U.S. DEPARTMENT OF ENERGY | Legacy Management

Tritium Transport Model Rulison, Colorado, Site

FACT SHEET

This fact sheet provides information about the Tritium Transport Model at the Rulison, Colorado, Site. This site is managed by the U.S. Department of Energy Office of Legacy Management.

Site Description and History

The U.S. Department of Energy (DOE) and its predecessor agencies conducted a program in the 1960s and 1970s that evaluated the use of nuclear detonations to enhance production from low-permeability natural gas reservoirs. Project Rulison was the second of three Plowshare Program tests designed to stimulate the production of natural gas by detonating a nuclear device in a deep, low-permeability geologic formation. On September 10, 1969, the U.S. Atomic Energy Commission, a predecessor agency of DOE, detonated a 43-kiloton nuclear device 8,426 feet below the ground surface in an attempt to release commercially marketable quantities of natural gas from the Williams Fork Formation of the Mesaverde Group.

The natural gas reservoirs of the Williams Fork Formation occur in low-permeability sandstone lenses interbedded with shale. A variety of radionuclides, primarily fission products, were generated as a result of the detonation. Most of the radionuclides are immobilized in a solidified melt glass in the detonation cavity created by the test. The majority of the mobile radionuclides were removed from the subsurface during the Rulison production testing. The most mobile radionuclide remaining in significant quantities after the production testing was tritium, and it is the contaminant of concern for the Rulison modeling. Tritium is a radioactive isotope of hydrogen that is most commonly found as part of the water molecule and as part of the methane (natural gas) molecule at Rulison. The tritiated methane produced by the detonation was removed during the production testing, and the tritium that remains is expected to be present as tritiated water, both in liquid water and in water vapor. Radioactive decay of tritium causes the amount to reduce by half every 12.3 years (the tritium half-life), decaying to nonradioactive helium. An estimated 75 percent of the original tritium was unaccounted for at the end of the testing. Today, more than 39 years later, much of the tritium has decayed away, and about 11 percent of the original amount remains.

What are the current drilling restrictions?

The nuclear detonation cavity is protected by more than 8,000 feet of rock and a recorded deed restriction on subsurface access. The restriction states that "no excavation, drilling, and/or removal of subsurface materials below a depth of 6,000 feet is permitted within Lot 11, NE ¼ SW ¼ of Section 25 Township 7 South, Range 95 West, 6th Principal Meridian, Garfield County, Colorado, without U.S. Government permission."

What is a model?

A model is a tool used to represent a simplified version of reality. For Rulison, scientists have prepared both a conceptual model and a numerical model. The conceptual model describes in words the Rulison site and the processes that could control the movement of contaminants. The numerical model expresses the conceptual model in mathematical terms that describe the physics of contaminant movement. The numerical model provides a mechanism for predicting or forecasting the future.

Purpose of the Model

Increasing natural gas exploration near the Rulison site has caused DOE to reexamine the institutional control that was established at the time of the test and to evaluate whether the restrictions remain effective at protecting the public. To support this evaluation, a model was developed to simulate the movement of tritiated water in response to nearby gas production in the subsurface at the Rulison site.

Steps of the Modeling Process

- Define the Objectives
- Develop a Conceptual Model
- Develop a Numerical Model
- Evaluate the Uncertainty
- Evaluate the Results
- Reach Conclusions

Define the Objectives

The objectives are to calculate the extent of tritium contamination in the subsurface from the time of the Rulison test to the present day; to identify the most susceptible natural gas production well location outside DOE's drilling restriction; and to evaluate tritium movement toward that location under a hypothetical gas production scenario.

The tritium transport model first calculates the migration of tritium from the time of the nuclear test until the present day. The model then simulates tritium movement in the direction of a hypothetical well that produces gas for 30 years. Concentrations of tritium at the well are calculated for the both the time that the hypothetical well is in use and for several hundred years after.

Develop a Conceptual Model

A conceptual model describes the processes that control the movement of contaminants in the subsurface. For the Rulison site, it includes a three-dimensional geologic model that represents possible distributions of sandstone and shale in the Williams Fork Formation. The geologic model is based on observations from two wells at the Rulison site, data from many wells in surrounding areas, and outcrop data from where the formation is exposed at the surface. The conceptual model of transport at Rulison identifies the most likely contaminant of concern as tritium and its primary transport mechanism as tritiated water vapor that moves with natural gas. The model accounts for properties important for movement of gas in the subsurface, such as porosity, permeability, tortuosity of the flow path, water content, and natural fracture trends in the formation.

Develop a Numerical Model

A numerical model expresses the conceptual model in mathematical terms that allow transport to be calculated. The Rulison numerical model simulates tritium migration within a geometric space that represents the subsurface below the test site. This space is divided into thousands of grid blocks, each with its own set of parameters depicting the rock type at that location. A computer program is used to calculate fluid flow and contaminant transport at each grid block based on parameter ranges developed from the conceptual model. The model examines various possibilities of sand and shale distributions, transport parameter ranges, hydrofracture properties at the production well, and production scenarios.

Rock properties important for movement of gas in the subsurface

Porosity: The amount of open space in the rock, like the holes in a sponge.

Permeability: The ease with which gas can move through the rock; permeability depends on how well-connected the pores are.

Tortuosity: A measure of how far something travels through the pores to get from one point to another; the more twists and turns, the longer the actual path.

Water content: The amount of water occupying the pore space; the more pore space occupied by water, the less space available for gas to move through.

Evaluate the Uncertainty

A model is limited by what is known and what is unknown. Because of the depth of the nuclear test, there is limited information from the subsurface, and the model is highly dependent on a combination of uncertain spatial features such as sand-shale geometry, permeability, porosity, and hydrofracture length. The uncertainties are addressed using a model approach that produces a range of possible outcomes. The outcomes are generated from a large number of simulations with random quantities used for uncertain variables. The variability in model outcomes provides decision makers with information that is helpful in developing strategies for site management.

Evaluate the Results

The Rulison model initially simulates the migration of tritium by natural diffusion, with no nearby gas production wells, to estimate the current extent of contamination. The model then simulates the additional migration that might be induced by production from a nearby gas well. The model results are evaluated to determine both the present extent of contamination and how near to the site a gas well can be placed without encountering contamination during the productive life of the well.

Computer simulation results indicate that tritium is currently confined within Lot 11, in the nuclear cavity and surrounding nuclear fractured region. Results also indicate that nearby wells with hydrofractures that do not enter Lot 11 are unlikely to encounter contamination. The modeling study incorporates the geology and hydrology surrounding the nuclear test horizon and includes the effects of current gas extraction technology. The model prediction of limited transport distances from the detonation is supported by the fact that the majority of wells drilled very close together (on 10-acre spacing) and producing natural gas from the same formation as the detonation, do not interact.

Reach Conclusions

Subsurface formation properties and site geology indicate that a production well located to the west of the nuclear detonation is likely to promote maximum contaminant transport from the Rulison site under relatively low-probability circumstances, such as when hydrofractures connect with nuclear test fractures. If nearby wells are kept at a distance so that their hydrofractures do not enter Lot 11, the probability that measurable amounts of radionuclides would be encountered at the well is low. However, there are always uncertainties in predictions of complicated processes in the subsurface.

Long-Term Management

DOE is developing a long-term management plan to ensure that conditions at the site continue to be protective of human health and the environment. DOE is using information from the model, feedback from state regulators, input from concerned citizens and the gas industry, and experience at similar sites to evaluate the site restrictions and design a long-term management strategy. Regardless of the model predictions indicating a low chance of radionuclide movement, DOE believes that all subsurface activities near the site need careful monitoring, and DOE will continue to conduct site inspections and long-term monitoring of surface water, groundwater, and natural gas.

Contacts

Documents related to the Rulison site are available on the DOE Office of Legacy Management website at http://www.LM.doe.gov/land/sites/co/rulison/rulison.htm.

For more information about DOE Office of Legacy Management activities at the Rulison site, contact

U.S. Department of Energy
Office of Legacy Management
2597 B¾ Road, Grand Junction, CO 81503

E-mail: Rulison@LM.doe.gov

(970) 248-6070 (monitored continuously), or
(877) 695-5322 (toll-free)