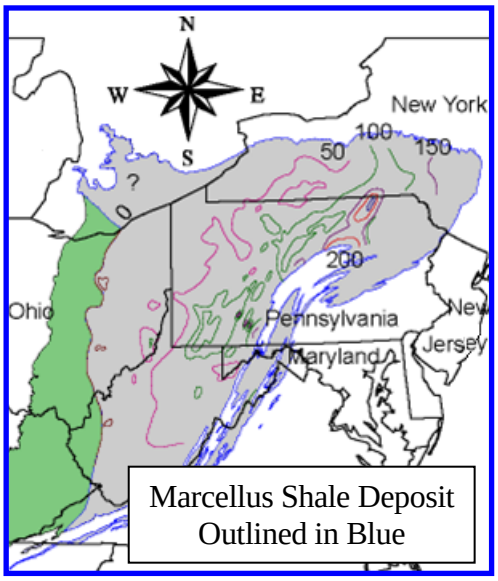
Treatment of Abandoned Mine Drainage for Use as Marcellus Gas Well Hydrofracture Makeup Water

TAB 1009



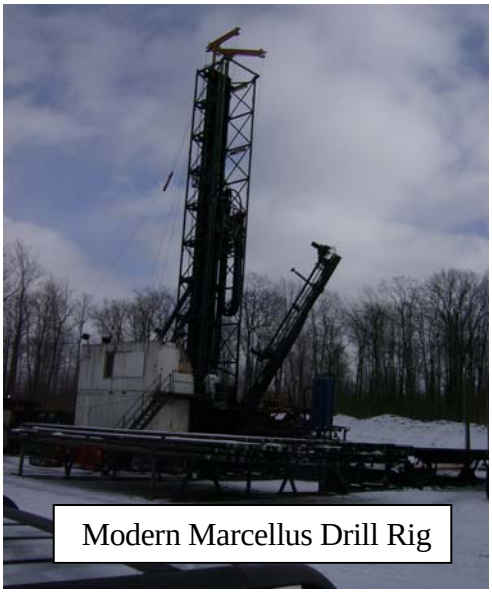
Marcellus Shale Deposit Outlined in Blue

Background: The huge Marcellus black shale deposit, which underlies most of northern Appalachia, is estimated to contain 168+ trillion cubic feet of natural gas. Due to the depth and compact nature of this formation, horizontal drilling with follow-up hydrofracture of the formation using a mixture of high pressure water and sand is required to obtain economic gas production.

From 2 to 5 million gallons of hydrofracture water, mixed with various additives, is required to completion fracture each horizontal deep well. Once used, this now contaminated water must be removed from the well, generally 10 to 20% is recovered, and is commonly referred to as "flowback" water. Typically, flowback water contains high dissolved solids with varying levels of various other constituents such as barium and strontium.

Due to the substantial water loss during the hydrofracture process, large amounts of new makeup water are required for developing each new gas well. Obtaining the fresh water needed to makeup hydrofracture water presents a significant problem for gas production firms as in many areas the amount of suitable water needed for formulation of hydrofracture water is often not available at the desired time due to stream flow limitations and regulatory restrictions.

One obvious solution to this water supply problem is to chemically treat abandoned mine drainage (AMD), which is common in many areas under laid by the Marcellus shale, to a quality suitable for use as hydrofracture makeup water. For hydrofracture makeup water use, the AMD water must be treated to remove anything that would cause plugging of the shale factures; constituents such as suspended solids, aluminum, barium, calcium, iron, magnesium, manganese, and strontium must be removed to a maximum total hardness of 2,500 mg/l[1] measured as $CaCO_3$.


Modern Marcellus Drill Rig

Both regulatory agencies involved, the PADEP and the SRBC, have indicated that treatment of AMD for use as hydrofracture makeup water would be favored over other means of obtaining the water supplies needed for continued development of the Marcellus gas shale.

Hydrofracture Makeup Water Supply: With the substantial amount of makeup water needed, from 80 to 90% for wells using recycled flowback to 100% for no recycle, supply of makeup water has been a limiting factor for many well drillers. In many areas of the state where the Marcellus shale is present, AMD from past coal mining activities is present in large amounts and is a major water quality problem. In February, 2009, approximately 3 million gallons of treated acid mine drainage water was obtained from the Blue Valley Fish Culture Station (BVFCS) for what is believed to be the first use of such water in a Marcellus completion hydrofracture.

Samples of the untreated and treated acid mine drainage were obtained during the course of the supply and analyzed with the following results obtained:

Parameter	untreated	treated
barium mg/l	<0.2	<0.2
calcium mg/l	196	198
iron mg/l	13.0	0.32
magnesium mg/l	56.0	55.5
manganese mg/l	2.6	3.54
strontium mg/l	3.6	3.6
total hardness mg/l as $CaCO_3$	752.7	734.5
total dissolved solids mg/l	1,004	1,076

Frac Water Tankers Loading At BVFC Lagoon

The BVFCS effluent, however, is not typical of treated acid mine drainage as it utilizes a unique chemical process with advanced design inclined plate clarifiers for removal of iron prior to use as makeup to the fish culture tanks and subsequent discharge into an on site lagoon. Since no calcium hydroxide is used in the process, and the acid and iron levels are low in the mine discharge, the treated water is usually lower in hardness than typical treated acid mine drainage.

With the high levels of iron often found in acid mine drainage, a maximum limit was needed for process design use. Information was found to the effect that a maximum level of 20 mg/l[2] iron could be tolerated in hydrofracture water. This same document also noted that calcium levels over 350 mg/l require increased levels of completion chemicals to be used.

To confirm that any acid mine drainage could be utilized, with specific treatment, as makeup water for Marcellus hydrofracture jobs, a "typical" sample of acid mine drainage was obtained from the extensively studied discharge at Hawk Run, PA. This sample was treated in our laboratory with the following results obtained:

Parameter	untreated	treated
aluminum mg/l	3.4	<0.1
barium mg/l	<0.1	<0.1
calcium mg/l	154	16
iron mg/l	58.5	<0.03
magnesium mg/l	65.5	42.0
manganese mg/l	5.45	<0.04
strontium mg/l	0.12	<0.02
total hardness mg/l as $CaCO_3$	788.6	212.9
total dissolved solids mg/l	1,004	1,520

This "typical" acid mine drainage, when treated using our non-calcium process, produced a very acceptable Marcellus hydrofracture makeup water.

Economics: The chemical operating cost to treat the Hawk Run acid mine drainage has been calculated at $2.50/1000 gallons. Sludge disposal costs have not been accounted for at this time. An AMD system rated at 720,000 gpd has an estimated equipment/building cost of $1,000,000 and could be operated by a two man crew.

Technology Leader: ProChemTech has designed and built many wastewater recycle and reuse systems in the past twenty+ years for many different industries utilizing various treatment chemistries and our unique inclined plate clarifiers. This well developed technology permits economical treatment of AMD waters for use as hydrofracture makeup water. Our inclined plate clarifier based process systems can be manufactured as either mobile trailer mounted systems, or as stationary units, in flow ratings from 10 to over 1000 gpm.

Clarifier at BVFCS

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[1] Personal communication, L. Case, Halliburton to T. Keister, PCT 02/09

[2] Proceedings and Minutes of the Hydraulic Fracturing Expert Panel, XTO Facilities, Fort Worth, TX, 09/26/07