Lawrence Berkeley National Laboratory: Subsurface Migration Modeling
EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Background
The goal of this work was to investigate the potential for subsurface migration of fluids from the stimulated oil and gas reservoir to an overlying drinking water aquifer. Researchers conducted two types of numerical simulation experiments: (1) exploration of hypothetical scenarios that could result in emergence of fluid pathways; and (2) evaluation of the range of conditions that may allow hydraulic fracturing fluids to migrate upwards and reach drinking water aquifers when fluid pathways are present. Some of the hypothetical scenarios included:

- Upwards migration of fluids using a well as the pathway, such as an improperly constructed well, or when a well is damaged during hydraulic fracturing operations from excessive pressures.
- Upwards migration of fluids using a fractured zone as a pathway, as may be caused by hydraulic fracturing operations that create fractures in the overburden (the rock units above the tight shale-gas reservoir and below the drinking water aquifer) or changes in pressure opening up pre-existing faults.

A series of peer reviewed journal articles about this research are available on the EPA's published papers webpage.

Study Limitations
The modeling techniques used in this work are well known in the field of subsurface modeling and have been peer reviewed. The new models developed in this study have not been tested and applied to site specific field data because such data were not available. The scope of investigations covered stimulation in tight shale-gas systems; the investigations did not cover hydraulic fracturing in tight sandstones or coal-bed methane systems.

Published Papers to Date
"Gas Flow Tightly Coupled to Elastoplastic Geomechanics for Tight and Shale Gas Reservoirs: Material Failure and Enhanced Permeability"
Researchers developed new models to better describe how gas flows in low permeability reservoirs. This work improved simulations of the physics in high stress-sensitive reservoirs through the representation of coupled flow and geomechanics (which involves the geologic study of the behavior of soil and rock). LBNL researchers used the new models to more accurately demonstrate the flow of gas during production in tight and shale gas reservoirs.

"MeshVoro: A three-dimensional Voronoi mesh building tool for the TOUGH family of codes"
Researchers developed a computer tool (MeshVoro) that assists in the setup of computer model representations of complex geology and well design associated with hydraulic fracturing scenarios. Once the foundation of a model is constructed using MeshVoro, investigators can simulate flow and transport using the TOUGH+ simulation system. The paper demonstrated use of the MeshVoro tool for a variety of applications, including simulation modeling of hydraulic fracturing scenarios.

"The RealGas and RealGasH2O options of the TOUGH+ code for the simulation of coupled fluid and heat flow in tight/shale gas systems"

Researchers developed two new computer codes to the TOUGH+ family of codes: RealGas and RealGasH2O allow the study of flow and transport of fluids and heat over a wide range of time frames and spatial codes in tight and shale gas reservoirs.

"Development of the T+M coupled flow-geomechanical simulator to describe fracture propagation and coupled flow-thermal-geomechanical processes in tight/shale gas systems"

Researchers developed and demonstrated a new coupled fluid flow, heat flow and geomechanical computer simulator which can be used to simulate hydraulic fracturing in tight and shale gas systems.

"Numerical analysis of fracture propagation during hydraulic fracturing operations in shale gas systems"

Researchers used the TOUGH+ geomechanics computational software and simulation system to examine the likelihood of hydraulic fracture propagation (the spread of fractures) traveling long distances to connect with drinking water aquifers. The simulations indicate that typical hydraulic fracturing operations do not appear to generate an unstable growth of a fracture in the shale gas reservoir to the drinking water aquifer unless unrealistic high pressure and high injection rates are directly applied to an extremely weak and homogenous geological formation that extends up to the near surface.

"Modeling of fault reactivation and induced seismicity during hydraulic fracturing of shale gas reservoirs"

Researchers used computer models to simulate fault reactivation and induced seismicity during the hydraulic fracturing of shale gas reservoirs. The simulations indicate that hydraulic fracturing may give rise to slightly larger microseismic events when faults are present than without faults present. Modeling suggests that the possibility is remote for induced fractures at great depths (thousands of meters) to activate faults and create flow paths that can reach shallow ground water.

"Modeling of fault activation and seismicity by injection directly into a fault zone associated with hydraulic fracturing of shale-gas reservoirs"

Researchers expanded upon a previous study by injecting directly into a 3D representation of a hypothetical fault zone located in the geologic units between the shale-gas reservoir and the drinking water aquifer. As before, modeling results suggest it is unlikely that activation of a fault by shale-gas hydraulic fracturing at great depth could create a flow path that could reach shallow groundwater. Furthermore, these results suggest that induced seismicity likely would not be felt at land surface.

"Numerical simulation of the environmental impact of hydraulic fracturing of tight/shale gas reservoirs on near-surface ground water: background, base cases, shallow reservoirs, short-term gas and water transport"

Researchers used the TOUGH+ geomechanics computational software and simulation system to examine gas and water transport between a deep tight gas reservoir and a shallow overlying aquifer in the two years following hydraulic fracturing operations, assuming a pre-existing connecting pathway (e.g. a fault in the formation or nearby abandoned well). This study examines separation distances of 200-800 meters between the gas reservoir and the aquifer. The research shows that such incidents of gas escape are likely to be limited in duration and scope and that the potential for brine migration tends to be downward (away from the aquifer).

Overview of the EPA's *Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources*

The EPA released a draft assessment of the potential impacts of oil and gas hydraulic fracturing activities on the quality and quantity of drinking water resources in the United States. The draft assessment is based upon extensive review of literature, results from EPA research projects, and technical input from state; industry; non-governmental organizations; the public; and other stakeholders. As part of this larger EPA effort, Lawrence Berkeley National Laboratory (LBNL) conducted a series of computer simulations to evaluate the well injection phase of the hydraulic fracturing water cycle, the results of which are being released in a series of journal articles.

For more information, please visit: www.epa.gov/hfstudy
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