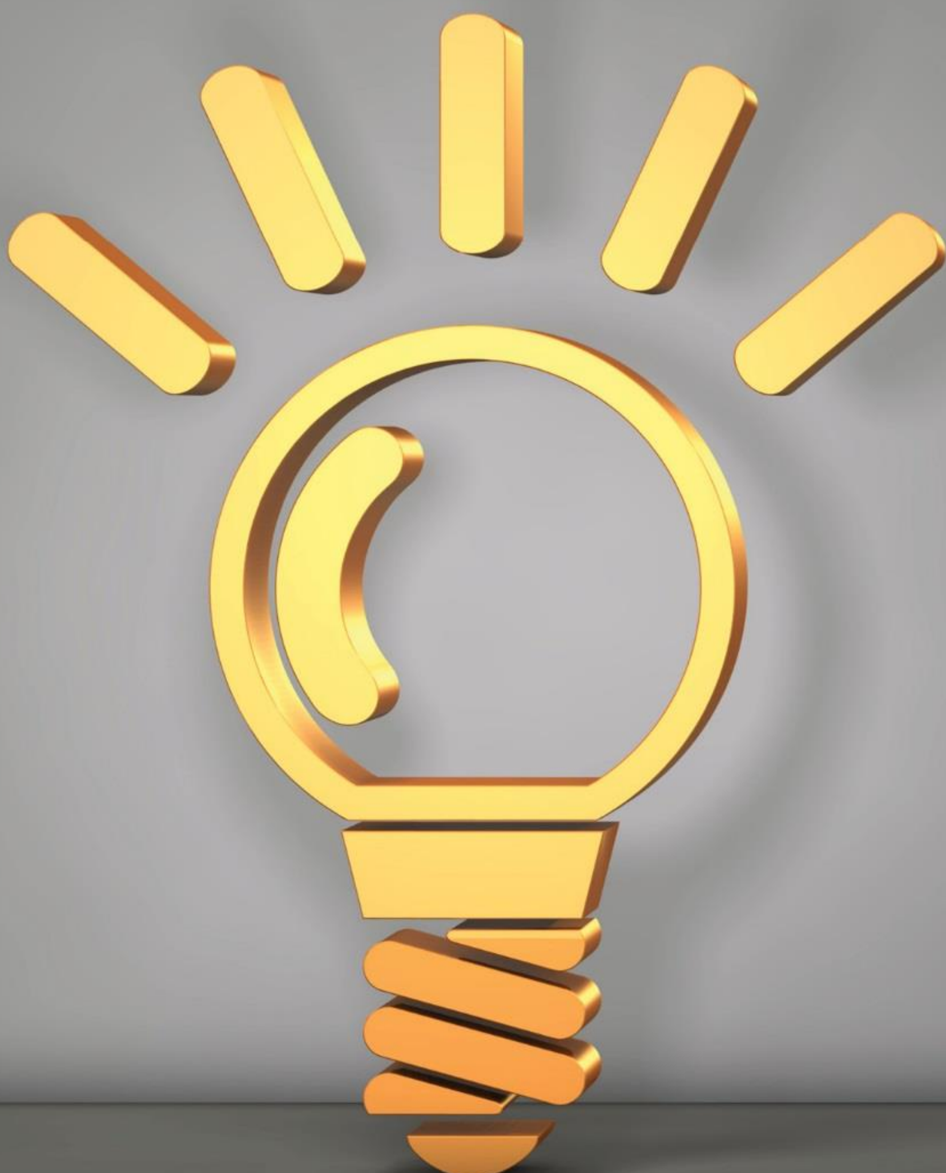
PROBABILISTIC RISK ANALYSIS OF DEEP WELL INJECTION: IMPLICATIONS ON HYDRAULIC FRACTURING FOR SHALE GAS



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Probabilistic Risk Analysis of Deep Well Injection: Implications on Hydraulic Fracturing for Shale Gas

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In 2005, The Hull Risk Analysis Center (HullRAC) published *A Probabilistic Risk Assessment of Class I Hazardous Waste Injection Wells* (Chapter 10, Underground Injection Science and Technology, Tsang and Apps editors, Lawrence Berkeley National Laboratory, Elsevier, 2005). In that study, 20 years of data and accounts of well failures were reviewed, constituting more than 800,000 well-years of data. The risk of injected liquid waste being released to underground sources of drinking water (USDW) was analyzed using:

- Failure modes identification, fault and event tree analysis
- Quantification of probability and uncertainty, and
- Identification of important contributors to risk and uncertainty.

The results of that study can be useful for compare technologies and practices of deep injection of hazardous waste and deep hydraulic fracturing for shale gas, considering the implications of the deep injection risk study findings on potential hydraulic fracturing risks to groundwater, and identifying data and research needs to better understand risks.

There are similarities between the two technologies. Both systems achieve isolation from underground sources of drinking water and the accessible environment through three elements: geologic separation and barriers to upward movement (e.g. deep injection beneath multiple layers of low permeable rock), engineered barriers that prevent release (e.g. surface casing and cement), and human performance (e.g. performance monitoring, alarms, and operator controls).

Extensive research and interviews were done during the 2005 study to identify a comprehensive set of ways that a well might lose its isolation function and have a release to an underground source of drinking water. The results showed a probability of loss of waste isolation of less than 10^{-6} over a 30 year well lifetime, for Class I hazardous waste injection wells meeting current USEPA requirements. The risk was found to be dominated by two failure scenarios:

- The possibility that an undetected transmissive micro-annulus develops in the cemented borehole outside the long string casing and extends from the injection zone up past multiple geologic confining zones into an underground source of drinking water, and
- The possibility of inadvertent future extraction of injected waste.

These findings offer confidence in the ability of hydraulic fracturing wells to not have a release to underground sources of drinking water. However, there are some differences between the two technologies that should be taken into consideration when making risk comparisons, as follows:

Site selection criteria are different:

- Hazardous waste injection sites are subject to strict selection criteria specified by USEPA, based on the ability to prevent releases to the accessible environment “forever” (i.e., a 10,000 year no migration petition). Also, the host formation is selected for capacity to accept the waste volume to be injected.
- Shale gas sites are selected based on ability to produce gas. There are, however, thousands of vertical feet of multiple layers of rock between the shale formations and underground sources of drinking water. The hydraulic fracturing (completion) phase of shale gas well development lasts for months, so the need for isolation “forever” is not a comparable issue.

Hydraulic fracturing does not include a pressurized annulus like that of Class I waste injection:

- Class I hazardous waste injection wells include a fluid-filled pressurized annulus between the injection tubing and long-string casing. This provides two release-prevention functions: an inward pressure barrier if the tubing or packer leaks, and annulus pressure changes to indicate a potential leak in real time.

- Gas wells using hydraulic fracturing have cement-filled annuli. It may not be immediately clear, as it is with a pressurized fluid-filled annulus, if fluid loss is deliberate (into the formation for fracturing) or due to a casing/cement leak.

The time frames are different:

- As stated above, Class I hazardous waste injection wells must isolate waste "forever", and the pressurized injection lasts for over 30 years of operation.
- Hydraulic fracturing at a gas well occurs over a time frame of months, or perhaps several years for multiple wells or re-stimulation. And, one fracture stimulation has a duration of hours. In addition, 50 to 70 percent of the original fracturing fluid volume is recovered within 30 days.

In summary, hazardous waste injection and shale hydraulic fracturing wells both use geology, engineered barriers, and human performance to protect against releases to underground sources of drinking water. A low probability of failure of this combination of geology, engineered barriers, and human performance is needed for a release to the accessible environment. The analysis did not account for volumes and rates of fluid that could realistically be released by feasible release mechanisms. A good risk analysis for either technology, waste injection or hydraulic fracturing, should include consideration of the components depicted below.