

THE HYDROFRACTURING WAS A SUCCESS

by Todd Giddings, Ph.D., P.G.

PGWA Treasurer and Education Committee Chairman

At the 2006 PGWA Summer Field Conference on June 9th the existing, low-yield PGWA 1 well at the Well Demonstration Site was hydrofractured to increase its yield. Hydrofracturing is a yield development technique that originated in the oil and gas industry. The water well hydrofracturing process involves injecting water under high pressure at rates of up to 180 gallons per minute into the bedrock formation surrounding the well bore below the casing. An inflatable packer is placed below the end of the casing and water is pumped through the packer under high pressure. The bedrock is not actually fractured by the water pressure, instead sediment is forced out of existing joints and fractures in the bedrock surrounding the well bore increasing their water-carrying capacity. See related article: What is hydrofracturing.

To determine the effectiveness of the hydrofracturing on the low-yield PGWA 1 well, I conducted before-and after-hydrofracturing pumping tests to determine the change in the specific capacity of the well caused by the hydrofracturing. After pumping the well at a fixed rate until the water level in the well stops declining and is stabilized, the specific capacity of the well is calculated by dividing the pumping rate in gallons per minute (gpm) by the drawdown (difference between the non-pumping (static) water level and the stabilized, pumping water level) in feet. It is important that the pumping water level is stabilized and is no longer declining in order to calculate a valid specific capacity value.

High-rate, short-term pumping tests will significantly overstate the sustained yield of a well because of the water that is pumped from borehole storage and obtained from aquifer dewatering. For example, a 400 foot deep, 8-inch diameter well with a static water level of 50 feet can be pumped at a rate of 30 gallons per minute for a half-hour when its sustained yield is only 1 gpm. The water produced by the short-term pumping test came from borehole storage and the 30 gpm pumping rate does not indicate the sustained yield of the well.

The 6-inch diameter, low-yield PGWA 1 well is 397 feet deep with 140 feet of casing, and was drilled by air-rotary into the Nittany Formation. This bedrock formation is comprised of coarsely-crystalline dolomite bedrock with sandy and cherty zones and a total thickness of 1,250 feet. Fractures, broken zones, and small solution openings were encountered in this well, but its blown yield using the air from the drill rig was approximately 10 gpm.

Dolomite is somewhat less soluble than limestone because it is composed of both Magnesium and Calcium carbonates in variable proportions. Magnesium carbonate is less soluble than Calcium carbonate that makes up a pure limestone. Nonetheless, in other hydrogeologic settings elsewhere in Pennsylvania, there are wells in the Nittany Formation that yield more than 500 gpm.

The hydrofracturing of the PGWA 1 well was done by Northeast Water Production, Inc. of Sterling, Massachusetts using a Kyle Equipment Co., Inc. hydrofracturing unit. The first of two hydrofracturing applications had the inflatable packer set at 160 feet below ground level or 20 feet below the bottom of the casing. The maximum pressure reached was 400 pounds per square inch (psi) and the water was pumped at a rate of 180 gpm for 10 minutes, until the pressure declined to 150 psi. The inflatable packer was then lowered and set at 300 feet below ground level. The maximum pressure reached was 450 psi and again water was pumped at a rate of 180 gpm for 10 minutes, when the pressure declined to 350 psi.

The first hydrofracturing treatment applied the water pressure to 230 feet of well bore, and then to only 40 feet of well bore below the second packer setting. The water pressure forcefully dislodged silt, clay, and sand that filled the fractures, bedding planes, and solution openings in the dolomite bedrock. The silt and

clay material in these openings in the bedrock are the natural product of the chemical weathering (dissolution) of the carbonate (soluble) bedrock. Because silt, clay, and sand filled most of the openings around this well bore, ground water was unable to enter the well bore easily, and this well had a low yield.

A very important part of the hydrofracturing well yield development process was the sustained high flow rate of water at 180 gpm for 10 minutes, because this sustained water flow eroded the silt, clay, and sand material from the walls of the potentially water-conducting openings. High water pressure alone is not enough to complete an effective hydrofracturing yield development process. This is why Northeast Water Production, Inc. also brought a 3,600 gallon water tank truck to the site to provide the 180 gpm flow rate for 10 minutes during each of the two hydrofracturing applications in this well.

The before-hydrofracturing pumping test ran for 4.75 hours at a pumping rate of 10.4 gpm with 116.7 feet of drawdown for a specific capacity of 0.09 gpm/ft. The after-hydrofracturing pumping test ran for 6 hours at a rate of 35.3 gpm with 94.4 feet of drawdown for a specific capacity of 0.37 gpm/ft. The increase in the specific capacity of this well was 400% or 4 times the before-hydrofracturing specific capacity value!

Comparison of Pumping Test Results	Pumping Rate in gpm	Drawdown in feet	Duration in hours	Specific Capacity in gpm/foot
Before Hydrofracturing	10.4	116.7	4.75	0.09
After Hydrofracturing	35.3	94.4	6.0	0.37

I continued the after-hydrofracturing pumping test for 6 hours because the well was producing a significant amount of sand and sand-sized particles of silt and clay that were eroded off the walls of the openings in the bedrock by the water flowing under pressure during the hydrofracturing. The significance of the removal of this granular material from the water-producing openings was evidenced by a 5.6 foot rise in the maximum drawdown level during the pumping test. This rise in the pumping water level was caused by the development of the well yield during the pumping test by the removal of granular material. After only 8 minutes of pumping, the clear water discharge turned very muddy when the borehole storage water was removed and water started flowing through the water-bearing fractures into the well bore.

There are useful lessons learned from this hydrofracturing demonstration on the PGWA 1 well:

- Water pressure forced silt and clay material out of the potentially water-producing fractures, bedding planes, and solution openings encountered by the well bore, opening them to convey aquifer water into the well bore.
- The high, 180-gpm flow rate for 10 minutes was a very important part of the hydrofracturing process that increased the specific capacity of this well 400%. The high flow rate of water eroded the silt, clay, and sand from the walls of the bedrock openings and this further increased the specific capacity of this well.
- The removal of eroded and loose silt, clay, and sand material during the 6-hour pumping test further increased the specific capacity of this well as evidenced by the 5.6 foot rise in the pumping water level during the 6-hours of the pumping test.
- The theoretical yield of this well following the after-hydrofracturing pumping test was 102 gpm.
- This well's yield would be increased further by additional development by air-lift pumping.

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