

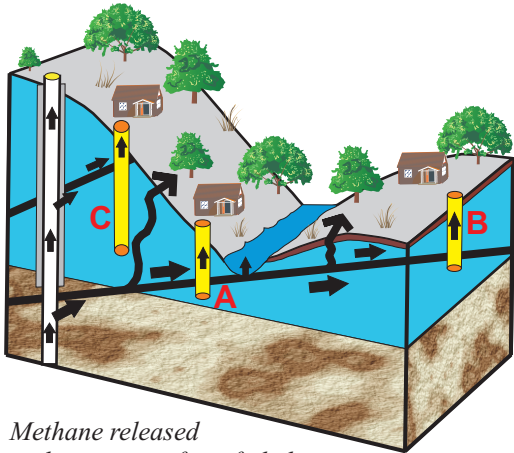


What the experts have to say about ...

NATURAL GAS DRILLING & AQUIFER PROTECTION



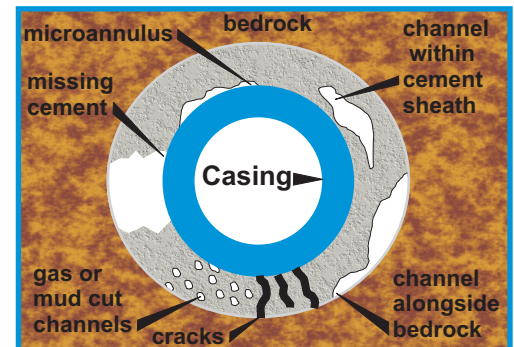
- ◆ Groundwater quality throughout the Delaware River Basin is at high risk of being degraded by natural gas (methane, ethane, ethene, propane, butane), uranium, radium, radon, chromium, lead, arsenic, barium, benzene, bromide, sodium chloride, H₂S, 2-butoxyethanol (2-BE) and other pollutants.
- ◆ The sealant materials (cement and steel) being used to line boreholes to isolate and protect aquifer waters have a short design life. In places, these materials are already failing.



Methane released under pressure from failed cement sheaths and casings follows fractures to home-owner wells, water bodies, and the land surface.

Life of Aquifers ♦ Through geologic time, layers of sediments were deposited and compacted into bedrock. The land was subsequently uplifted and then eroded for over 1,000,000 years by the Delaware River and its many tributaries. In response, fresh groundwater flow now moves slowly from upland areas towards valleys. These freshwater aquifers are physically isolated and far above deep, saline, waters and gas-rich bedrock formations. Wells tap the pure freshwater aquifers we drink from. Gas wells pose a real threat to well water quality because they provide unnatural pathways for contaminants to rise under pressure from deep within the earth and to mix with potable water. If saline and freshwater zones remain disconnected, our aquifers will continue to provide pristine water to our children and their grandchildren for another 1,000,000 plus years. If the two become connected, the results would be devastating for future generations - robbing them of needed groundwater.

Life of a Well ♦ The gas industry considers the life of a well in terms of its productive life, which typically ranges between 4 and 20 years. This is the time period when isolation of gas-rich formations from the overlying freshwater aquifers matters most to them. Loss of zonal isolation equates directly to loss of profits because the gas is not captured. When a gas well is no longer profitable, it is plugged and abandoned. Plugging involves removal of an inner steel casing placed during well construction and then cementing of the open borehole to seal off gas bearing and saline geologic horizons from the overlying freshwater aquifer. To provide long-term protection, the cement sheath, casing, and inner cement plug must remain fully intact for the life of the aquifer (999,980+ years).



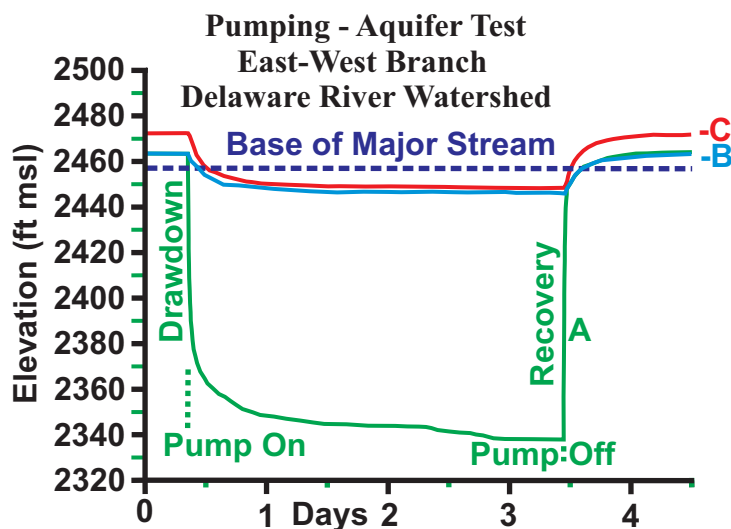
Types of cement channels in annular spaces that may permit upward methane migration. Modified from Newhall (2006).



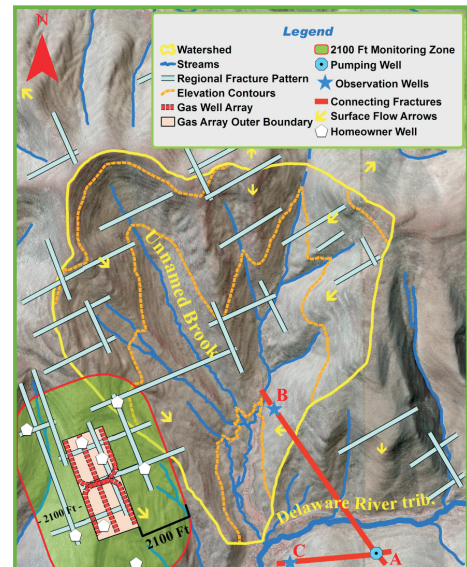
Corroded and pitted casing (Shutterstock). Steel and cement subjected to harsh, corrosive, downhole conditions can degrade in a matter of years, thereby resulting in an explosive, contaminant, and health risk to nearby landowners.

Life of Cement & Life of Steel ♦ Long-term protection of freshwater aquifers from deep, contaminant-laden, bedrock formations breached by gas wells relies completely on the durability of the materials used to physically isolate them. Water quality protection must be viewed relative to the life of aquifers. Therefore, sealant materials must also have a design life equal to the useful life of aquifers. Extensive research conducted by the gas industry and others reveals that cement failure will occur in less than 100 years due to numerous factors that include shrinkage, debonding, and the development of channels that allow gas and fluid migration. Debonding occurs at the casing/bedrock and cement/casing interfaces. A micro-annulus of 0.001 inches is sufficient to allow gas flow. Similarly, research shows that steel casing also has a design life of less than 80 years - in some cases far less due to exposure to saline water and acid gases (i.e., < 4 years). ***Thereafter, material failure and groundwater degradation are assured.***

Setback Distances From Water Bodies & Homeowner Wells ♦ Analysis of hydrologic data reveals that gas well array (i.e., multiple horizontal boreholes stemming from a single well pad) setback distances of less than 2,100 feet from water bodies (e.g., reservoirs, lakes, rivers, streams, wetlands) and homeowner wells may pose a significant water quality risk. DRBC draft gas drilling regulations propose a setback distance of 500 feet between vertical boreholes and water bodies. This distance appears to lack the empirical data needed to document that it will protect water resources. One key hydrogeologic factor involved is whether cement sheath failure coincident with hydrofracking events and well decommissioning will result in rapid transmission of 1) pressurized methane, Light Non-Aqueous Phase Liquids (LNAPLs), and other pollutants to homeowner wells and water bodies, and 2) free and dissolved gas flow through leaking well annuli and fractures during gas production. Pumping tests and analyses of known contaminant incidents provide a means of assessing this. Pumping tests that stress groundwater within fractured bedrock aquifers provide a rigorous means of assessing fracture interconnectivity. The hydrograph of a pumping test (below) conducted in the Delaware River Basin documented the effects of turning a pumping well on and off in less than five minutes in observation wells up to 2,100 feet away. Because this documents long-distance hydraulic connections, it is likely that contaminants driven by high pressures during hydraulic fracturing events and after well decommissioning will adversely impact wells. There is also evidence that methane is released from fractures and wellbores at far greater distances. In addition, some fractures naturally release methane. Because hydraulic fracturing within gas well arrays may interconnect these fractures, it would, from a water quality protection standpoint, be prudent to expand the setback distance beyond the well array. **Pumping test data provides solid documentation for mandating minimum setback distance to at least 2,100 feet as measured from the outer boundary of well arrays to all water resources and homeowner wells.**



Hydrograph showing rapid hydraulic response between a pumping well and two observation wells



Schematic showing minimum setback distance from a gas well array and well A, B, C orientation. Homeowner wells should not be within the array.

Fracture Sets Are Connected Over Thousands Of Feet ♦ The above hydrograph documents the hydraulic response of observation wells B and C from pumping well A. The schematic set-up of the orientation of these wells relative to themselves and a major stream is depicted on the figure above. Well B is 2,100 feet NW of Well A and Well C is 1,000 feet to the west. Observation Well B is situated on the opposite side of a valley, beyond a major Delaware River tributary that hydrologists might have considered to be a significant groundwater divide (see also front page figure). This test demonstrates that pressurized methane-rich waters can impact water supplies across major groundwater divides in different watersheds - anywhere along open, permeable, portions of fractures.

Rapid Contamination of Homeowner Wells ♦ Methane excursions from gas wells constructed along the same fracture set as homeowner wells will contaminate drinking water supplies. This will occur when zonal isolation sealant materials fail, in a time frame ranging from days to 100 years.