 well.

			Dynamic Elastic Values								
Core No.	Depth (ft)	Bulk Density (gm/cc)	Vp (ft/s)	Vs (ft/s)	Bulk Modulus ($x10^6$ psi)	Young's Modulus ($x10^6$ psi)	Shear Modulus ($x10^6$ psi)	Poisson's Ratio	Porosity (%)	Unconfined Strength (psi)	Interpolated from Young's Modulus (psi)
1	1384	1.58	6320	3911	0.42	0.78	0.33	0.19	41.9	845	
2	1355	1.52	6673	4023	0.47	0.81	0.33	0.21	43.8	795	
3	1304	1.71	6680	4272	0.47	0.97	0.42	0.15	37.4	1028	
4	1165	1.59	7932	4567	0.75	1.12	0.45	0.25	42.1	409	
5	1143	1.58	4977	2508	0.35	0.36	0.13	0.33	41.8		530
6	1117	1.58	5077	2463	0.38	0.35	0.13	0.35	41.8		530
7	1093	1.55	4642	2269	0.31	0.29	0.11	0.34	42.7		500
8	1044	2.37	16937	9240	5.53	7.03	2.73	0.29	12.6	3873	
9	1008	2.36	16454	9002	5.18	6.63	2.58	0.29	13.7	2745	
10	981	1.89	5038	2673	0.40	0.47	0.18	0.30	31.7		580
11	1306	1.61	6789	4122	0.51	0.89	0.37	0.21	40.6	800	

Table 2. Bottom hole pressure variation with different flow rates using measured formation permeability of 700 mD.

Drainage radius = 1 mile, Formation permeability = 700 mD						
Reservoir pressure, P_e (psi)	621	621	621	621	621	621
Flow rate, q (gpm)	3500	3056	3000	2500	2000	1500
Viscosity, μ (cp)	1	1	1	1	1	1
Permeability, k (mD)	700	700	700	700	700	700
Reservoir thickness, h (ft)	400	400	400	400	400	400
Drainage radius, r_e (ft)	5280	5280	5280	5280	5280	5280
Well radius, r_w (ft)	1	1	1	1	1	1
Bottom hole pressure, P_{wf} (psi)*	**102**	**168**	**176**	**251**	**325**	**399**
Min pump outlet pressure (psi)*	**533**	**599**	**607**	**682**	**756**	**830**
Drainage radius = 2 mile, Formation permeability = 700 mD						
Reservoir pressure, P_e (psi)	621	621	621	621	621	621
Flow rate, q (gpm)	3500	3000	2828	2500	2000	1500
Viscosity, μ (cp)	1	1	1	1	1	1
Permeability, k (mD)	700	700	700	700	700	708
Reservoir thickness, h (ft)	400	400	400	400	400	700
Drainage radius, r_e (ft)	10560	10560	10560	10560	10560	10560
Well radius, r_w (ft)	1	1	1	1	1	1
Bottom hole pressure, P_{wf} (psi)*	**60**	**140**	**168**	**221**	**301**	**485**
Min pump outlet pressure (psi)*	**491**	**571**	**599**	**652**	**732**	**916**

Table 3. Bottom hole pressure variation with different flow rates using measured formation permeability of 300 mD. Negative pressure indicates that the pump cannot handle the given flow rate.

Drainage radius = 1 mile, Formation permeability = 300 mD						
Reservoir pressure, P_e (psi)	621	621	621	621	621	621
Flow rate, q (gpm)	3500	3056	3000	2500	2000	1500
Viscosity, μ (cp)	1	1	1	1	1	1
Permeability, k (mD)	300	300	300	300	300	300
Reservoir thickness, h (ft)	400	400	400	400	400	400
Drainage radius, r_e (ft)	5280	5280	5280	5280	5280	5280
Well radius, r_w (ft)	1	1	1	1	1	1
Bottom hole pressure, P_{wf} (psi)*	**-589**	**-436**	**-416**	**-243**	**-71**	**102**
Min pump outlet pressure (psi)*	**-158**	**-5**	**15**	**188**	**360**	**533**
Drainage radius = 2 mile, Formation permeability = 300 mD						
Reservoir pressure, P_e (psi)	621	621	621	621	621	621
Flow rate, q (gpm)	3500	3000	2828	2500	2000	1500
Viscosity, μ (cp)	1	1	1	1	1	1
Permeability, k (mD)	300	300	300	300	300	300
Reservoir thickness, h (ft)	400	400	400	400	400	400
Drainage radius, r_e (ft)	10560	10560	10560	10560	10560	10560
Well radius, r_w (ft)	1	1	1	1	1	1
Bottom hole pressure, P_{wf} (psi)*	**-687**	**-500**	**-436**	**-313**	**-126**	**60**
Min pump outlet pressure (psi)*	**-256**	**-69**	**-5**	**118**	**305**	**491**

Table 4. Bottom hole pressure variation with different flow rates using measured formation permeability of 500 mD. Negative pressure indicates that the pump cannot handle the given flow rate.

Drainage radius = 1 mile, Formation permeability = 500 mD						
Reservoir pressure, P_e (psi)	621	621	621	621	621	621
Flow rate, q (gpm)	3500	3056	3000	2500	2000	1500
Viscosity, μ (cp)	1	1	1	1	1	1
Permeability, k (mD)	500	500	500	500	500	500
Reservoir thickness, h (ft)	400	400	400	400	400	400
Drainage radius, r_e (ft)	5280	5280	5280	5280	5280	5280
Well radius, r_w (ft)	1	1	1	1	1	1
Bottom hole pressure, P_{wf} (psi)*	**-105**	**-13**	**-1**	**102**	**206**	**310**
Min pump outlet pressure (psi)*	**326**	**418**	**430**	**533**	**637**	**741**
Drainage radius = 2 mile, Formation permeability = 500 mD						
Reservoir pressure, P_e (psi)	621	621	621	621	621	621
Flow rate, q (gpm)	3500	3000	2828	2500	2000	1500
Viscosity, μ (cp)	1	1	1	1	1	1
Permeability, k (mD)	500	500	500	500	500	500
Reservoir thickness, h (ft)	400	400	400	400	400	400
Drainage radius, r_e (ft)	10560	10560	10560	10560	10560	10560
Well radius, r_w (ft)	1	1	1	1	1	1
Bottom hole pressure, P_{wf} (psi)*	**-164**	**-52**	**-13**	**60**	**173**	**285**
Min pump outlet pressure (psi)*	**267**	**379**	**418**	**491**	**604**	**716**

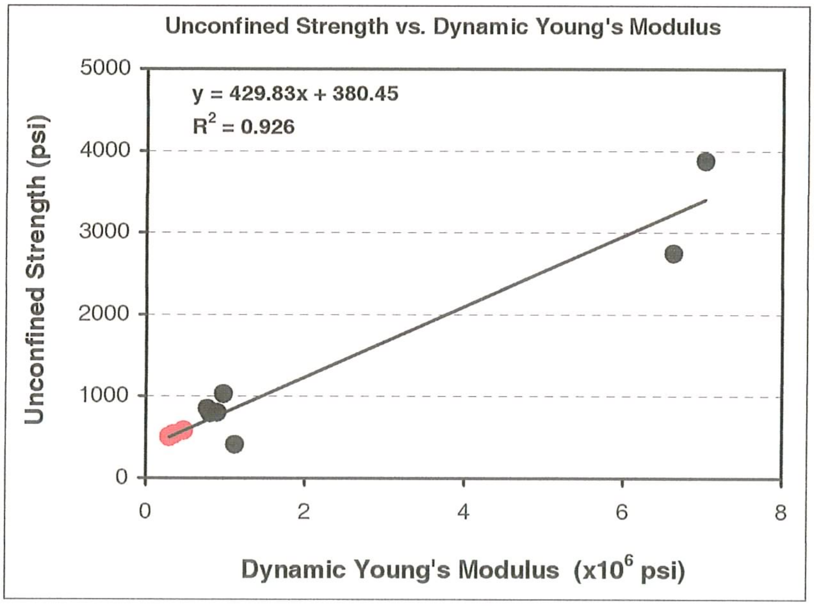
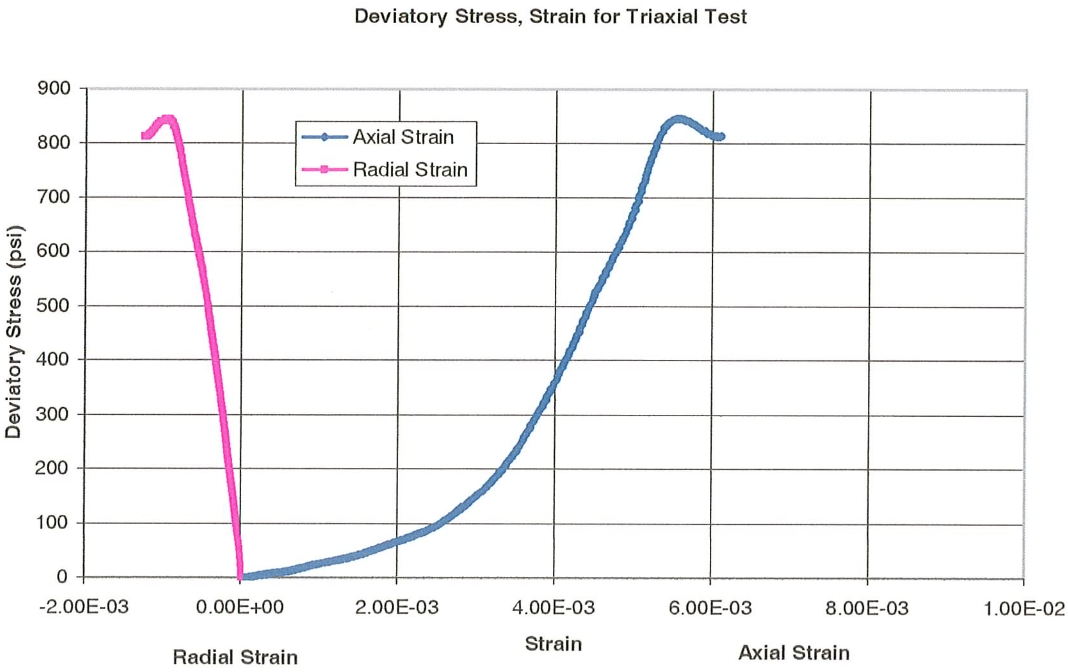
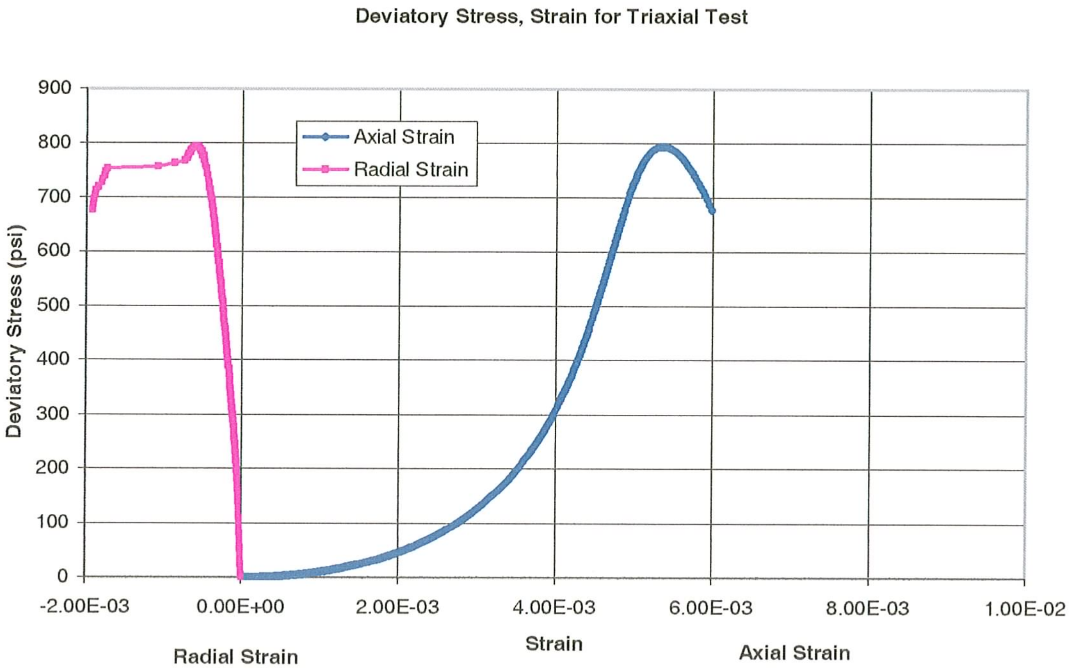


Figure 1. Unconfined compressive strength plotted against dynamic Young's modulus for samples from Eastern Hillsboro FAMW-1 well. Interpolated unconfined strength are shown in red.



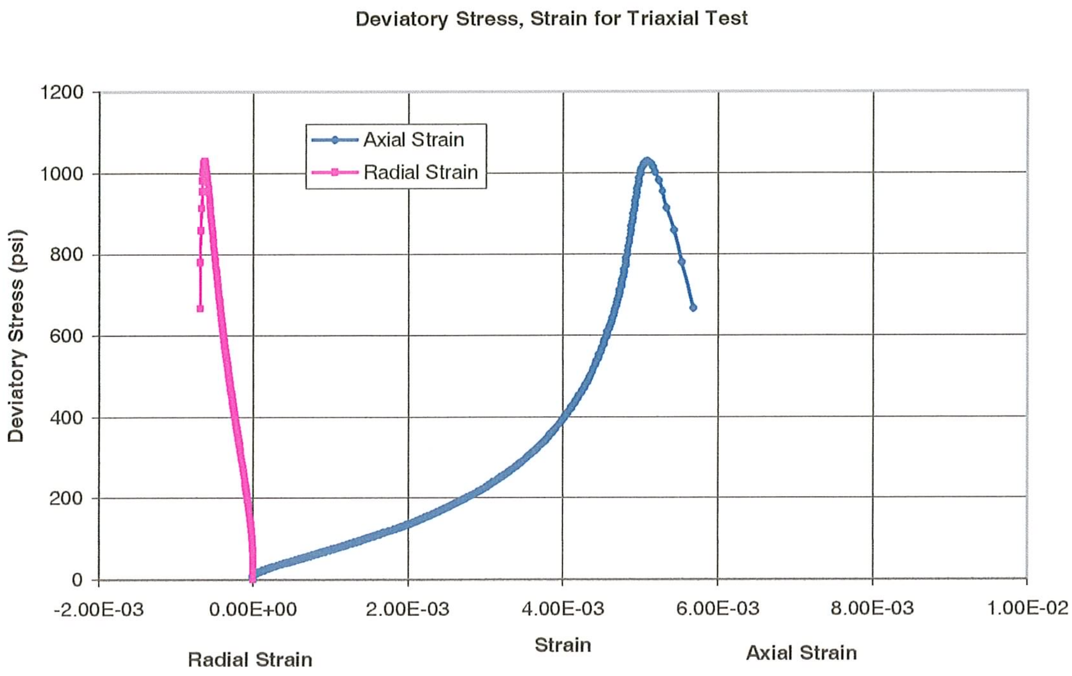
Test Type	**Unconfined Compressive Strength**
Company	**Integrity Well and Pump**
Well	**Eastern Hillsboro FAMW-1**
Sample	1
Core/Depth (ft)	1384-1385
Diameter (in)	3.8940
Length (in)	6.8255
Mass (g)	2016.9
Saturation Fluid	dry
Sample Density (g/cc)	1.51
Effective Confining Pressure (psi)	0
Pore Pressure (psi)	0
Static Young's Modulus (X10^6 psi)	0.310
Static Poisson's Ratio	0.377
Unconfined Compressive Strength (psi)	845

Figure 2. Stress-strain curves for sample #1 from Eastern Hillsboro FAMW-1 well.



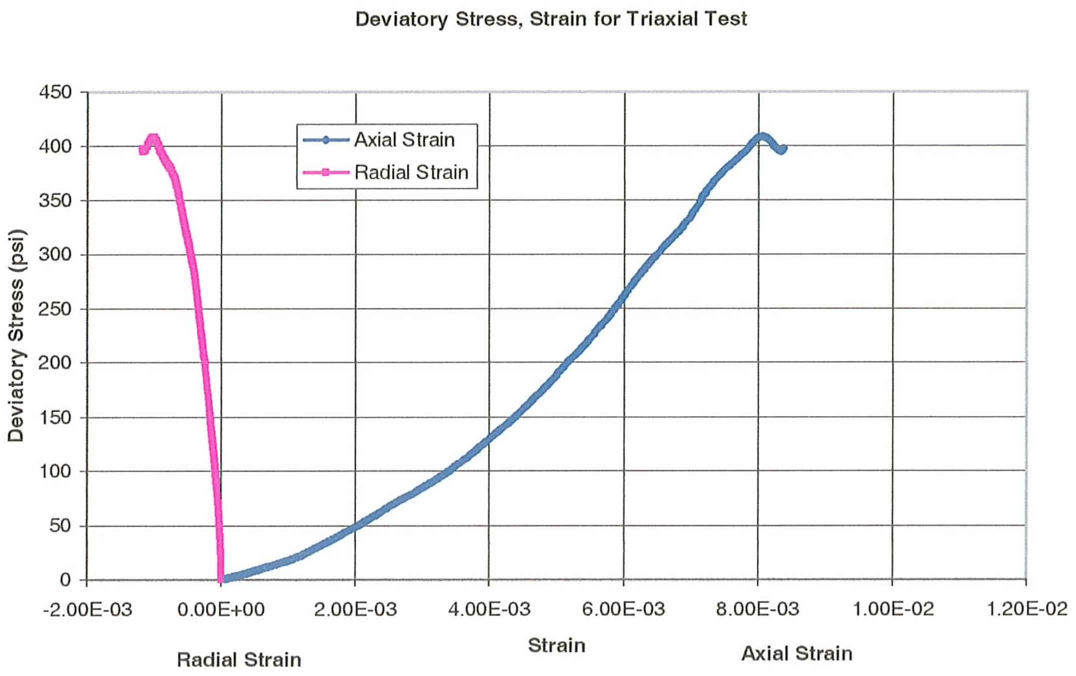
Test Type	**Unconfined Compressive Strength**
Company	**Integrity Well and Pump**
Well	**Eastern Hillsboro FAMW-1**
Sample	2
Core/Depth (ft)	1355-1355.75
Diameter (in)	3.8635
Length (in)	7.1933
Mass (g)	2096
Saturation Fluid	dry
Sample Density (g/cc)	1.52
Effective Confining Pressure (psi)	0
Pore Pressure (psi)	0
Static Young's Modulus (X10^6 psi)	0.455
Static Poisson's Ratio	0.304
Unconfined Compressive Strength (psi)	795

Figure 3. Stress-strain curves for sample #2 from Eastern Hillsboro FAMW-1 well.



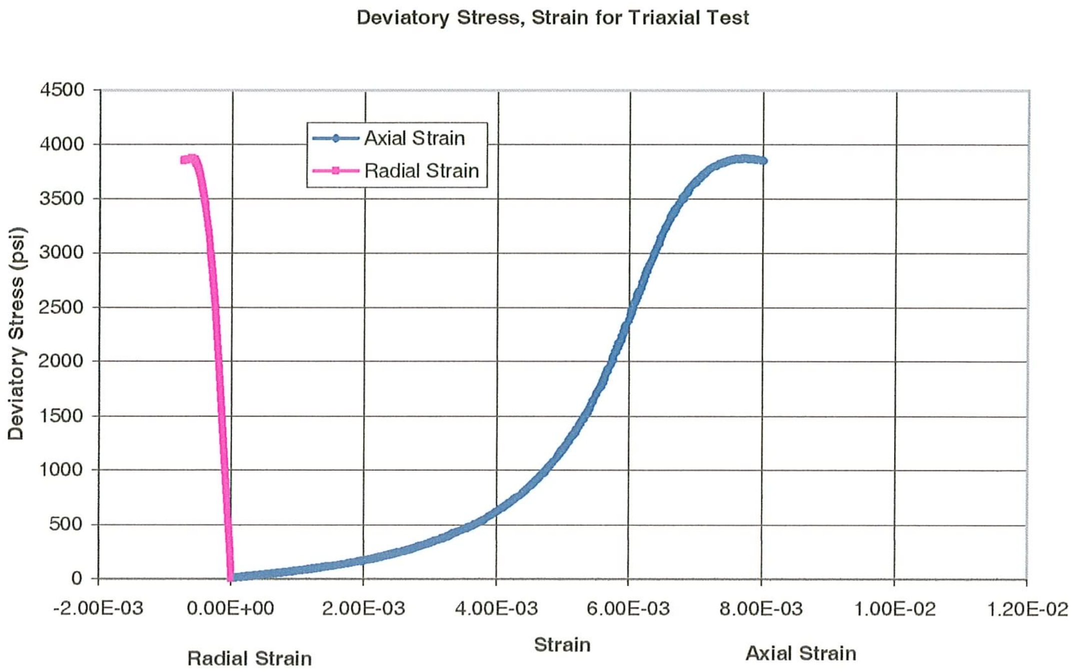
Test Type	**Unconfined Compressive Strength**
Company	**Integrity Well and Pump**
Well	**Eastern Hillsboro FAMW-1**
Sample	3
Core/Depth (ft)	1304.25-1305
Diameter (in)	3.9003
Length (in)	7.1305
Mass (g)	2308
Saturation Fluid	dry
Sample Density (g/cc)	1.65
Effective Confining Pressure (psi)	0
Pore Pressure (psi)	0
Static Young's Modulus (X10^6 psi)	0.436
Static Poisson's Ratio	0.305
Unconfined Compressive Strength (psi)	1028

Figure 4. Stress-strain curves for sample #3 from Eastern Hillsboro FAMW-1 well.



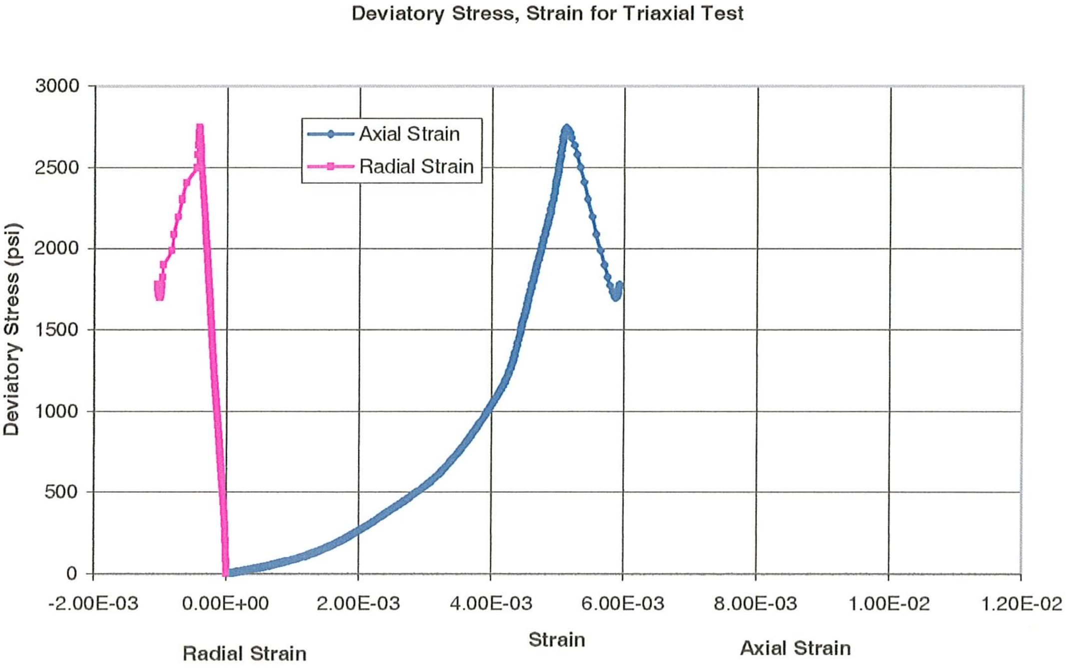
Test Type	**Unconfined Compressive Strength**
Company	**Integrity Well and Pump**
Well	**Eastern Hillsboro FAMW-1**
Sample	4
Core/Depth (ft)	1156.5-1166.2
Diameter (in)	3.7286
Length (in)	3.2510
Mass (g)	897.8
Saturation Fluid	dry
Sample Density (g/cc)	1.54
Effective Confining Pressure (psi)	0
Pore Pressure (psi)	0
Static Young's Modulus (X10^6 psi)	0.072
Static Poisson's Ratio	0.168
Unconfined Compressive Strength (psi)	409

Figure 5. Stress-strain curves for sample #4 from Eastern Hillsboro FAMW-1 well.



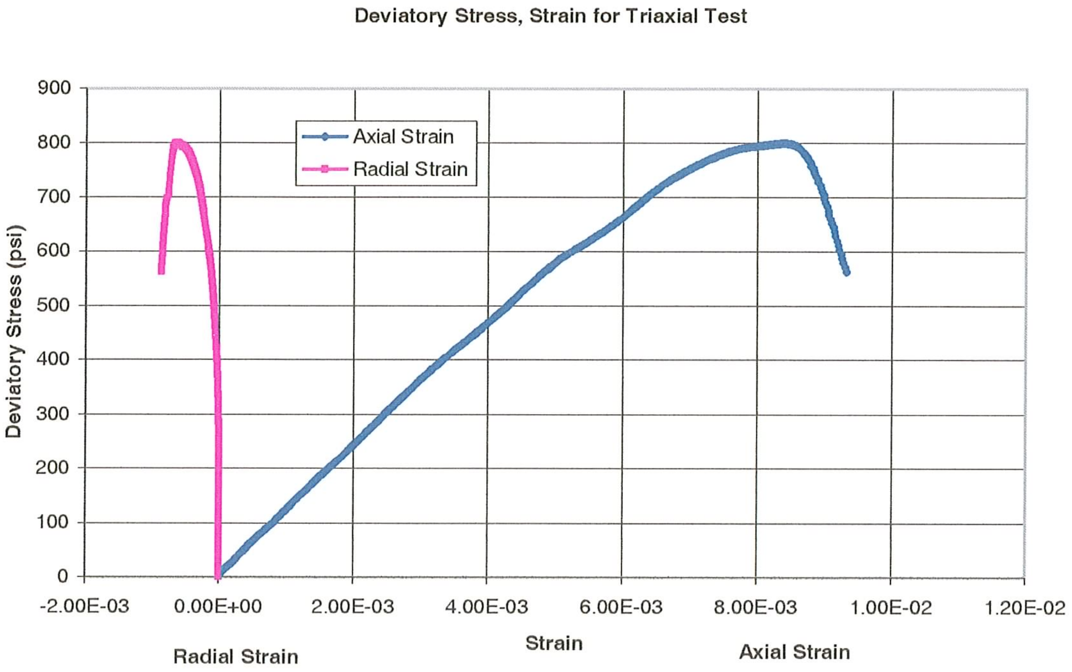
Test Type	**Unconfined Compressive Strength**
Company	**Integrity Well and Pump**
Well	**Eastern Hillsboro FAMW-1**
Sample	8
Core/Depth (ft)	1044-1045
Diameter (in)	1.5003
Length (in)	2.8130
Mass (g)	193.64
Saturation Fluid	dry
Sample Density (g/cc)	2.38
Effective Confining Pressure (psi)	0
Pore Pressure (psi)	0
Static Young's Modulus (X10^6 psi)	1.217
Static Poisson's Ratio	0.242
Unconfined Compressive Strength (psi)	3873

Figure 6. Stress-strain curves for sample #8 from Eastern Hillsboro FAMW-1 well.



Test Type	**Unconfined Compressive Strength**
Company	**Integrity Well and Pump**
Well	**Eastern Hillsboro FAMW-1**
Sample	9
Core/Depth (ft)	1008-1008.5
Diameter (in)	1.4999
Length (in)	3.0785
Mass (g)	205.65
Saturation Fluid	dry
Sample Density (g/cc)	2.31
Effective Confining Pressure (psi)	0
Pore Pressure (psi)	0
Static Young's Modulus (X10^6 psi)	1.773
Static Poisson's Ratio	0.254
Unconfined Compressive Strength (psi)	2745

Figure 7. Stress-strain curves for sample #9 from Eastern Hillsboro FAMW-1 well.



Test Type	**Unconfined Compressive Strength**
Company	**Integrity Well and Pump**
Well	**Eastern Hillsboro FAMW-1**
Sample	11
Core/Depth (ft)	1306-1307
Diameter (in)	1.4893
Length (in)	2.9945
Mass (g)	136.61
Saturation Fluid	dry
Sample Density (g/cc)	1.60
Effective Confining Pressure (psi)	0
Pore Pressure (psi)	0
Static Young's Modulus (X10^6 psi)	0.110
Static Poisson's Ratio	0.113
Unconfined Compressive Strength (psi)	800

Figure 8. Stress-strain curves for sample #11 from Eastern Hillsboro FAMW-1 well.

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