LMS/RUL/S04617

Final
Rulison Path Forward

June 2010

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Executive Summary

The U.S. Department of Energy (DOE) Office of Legacy Management developed this report as a guide for discussions with the Colorado State regulators and other interested stakeholders in response to increased drilling for natural gas reserves near the underground nuclear explosion site at Rulison, Colorado.

The Rulison site is located in the Piceance Basin of western Colorado, 40 miles northeast of Grand Junction. The Rulison test was the second natural gas reservoir stimulation experiment in the Plowshare Program, which was designed to develop peaceful uses for nuclear energy. On September 10, 1969, the U.S. Atomic Energy Commission, a predecessor agency of DOE, detonated a 40-kiloton nuclear device 8426 feet below the ground surface in an attempt to release commercially marketable quantities of natural gas. The blast vaporized surrounding rock and formed a cavity about 150 feet in diameter. Although the contaminated materials from drilling operations were subsequently removed from the surface of the blast site, no feasible technology exists to remove subsurface radioactive contamination in or around the test cavity.

An increase in drilling for natural gas near the site has raised concern about the possibility of encountering residual radioactivity from the area of the detonation. DOE prohibits drilling in the 40-acre lot surrounding the blast site at a depth below 6000 feet. DOE has no evidence that indicates contamination from the Rulison site detonation has migrated or will ever migrate beyond the 40-acre institutional control boundary. The Colorado Oil and Gas Conservation Commission (COGCC) established two wider boundaries around the site. When a company applies for a permit to drill within a 3-mile radius of surface ground zero, COGCC notifies DOE and provides an opportunity to comment on the application. COGCC also established a half-mile radius around surface ground zero. An application to drill within one-half mile requires a full hearing before the commission.

This report outlines DOE's recommendation that gas developers adopt a conservative, staged drilling approach allowing gas reserves near the Rulison site to be recovered in a manner that minimizes the likelihood of encountering contamination. This staged approach calls for collecting data from wells outside the half-mile zone before drilling closer, and then drilling within the half-mile zone in a sequential manner, first at low contamination probability locations and then moving inward. DOE's recommended approach for drilling in this area will protect public safety while allowing collection of additional data to confirm that contamination is contained within the 40-acre institutional control boundary.

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1.0 Introduction

In response to increased drilling for natural gas reserves near the Project Rulison underground nuclear test site (Rulison site), the U.S. Department of Energy (DOE) is developing a path forward as a guide for discussions with the Colorado Oil and Gas Conservation Commission (COGCC) and natural gas operators with nearby lease interests.

1.1 Location and Background

The Rulison site is located in the Piceance Basin of western Colorado, 40 miles northeast of Grand Junction in Garfield County, Section 25, T7S, R95W, 6th Principal Meridian (Figure 1). The Mesaverde Group formations within the Piceance Basin (Figure 2) contain significant reserves of natural gas in poorly connected, low-permeability (tight) sandstone lenses. The Rulison test was designed and conducted to evaluate the use of a nuclear detonation to enhance gas production in these tight sandstone reservoirs.

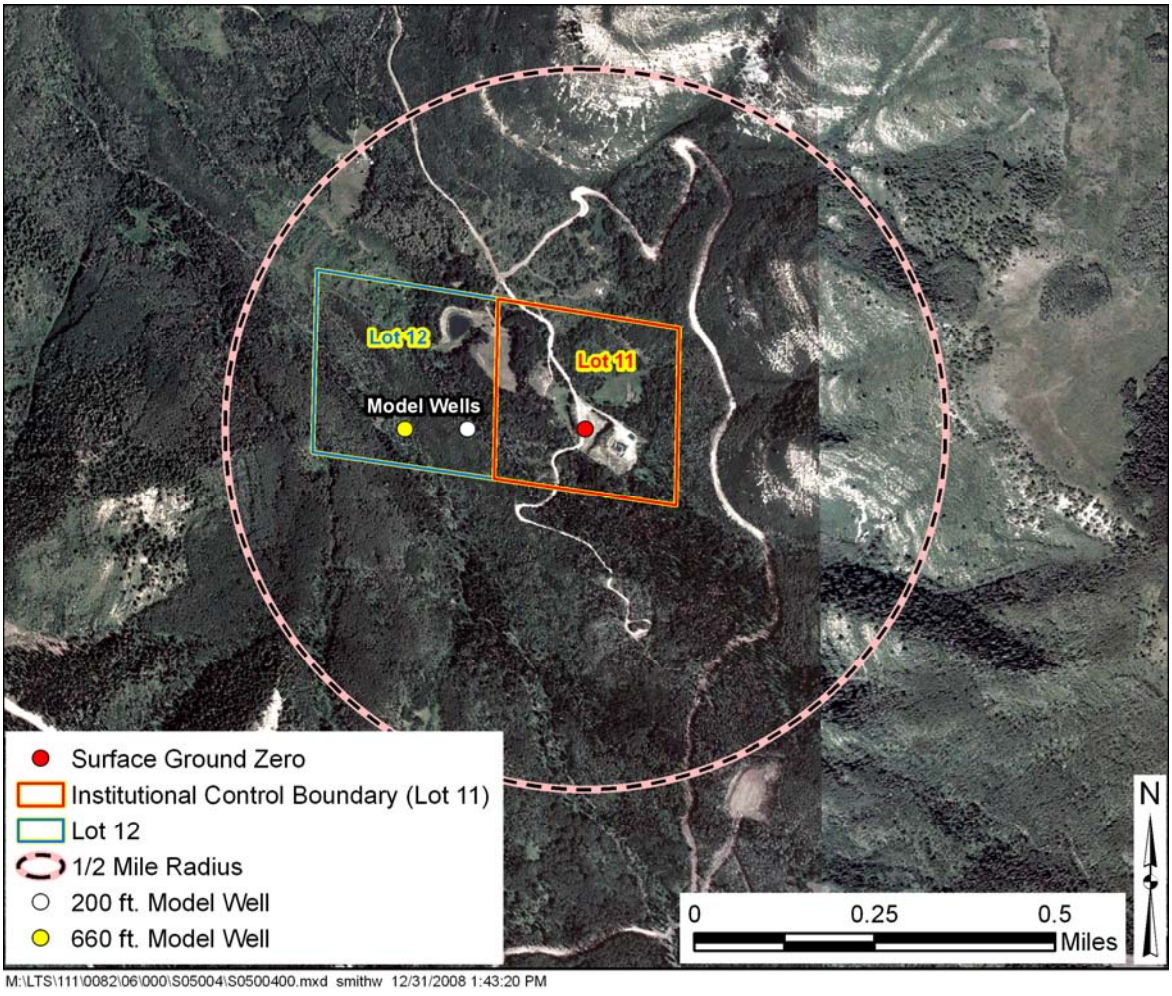


Figure 1. Current Institutional Control Boundary (Lot 11) and the Half-Mile Hearing Radius

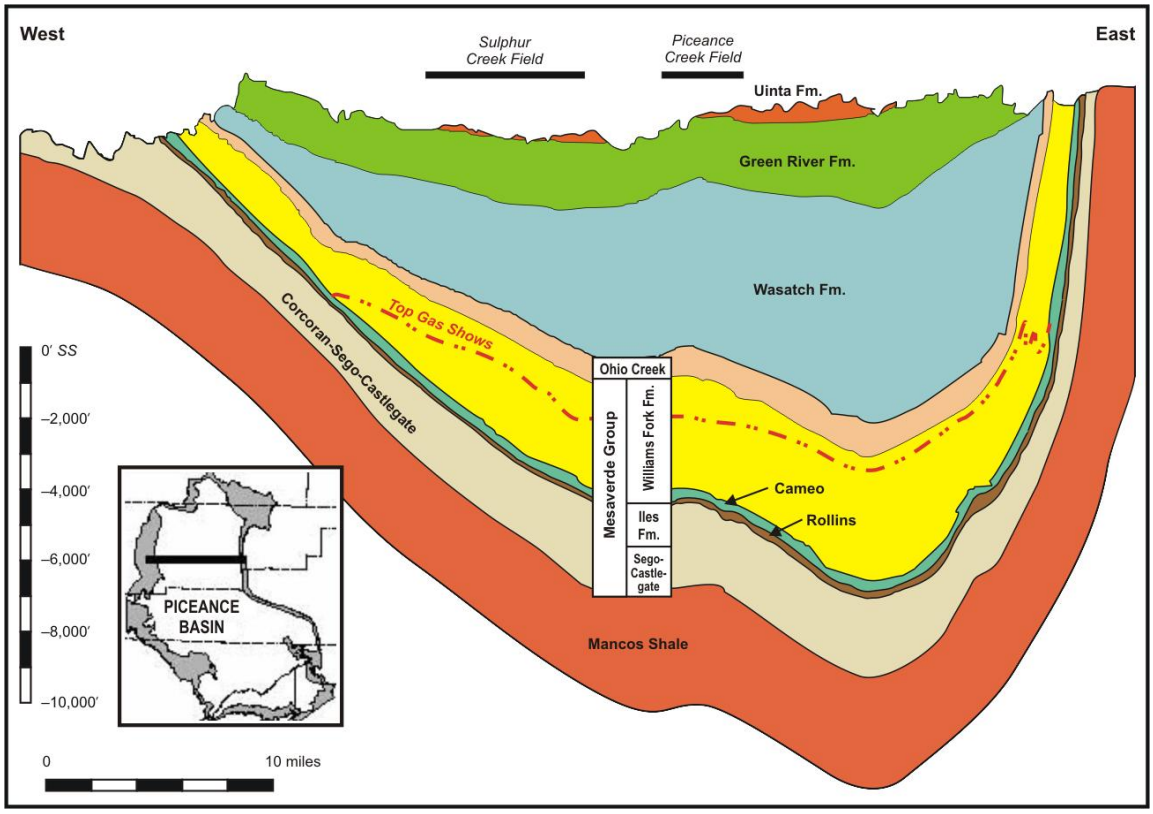


Figure 2. Piceance Basin Cross Section (modified from Yurewicz 2003)

A 40-kiloton device was detonated on September 10, 1969, at a depth of 8426 feet (ft) below ground surface in the Williams Fork Formation of the Mesaverde Group. The detonation created a cavity, a chimney, and a fractured zone surrounding the cavity (detonation zone). A highly fractured area encountered by the reentry well 275 ft above the detonation level was interpreted as the top of the chimney (Figure 3). Four production tests conducted on the reentry well between October 1970 and August 1971 produced a total of 455 million standard cubic feet of natural gas. The estimated volume of gas generated during the testing was approximately 10 times that of a conventionally stimulated well in the same production zone (AEC 1973). The concentrations of radionuclides dropped throughout the production testing, but the remaining presence of radionuclides within the produced gas made it unmarketable. The reentry well was shut in after the final test in 1971 and remained so until abandonment in 1976 (IT 1996). Drilling at the site was limited to the exploratory well (Hayward A 25-95 [R-EX]), the emplacement well (Hayward A 25-95 [R-E]), the reentry well (a sidetrack from the exploratory well after the detonation), and one shallow instrument hole (CER test well). Near-surface nonradiological contamination associated with the drilling mud pits and effluent pond was remediated in 1996, and the Rulison Site Surface Closure Report was issued in July 1998.

The ability to enhance natural gas production from tight sands has recently become feasible through advances in hydrofracturing technology. Fluids with entrained sand are pumped into the gas reservoirs at high pressure, creating fractures that extend outward from the wellbore. After fracturing, the fluid is pumped out, and the sand remains to keep the fractures propped open, enhancing gas flow to the well. With the combination of technological advances in hydrofracturing, higher natural gas prices, and increased demand, gas development near the

Rulison site has increased dramatically. The increase in gas development near the site has raised concerns about the possibility of encountering residual radioactivity from the area of the detonation.

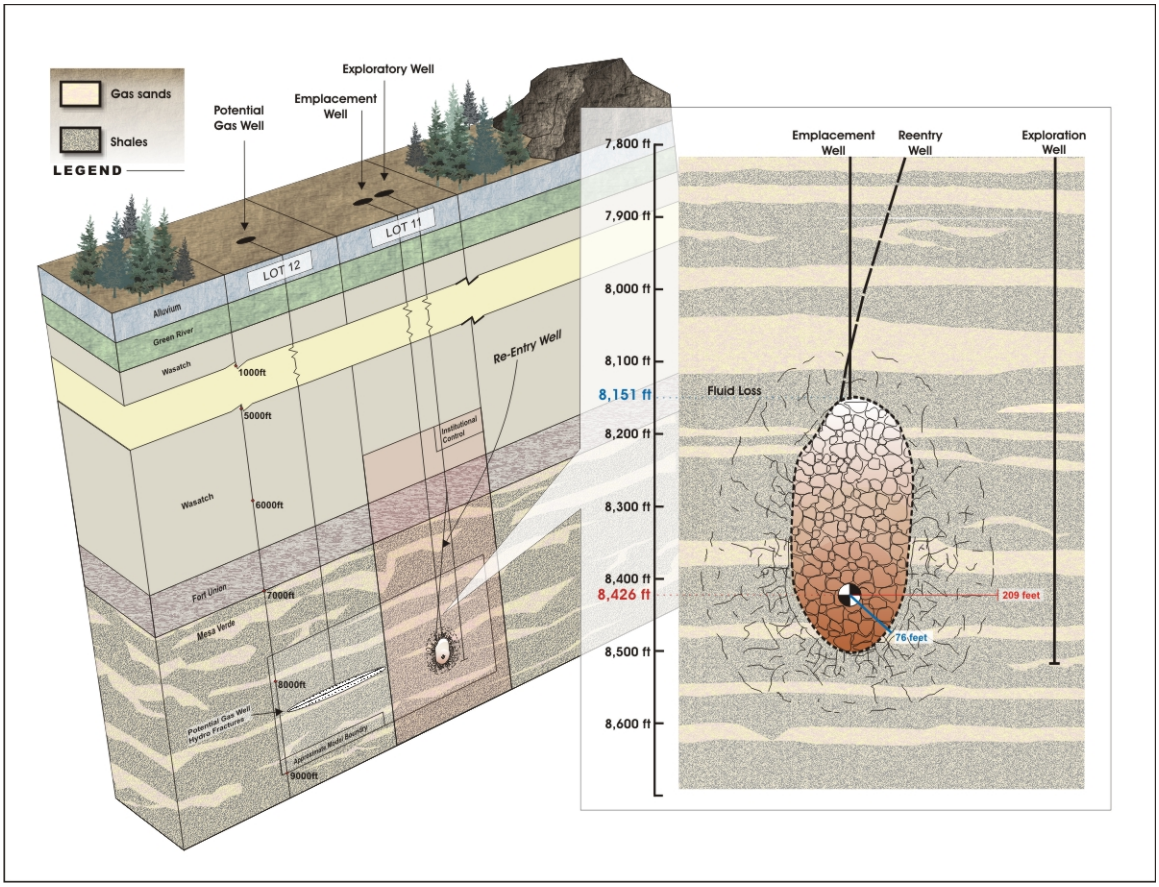


Figure 3. Schematic Cross Section of the Rulison Detonation Zone

The COGCC has decision authority over applications for permits to drill oil and gas wells in Colorado and has imposed administrative controls on drillers in the vicinity of the Rulison site. The COGCC notifies DOE of any drilling permit activity within 3 miles of the site. For approval of permits in this area, the COGCC requires adherence to a prescribed sampling and analysis plan that varies depending on distance from the site (URS 2008). Drilling permit applications within a half-mile of the site require a hearing before the commission prior to approval.

1.2 Potential Source of Contamination

The detonation zone at the Rulison site is a potential source of radionuclide contamination that is currently contained in the subsurface. The detonation zone consists of a cavity with a 76-ft radius and an overlying collapse chimney that extends about 275 ft above the detonation level. A high-permeability fractured region surrounds the cavity and chimney and extends an estimated 209 ft radially from the detonation. The top of the chimney was determined during the drilling of the reentry well when the first major fractures were identified at a depth 8151 ft below ground surface (AEC 1973). The extent of the surrounding fractured zone is based on analysis of data from the reentry well production testing that indicated a 33-fold increase in permeability to a distance of 2.75 cavity radii (Montan 1971; Rubin, Schwartz, and Montan 1972).

Most of the longer-lived radionuclides produced by the Rulison detonation are solid at relatively high temperatures and were incorporated within the molten rock as it cooled to form a melt glass at the base of the cavity. At sites where water-saturated rock or alluvium is in contact with the melt glass, solidified radionuclides can be subject to dissolution by and transport with passing groundwater. Studies of radionuclide releases to and transport within groundwater at underground test sites on the Nevada Test Site discuss the physical and chemical phenomena that influence the dissolution and transport processes (e.g., Tompson et al. 1999, Pawloski et al. 2001). These studies indicate that most of the radionuclides incorporated in the melt glass at the base of a detonation cavity are released to groundwater very slowly. Moreover, transport away from the cavity is typically impeded because the dissolved radionuclides either sorb to mineral grains or react chemically with the geologic media, and radionuclide movement is slowed with respect to groundwater movement. Though dissolution of radionuclides from melt glass at the base of a cavity can represent a long-term source of subsurface contamination, dissolved-phase transport of radionuclides away from the cavity area at the Rulison site is considered insignificant, because the rock surrounding the cavity and chimney area is unsaturated with respect to water. The presence of gas in the surrounding Williams Fork Formation severely limits liquid movement, making any solidified radionuclides that may have dissolved in the cavity essentially immobile. The relative permeability of the formation to liquid is 3 to 4 orders of magnitude lower than the relative permeability to gas, and gas has remained in the formation until recently, when hydrofracturing techniques were employed to extract it from zones near wells.

Several of the longer-lived radionuclides produced by the detonation in quantities large enough to potentially affect public health or the environment (tritium, krypton-85, and carbon-14) do not solidify at lower temperatures and can exist in either liquid or gas phases. When present in the gas phase, these radionuclides are far more mobile than those bound in the solid phase or those dissolved in the liquid phase. Tritium (an isotope of hydrogen) is primarily present as tritiated hydrogen gas (HT in place of H_2), tritiated methane (CH_3T in place of CH_4), or tritiated water (THO in place of H_2O). Carbon-14 is primarily present as part of the methane molecule ($^{14}CH_4$ in place of $^{12}CH_4$), and krypton-85 is an inert gas. The gas production testing on the reentry well removed almost all the carbon-14 and krypton-85 created by the detonation (AEC 1973), leaving tritium as the most mobile radionuclide that remains in quantities sufficient to pose a potential health concern (10,000 curies produced by the detonation were reduced to 7,000 curies after production testing, and the post-production testing quantity has since decayed to 700 curies as of late 2009). Tritiated water occurs both as liquid water and as water vapor, allowing it to readily migrate with either the liquid (mobile formation water, limited at the Rulison site) or gas phases (plentiful at the Rulison site). Tritium can also be incorporated in the solidified melt glass, though to be conservative in considering potential migration scenarios, tritium is treated as if all of its mass remains in the liquid or gas phases.

Upward migration of radionuclides to a depth at which they might affect public health or the environment solely by way of natural pathways (with fluids moving through pores and fractures) is extremely unlikely due to the depth of burial (more than 8000 ft) and the low permeability of the surrounding formations, which limit fluid movement. The detonation zone is in the lower part of the approximately 2500-ft-thick Williams Fork Formation, more than 1000 ft below the overlying Ohio Creek Formation, an unnamed formation, and the Wasatch Formation, which have a combined thickness of about 4400 ft at the Rulison site (Voegeli 1969). The pores of the

tight, poorly connected sandstone reservoirs of the Williams Fork contain approximately 50 percent gas and 50 percent formation water (brine) and are isolated within lower-permeability shale. The presence of commercial amounts of gas and the need to use hydraulic fracturing methods to affect even small areas (each well drains roughly a 10-acre area) support the concept of essentially no movement of fluids within a time frame of significance for tritium migration to be of concern. In the absence of wells that penetrate near the detonation zone, there is no realistic pathway for contamination to reach the surface or near-surface. Thus, the most likely tritium transport mechanism at the Rulison site is tritiated water vapor migrating with natural gas to a nearby producing well.

1.3 How Close to the Detonation Zone Can Natural Gas Be Safely Produced?

Institutional controls are legally enforceable spatial boundaries that limit intrusion at a site to a safe distance in order to protect human health and the environment. The institutional controls at Rulison prohibit drilling below the 6000-ft depth in Lot 11 (NE quarter of SW quarter) of Section 25, T7S, R95W (Figure 1). Tritium is likely restricted to the vicinity of the detonation zone within the 40-acre Lot 11 boundary. This finding is based on the results of the modeling study conducted by Desert Research Institute (DOE 2007) that calculates potential transport distances using many combinations of sandstone distribution possibilities and hydraulic parameter ranges typical of Williams Fork sandstones. However, just as the blast fractured the formation, increasing the permeability and releasing much of the gas within the detonation zone, each modern gas well is completed using hydrofracturing technology that increases the permeability of local sandstone reservoirs and releases the gas in the vicinity of the well. In all cases, the proximity of gas wells to the Rulison site should be limited to a distance beyond which no interaction between the detonation zone and hydrofracturing zone can occur.

The primary factors that determine a safe distance for a gas well from the detonation are the extent of the nuclear fracture zone and the maximum distance from a well that hydrofracturing increases permeability. These factors plus others were included in the modeling study, which predicts that, in over 95 percent of the simulations, no tritium above background levels will reach a gas well in Lot 12, 200 ft from the west border of Lot 11 (850 ft from the detonation). Additional recent modeling (Cooper et al. 2009) indicates that by moving the gas-producing well to the center (relative to east-west) of Lot 12 (660 ft from the boundary and 1310 ft from the detonation), no significant amount of tritium reaches the well in any of the simulations. This location for the simulated gas well is more consistent with the location of actual wells that will be drilled to develop gas reserves to the west of Lot 11. This location also currently limits the possibility that hydrofractures at the simulated well would penetrate Lot 11, which is prohibited. Each lot is approximately 40 acres, and the typical well drains an east-west elongate area of 10 acres. This results in four wells centered within a lot east-west and equally spaced north-south as the typical developed configuration. Model well locations are shown on Figure 1.

The extent of the nuclear detonation zone is known from analysis of reentry-well production test data that indicate nuclear fracturing increased formation permeability out to a distance of approximately 209 ft from the detonation point. Nuclear fracturing distance was treated as a deterministic (fixed) parameter in the model (the same distance was used for all simulations). The average and maximum extents of typical hydrofractures are known based on data from the many gas wells in the Piceance Basin. Hydrofractured zones, which elongate in the direction of the natural fracture trend of the Williams Fork Formation, have an average propped length (kept

open by sand injected with the hydrofracturing fluid) of 200–300 ft and can reach lengths up to 600 ft from the well in the direction of the natural fracture trend. Because of the range in possible propped hydrofracture length, it was treated as a random parameter in the model (the length for each simulation was selected from a probability distribution based on industry data).

The results of the most recent conservative modeling provide confidence that wells at the half-mile radius, even in the direction of the natural fracture trend, are safe for gas production. The half-mile radius is 2640 ft from the detonation, yet no significant amount of tritium reached the hypothetical gas well for any simulation with a well 1310 ft from the detonation (center of Lot 12 to the west). Even if tritium were to reach a gas well, the risk is low, in that there is no reasonable exposure scenario that would endanger public health. Almost all of the tritium (migrating as tritiated water vapor along with the methane gas) would be captured at the wellhead where the water vapor condenses and is removed from the gas prior to entering the gas distribution system. Despite the low risk, a cautious approach to gas development near the Rulison site is recommended and is described in the following sections.

1.4 Path Forward Objective

The objective of this document is to encourage gas developers to adopt a conservative, staged-drilling approach that allows gas reserves near the Rulison site to be recovered in a manner that minimizes the likelihood of encountering contamination. There is no evidence that leads DOE to suspect that contamination from the Rulison site detonation has migrated or will ever migrate beyond the current institutional control of Lot 11. The approach presented below is suggested as a way to further enhance public safety while allowing additional data to be collected to confirm the conclusion of limited contaminant migration. Success of the approach will depend on the joint cooperation of companies with lease interests near the Rulison test site, the COGCC, and DOE. The public should be informed once a comprehensive approach has been adopted, and subsequently kept informed on drilling progress and monitoring results.

2.0 Guidelines for Gas Development near Rulison

DOE recommends a staged approach that initially uses conservative modeling but primarily relies on the collection of data to determine a safe drilling distance from the Rulison site. The results of the original model and the results of an additional set of model simulations that apply more conservative transport parameters indicate that gas-production wells can safely be located in the lots west and east of the Rulison site so long as the hydrofractures emplaced during well completion remain outside of the institutional control of Lot 11. The simulated tritium concentration at a hypothetical well located west of the site, in the center of Lot 12, is below background for all simulations during the life of the well.

The first stage of the proposed approach calls for identifying the orientation and potential variability of the natural fracture trend in the area by collecting data at wells drilled and completed approximately 1 mile from the Rulison site (1.25, 1.0, and 0.75 miles). If sampling and analysis results from the 1-mile wells confirm the lack of contamination at this distance, wells just outside the one-half-mile hearing radius can then be drilled. If possible, it is recommended that the initial half-mile wells be located north and south of the site, normal to the natural fracture trend and detonation zone. This places the initial half-mile wells in a location

where the low-permeability direction of the formation and least likely growth direction of the hydrofractures will be toward the detonation zone, minimizing the likelihood of transport. Once installed and completed, the wells surrounding the half-mile radius will act as a focused monitoring network, with sampling and analysis of fluids from the wells confirming that no contaminant transport occurs beyond the half-mile radius. One well, Battlement Mesa 36-13, has already been drilled near the half-mile radius south-southeast of the site, and no contamination has been detected in this well. The orientation of the natural fracture trend should be confirmed by the best available technology at several of the half-mile wells prior to considering wells nearer the detonation.

DOE recommends staging the wells within the half-mile radius on the basis of sampling results from wells just outside the half-mile radius and on the orientation of the natural fracture trend. The initial wells inside the half-mile radius should be located north and south of the detonation to minimize the possibility of encountering contamination. Drilling wells in line with the predominant fracture trend and the detonation within the half-mile radius (Lot 12 to the west and Lot 10 to the east) is recommended after locations to the north and south are drilled and monitored. An additional conservative approach recommends that when wells are drilled in Lot 12 and Lot 10, completing and producing from sandstone reservoirs at the interval affected by the detonation should be delayed. This suggested approach will require the cooperation of gas operators in the area, the COGCC, and DOE.

DOE does not believe the presented approach is a burden on gas operators, but rather an approach that a reasonably cautious operator would have likely developed independently. DOE believes that it would be helpful if gas operators with lease holdings in the vicinity of the site coordinate their planning for gas development in the area with COGCC and DOE to reduce the possibility of any misunderstanding. For example, given DOE's stated interpretation that no contamination is expected to ever migrate beyond Lot 11, an operator might apply for a permit to drill within the half-mile radius in the most likely direction of potential transport before other wells in safer directions have been installed. Though DOE believes it is unlikely the operator would encounter contamination, the suggested staged approach is preferred because it adds another layer of safety that only requires a better planning sequence for well installation. This path forward assumes that the current industry Sampling and Analysis Plan (URS 2008) for wells inside the 3-mile notification area will be in effect until a focused network around the site is sufficiently developed. DOE is currently developing its own sampling and analysis plan to supplement the industry plan.

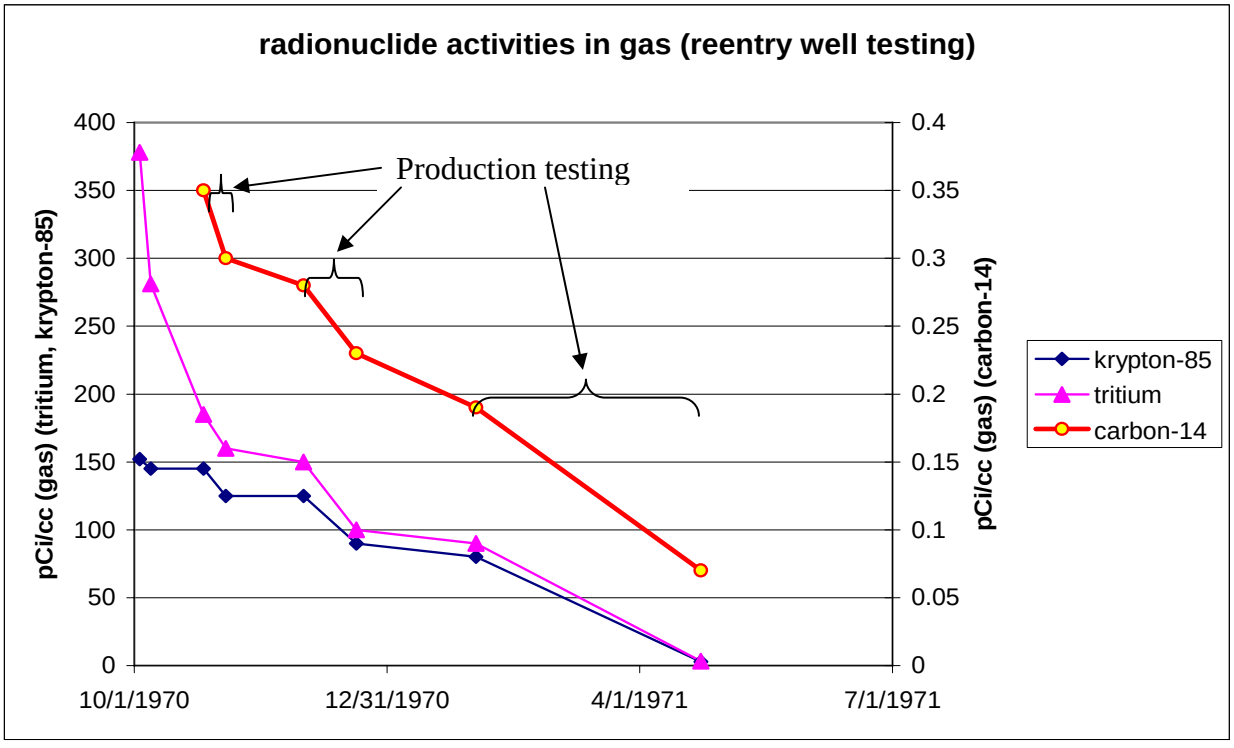
2.1 Selection of Tritium as the Contaminant of Concern

The selection of tritium as the only contaminant of concern for gas production is consistent with the gas testing results from the reentry well given in the Project Rulison Manager's Report (AEC 1973). The reentry well produced 455 million cubic feet of gas, and the only radionuclides detected were tritium, krypton-85, carbon-14, argon-37, argon-39, and mercury-203. On the basis of estimated inventories of radionuclides produced by the detonation and the amounts removed by production testing, tritium is the only mobile radionuclide that remains in any significant quantity in the detonation zone. This finding is shown in Table 1 and is derived from the Project Manager's Report (AEC 1973), Nork and Fenske (1970), Reynolds (1971), Smith (1971), and separate calculations. Nonvolatile isotopes such as those of uranium and plutonium are not present in the gas phase and were not detected in samples produced from the reentry well.

Table 1. Radionuclides in Reentry Well Gas

Radionuclide	Estimated from Detonation (curies)	Estimated Removed by Production Testing (curies)	Half-life	Estimated Remaining 2009 (curies)
Tritium	10,000	2,824	12.32 years	700
Krypton-85	1,100	1,064	10.8 years	< 10
Carbon-14	2.2	2.4	5,730 years	< 1
Argon-37	10–100	Not available	34 days	< 1
Argon-39	2–20	Not available	260 years	NA
Mercury-203	NA	0.0001	47 days	< 1

The minute amounts of mercury-203 (0.00004, 0.00003, and 0.00003 curie) removed in the first, second, and third production tests are consistent with the amount found naturally in the formation (Reynolds 1971). The original estimate of 2.2 curies of carbon-14 produced by the detonation (Smith 1971) is slightly less than the amount observed to be removed during production testing. The declining activities of the radionuclides produced in the gas are shown on Figure 4. The tritium concentrations in the extracted gas declined similarly to those of the other volatile radionuclides, even though approximately 7,000 curies of tritium remained. This is primarily attributed to the likelihood that after the tritiated hydrogen gas and tritiated water vapor were removed during the gas-flow testing, the remaining tritium was present as tritiated liquid water with some possibly incorporated into the melt rock. Over time, a portion of the tritiated liquid water will move into the gas phase as water vapor.



pCi/cc = picocuries per cubic centimeter

Figure 4. Activity of Radionuclides in Gas from the Production Tests on the Reentry Well
(Note that the scale for carbon-14 is on the right side of the graph.)

2.2 Modeling

The contaminant transport model for the site was revisited with the intent of determining the nearest distance, in the direction of greatest permeability from the detonation, at which a hypothetical gas-producing well could be located with no reasonable expected risk of encountering contamination. The initial modeling suggested that it would likely be safe to place a production well near the minimum legal distance (200 ft prior to 2005) from the Lot 11 boundary (within Lot 12) along the trend of natural fracturing. However, the restrictions that prevent removal of material from Lot 11 make it unlikely that a well would be drilled this close to the lot boundary. Over 95 percent of the simulations with the producing well 200 ft from the lot boundary showed no breakthrough above background levels, even though some simulations had hydrofractures that intruded into Lot 11. The additional simulations undertaken in the modeling addendum focused on more conservative, yet still reasonable, transport parameters than those used in the initial modeling (DOE 2007) in an effort to add an extra margin of safety to the interpreted modeling results.

The results of the additional modeling indicated that tritium levels for a well located in the center of Lot 12 (660 ft from the Lot 11 boundary) only slightly exceeded background levels for the most conservative simulations and were well below background levels for all simulations that use a partitioning coefficient consistent with formation temperatures. The partitioning coefficient specifies how much water is in the form of liquid water (immobile) or water vapor (mobile). The model results provided confidence that the half-mile radius is safe and indicated that even the most vulnerable well location in a lot adjacent to the site was unlikely to be affected. However, on the basis of possible unrecognized variations from model assumptions, a cautious approach is warranted. The nuclear fracture radius used in the model was 263 ft (80 meters) instead of the 209 ft (63.7 meters) reported from the reentry well pressure analysis. Due to the model being discretized into 20-meter grid blocks, the extent of the nuclear fractures in the model was set at 80 meters instead of 60 meters to be conservative.

2.3 Determination of Natural Fracture Trends near the Site

The Williams Fork Formation of the Piceance Basin has a natural fracture field that generally trends east to west, though the orientation can vary somewhat depending on location within the basin. The permeability of the formation is greater in the direction of the natural fracture trend, and hydrofractures used to further increase permeability during well development tend to elongate in this direction. The orientation of the fracture trend in a given area can be measured using several methods. The dipole sonic log can be used to determine the minimum and maximum principal stress directions within the formation, which can then be used to infer the stress field orientation. Microseismic mapping uses geophones placed in one or more wells near a well being completed to record hydrofracture propagation, which tends to follow the higher-permeability direction of the natural fracture field.

Microseismic mapping was used to detect average fracture orientation in a portion of the Rulison Field, a gas-producing area located approximately 6 to 8 miles northeast of the Rulison site. Results from the microseismic testing, illustrated in Figure 5, identified a fracture orientation of N75°W, with a local range of plus or minus 10 degrees (Wohlart et al. 2005). In the Grand Valley Field (approximately 8 miles northwest of the test site), the average fracture orientation was determined to be N84°W, with a local range of plus or minus 5 degrees

(Wohlart et al. 2005). Until data are collected near the Rulison site, it will be assumed that a fracture orientation of N75°W also applies to the area surrounding the Rulison site.

As part of the path forward, it is recommended that the natural fracture orientation near the Rulison site be confirmed prior to drilling near the half-mile radius. Noble Energy has applied for 25 permits to drill west of the site, with bottom-hole locations that range from 0.75 to 1.25 miles from the test point (Figure 5). These locations are good candidates for dipole sonic logs and possibly a microseismic survey. A dipole sonic log was run in Noble Energy well BM 26-34A, 0.75 mile west of the site, and the results confirm the east–west orientation of the natural fracture trend. The results of the dipole sonic logs and the microseismic mapping, if performed, will be used to guide the drilling sequence of future wells located just outside the half-mile hearing radius.

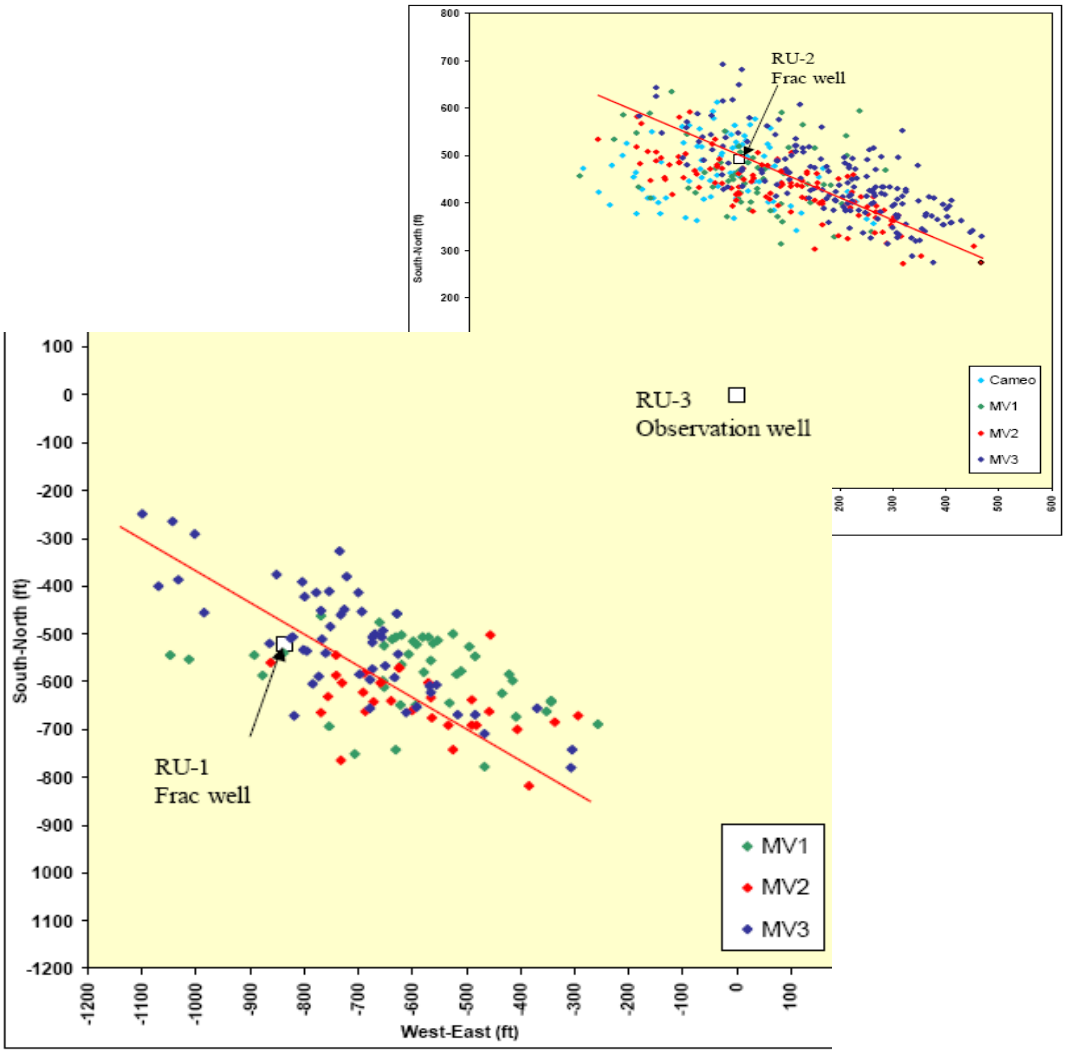


Figure 5. Microseismic Mapping of the Hydrofracturing of Two Wells

Mapping was conducted at different times during the winter of 2001–2002 using the same observation well (RU-3) in the Rulison Field (modified from Wolhart et al. 2005). The points are microseisms, small seismic events associated with hydrofracture propagation. The point colors represent different hydrofracture stages (sandstone reservoirs fractured as a group within a given depth range; Cameo is the deepest and Mesaverde-3 is the shallowest). Note that the hydrofracture wing nearest the observation well has an apparent length greater than the opposite wing. This is interpreted as an artifact of detection distance from the observation well, not actual asymmetry of hydrofracturing extent.

2.4 Confirmation That the Half-Mile Radius Is Safe

It can be confirmed that locations beyond and approaching the half-mile hearing radius are safe for natural gas development by drilling a series of gas wells just outside this radius, producing the wells, and monitoring them for radionuclides potentially associated with the nuclear test. The wells will be drilled by gas operators with lease interests near the site as part of their ongoing development of gas reserves in the area. These wells, depicted as ovals in Figure 6 to indicate an approximate hydrofracture extent, should confirm that contamination has not migrated appreciably from the site and will also act as a focused network that monitors for any contaminant migration that might occur in the future. One well, Battlement Mesa 36-13, has already been drilled near the half-mile radius south-southeast of the site, and no contamination has been detected in this well.

As previously discussed, a conservative approach to this confirmation process would be to place the first of the half-mile wells almost directly north and south of the test site (assuming a general east-west natural fracture trend). Subsequent wells would be drilled progressively closer to the linear band aligned with the predominant natural fracture trend and the test site, and wells located within that band would be installed last. All well locations at the half-mile distance are considered safe, though following the staged approach, even at this distance, would be preferred if possible. At this distance, the timing of installing and producing the north-south wells first and then the east-west wells is a suggestion and need not be rigidly adhered to or required by the COGCC if there are other overriding concerns, such as the logistics of locating new drill pads. Test findings from the wells installed at the half-mile radius will be used to make decisions regarding the locations and construction of subsequent wells.

The tests that can be conducted at the wells as they are installed include dipole sonic logs (information about the orientation of the natural fracture trend), formation micro-imaging logs (which provide images of fractures in wellbore walls), and geophysical logs (gamma ray, resistivity, density, neutron, and sonic), most of which are run on all new wells to gain information on the lithology, permeability, porosity, and gas content of the formation intercepted by the well. Conducting a microseismic survey during the hydrofracturing of one of the half-mile wells could be considered to confirm fracture orientation from the dipole sonic logs and to estimate hydrofracture distance. Collecting rock core from above, within, and below the detonation horizon, at one of the half-mile wells could also be considered to show that the formations opposite the detonation depth were not materially affected by the blast.

The application for a permit to drill wells just outside the half-mile radius does not require a COGCC hearing. If a permit request is submitted for a well location within the half-mile hearing radius before a number of wells are installed just outside this distance, COGCC would have to make any decision without the benefit of additional data from the half-mile wells. The suggested approach allows all parties involved to make more-informed decisions regarding potential well installations within the half-mile hearing radius.

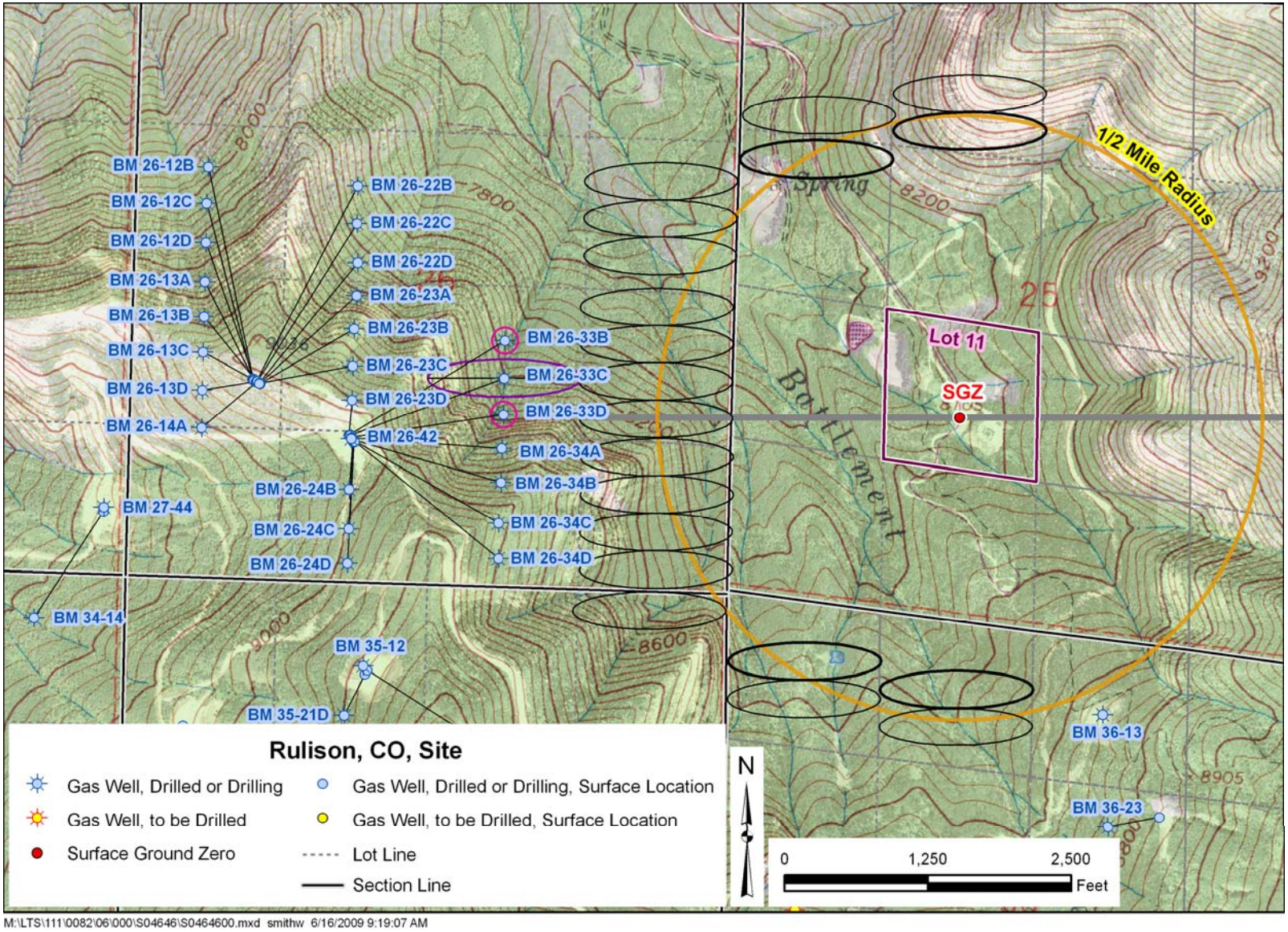


Figure 6. Map of the Rulison Area Showing Potential Well Locations for Production and Monitoring Outside the Half-Mile Hearing Radius (ovals indicate the extent of influence of potential half-mile well locations).
Planned well locations shown above were in the process of being drilled at the time of this report.

2.5 Wells Within the Half-Mile Radius

The COGCC notifies DOE when they receive applications for drilling permits within 3 miles of the Rulison site and considers comments from DOE in the approval process. For well permit applications inside a half-mile of the site, a hearing before the commission is required. DOE does not encourage wells within the half-mile radius until data have been collected from wells just outside the half-mile radius. The data to be collected include not only information about the orientation of the natural fracture trend near the test site, but more importantly, concentration data from fluid samples at these wells. DOE does not believe that contamination has migrated or will migrate beyond Lot 11. The support of wells inside the half-mile radius would be more convincing to both the public and regulators if a data set confirmed the lack of radionuclides at wells just outside the half-mile radius. As in the case of the half-mile wells, it is recommended that the first wells installed within the half-mile radius be located almost directly north and south of the detonation zone (see bolded ovals in Figure 6), in the least likely transport direction. To ensure that the initial wells are drilled in the least likely transport direction, it is also recommended that the natural fracture orientation in the vicinity of the Rulison site be confirmed by the best available technology on at least one of the half-mile wells before drilling within the half-mile radius is allowed. Subsequent wells could then be installed in a sequence that gradually approaches the higher-risk transport direction, currently believed to be roughly east-west of the site. Color-coded hydrofracture ovals in Figure 7 show how this gradual approach to developing the area within the half-mile radius could be carried out.

DOE recommends that the gradual approach suggested for developing gas reserves just beyond the half-mile radius be more closely adhered to for drilling within the half-mile radius. Testing and monitoring results from each newly installed well should be used to evaluate successive well locations as to their potential risk. If testing confirms that the natural fracture trend is oriented east-west at the site, the areas of greatest risk will be Lot 12, west of the site and Lot 10, east of the site. Drilling and producing from these two lots is not recommended until the lack of radionuclide contamination is confirmed by data from producing wells located in safer directions within the half-mile radius.

When wells are eventually drilled in the lots immediately west and east of the test location, completing and producing from sandstone reservoirs at the interval affected by the detonation should be avoided until data indicate that it is unlikely that test-related radionuclides are present at this location. The interval affected by the detonation is considered to be the zone from just above the top of the chimney to the bottom of the cavity, approximately from an elevation of 50 ft above to 400 ft below mean sea level. For example, micro-imaging logs would indicate whether this level has increased fracturing relative to the rest of the gas-bearing formation.

Under no circumstances shall a well be located such that encroachment into or removal of materials from Lot 11 might occur. This includes all hydrofractures, propped or not, and flow-inducing gradients by way of production near Lot 11 that could cause contaminant migration from Lot 11. To ensure that encroachment into Lot 11 does not occur, it is recommended that microseismic mapping be conducted during the hydrofracturing of any well completed beneath either Lot 10 or Lot 12. It is also recommended that, if a microseismic survey conducted during the hydrofracturing of a well indicates fracture movement beneath the footprint of Lot 11, the well should not be given a permit for operation.

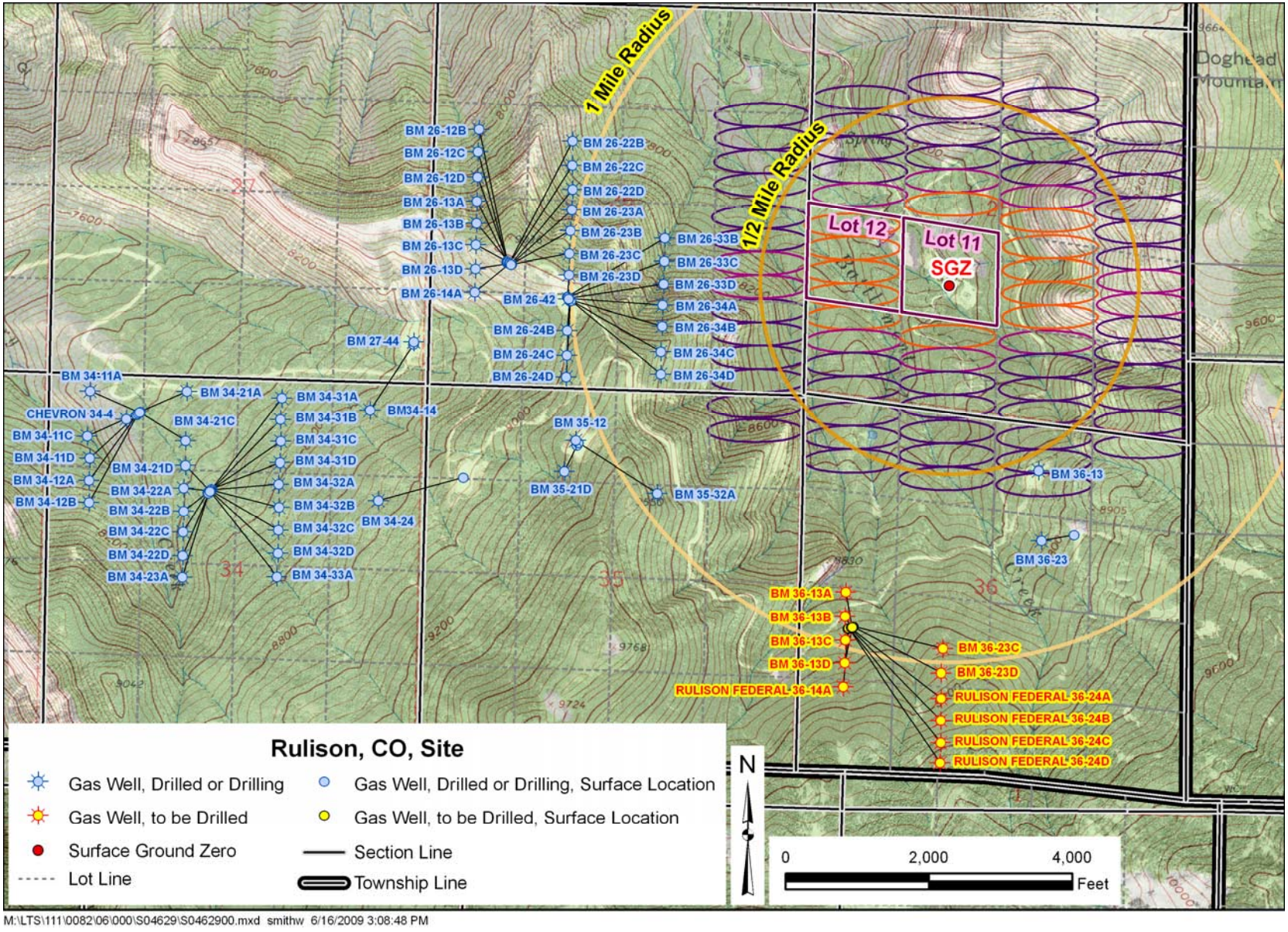


Figure 7. Rulison Area Map Showing Potential Well Locations for Production and Monitoring Outside and Inside the Half-Mile Hearing Radius Possible well locations (ovals) in the vicinity of the Rulison site, color coded by relative risk of encountering any contamination (based on distance and orientation from the site).

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Appendix A

Responses to Comments on the Draft Rulison Path Forward

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Appendix A

Responses to Comments on the Draft Rulison Path Forward

Commenters:

1. Steve Tarlton—Colorado Department of Public Health and Environment (CDPHE)
2. Wesley and Marsh Kent, Randy and Pat Warren, Cary and Ruth Weldon—Rulison-area property owners
3. Randy Fricke—citizen

Item Number	Comment Type	Comment	Department of Energy Response
1	General CDPHE 1	CDPHE does not believe DOE has gathered, evaluated, or presented sufficient actual data to adequately characterize the Rulison blast site and thus is unable to determine where it is safe to develop oil and gas resources within a ½ mile of the blast site.	The Department of Energy (DOE) has determined that it is safe to develop gas resources outside of the 40-acre institutional control area consisting of Lot 11. This determination was made using information from multiple sources that are accessible by DOE and the public. Some of this information occurs in the form of data collected from a reentry well that was drilled in 1970 into the top of the chimney created by the nuclear test. These data provide insight into the physical geometry of the chimney and of the fractured zone that was created in the rock surrounding the chimney. For example, analysis of gas production from the reentry well during the early 1970s indicated that the zone of increased permeability (interpreted as the fractured region) created by the blast extended 209 feet radially from the blast point, well short of the Lot 11 boundary. This observation is consistent with the data acquired from hundreds of underground nuclear tests conducted elsewhere. CDPHE has shown interest in having the Rulison site characterized, including a demarcation of areas that might have been impacted by radioactive contaminants generated by the Rulison blast. However, DOE believes that traditional methods of defining the nature and extent of contamination, specifically using characterization wells, would be ineffective in this case. Because the tight sandstones in which the nuclear test occurred strongly

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			impede gas flow, a conventional well installed for the purpose of detecting contamination would only provide information on fluids located within a few tens of feet from the well. Accordingly, traditional site characterization based on subsurface penetration would require many wells drilled to depths approaching 9,000 feet below ground surface. Even if tens of wells were drilled in areas surrounding the chimney created by the nuclear test, it is possible that the contamination would not be detected. DOE objects to the hydrofracturing of any well that might be installed for characterization purposes because such a step will increase the mobility of gases intercepted by the hydrofractures and, as a consequence, potentially spread contamination beyond existing areas affected by the test.
2	General CDPHE 2	In addition to the suggested sonic dipole logs and microseismic mapping of hydro-fracture propagation, CDPHE believes a commitment from DOE to develop and implement a definitive plan for drilling within the ½ mile radius is necessary to confirm the safety of oil and gas exploration activity. Such a plan should include collection of site specific data and create a monitoring system independent of production wells. Completion of a boring(s) near the blast site and within ½ mile radius would provide direct evidence, rather than assumptions and modeling, to support DOE's conclusion that there is a lack of contaminant migration. This approach would allow DOE to convert the boring(s) to pressure monitoring wells to record formation pressure changes over time and thus provide further understanding of the impacts to the blast constituents and characteristics including contaminated gas migration, from present day gas production.	DOE believes that the installation of a system of monitor wells separate from production wells would provide only minimally useful information regarding gas flow and transport within the half-mile radius. Currently available information on the geometry of the chimney and fractures created by the nuclear test indicates that these features lie well within the boundary of the 40-acre institutional control area consisting of Lot 11. As a consequence, characterization wells drilled between the Lot 11 boundary and the half-mile radius are not expected to provide new information about the transport of radioactive contaminants away from the blast chimney.
3	General CDPHE 3	Alternatively, DOE could demonstrate that significant data exists from other underground nuclear detonations to determine the degree to which contaminants migrate in natural gas or groundwater over long time periods and to elaborate on what is known about isotopic decay and mobility changes over time. This data could then be used to upgrade DOE's current modeling or to perform a detailed assessment of potential risk or dose from collection and use of contaminated natural gas.	Significant data from other underground nuclear detonations are available, and DOE has made use of the data. DOE has used this information to evaluate estimates of the spatial dimensions of the test-related chimney and fractures extending radially from the chimney. Historical information regarding the radionuclides generated by the test, their mobility, decay, and longevity has also been used.

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			DOE upgrades the existing numerical model as additional information becomes available. The model essentially analyzes flow and transport in the gas phase, since all available data indicate that the Williams Fork Formation is unsaturated (with respect to water) and that the water present is relatively immobile in comparison to the gas. Therefore, "groundwater" transport in the formation is not considered an issue as it is at many other underground tests. Investigations of "hot wells" (post-shot drill holes and other near-cavity wells) at the Nevada Test Site have found that the only radionuclide consistently measured above its maximum contaminant level is tritium.
4	General CDPHE 4	As you will note from earlier comments we provided DOE regarding the modeling at Rulison (See 11/30/07 memorandum from Steve Tarlton to Dave Neslin, and 4/15/09 letter from Steve Tarlton to Jack Craig), CDPHE remains convinced that The Sampling, Analysis and Monitoring Program and associated permit conditions articulated in the *COGCC December 21, 2007 Policy "Action on Applications for Permits to Drill At locations from One-Half Mile to Three Miles From the Project Rulison Blast Site"* are a necessary component of drilling activity within 3 miles and up to ½ mile from the blast site. The draft Path Forward document does not change this view because it still relies on a DOE modeling approach based almost entirely on previous modeling, and depends heavily on assumptions and little actual data. More specifically, DOE's "modeling-only approach" includes dated estimates (based on old models and limited data) of the initial blast characteristics and fracture lengths. In recent years, hydro-fracturing (fracking) technology has significantly improved, allowing for greater fracking distances. This means that more current data regarding the "reach" of fracking would render more accurate predictions of where it is safe to drill in the Rulison area.	DOE understands that CDPHE is in agreement with the Sampling and Analysis Plan overseen by COGCC (the COGCC SAP) as well as with the policy action published by COGCC. DOE did not intend for the Path Forward to replace or contradict the actions of COGCC. DOE developed the document as a starting point or basis for discussions with the Colorado State regulators and other interested stakeholders in response to increased drilling near the blast site. DOE makes use of several kinds of data to conduct the modeling. To the maximum extent possible, these data are taken from information that is specific to either the Rulison site or the Williams Fork Formation within the Piceance Basin. For example, the geometry of the cavity and chimney created by the nuclear test and the test-related fractures surrounding these features are based on analyses of data collected from the reentry well. The reentry well testing results are also used to identify which radionuclides are potentially mobile at the site and the concentrations that were measured after the nuclear test was conducted. In addition, permeabilities and porosities used in the model to represent sandstones and shales in the Williams Fork Formation are based on reported results from testing of wells drilled into the Williams Fork Formation. Further, the gas production rates and volumes

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			employed in the model are based on data reported by the industry for multiple wells in the Piceance Basin. In the case of other model parameters, there is no site-, formation-, or basin-specific information that can be developed quantitatively to represent them. In these cases, the model inputs are based on data from sites having subsurface features similar to those of the Rulison site. The observation-based estimates of cavity, chimney, and test-related fracture properties are not affected by recent technological advances in hydrofracturing. DOE acknowledges that hydrofracturing technology has improved and could continue to improve so that hydrofracturing distances in the future could increase beyond those currently measured using microseismic surveys. However, intrusion of hydrofractures into Lot 11 is explicitly prohibited in DOE's Institutional Controls for the subsurface. The Path Forward also recommends that microseismic surveys be required in any wells completed in Lots 10 and 12, which lie to the east and west, respectively, of Lot 11. Furthermore, if a microseismic survey associated with a production well indicates that fracture movement has occurred within Lot 11 due to hydrofracturing processes at the well, DOE recommends that the well should not be given a permit for operation.
5	General CDPHE 5	CDPHE also wishes to reaffirm the importance of the Sampling and Analysis Program (SAP) as it is currently designed. This important tool not only assists with generating actual data necessary to better understand the nature of the Rulison blast site, it provided assurances that public health, safety, and the environment will not be compromised by gas drilling between ½ and 3 miles of the blast site. CDPHE agrees that future evaluation of this data may support a modification to the SAP and associated conditions of operations imposed on gas development companies by the COGCC in its *December 21, 2007 Policy "Action on Applications for Permits to Drill At locations from One-Half Mile to Three Miles From the Project Rulison Blast Site".*	DOE acknowledges that CDPHE affirms the importance of the SAP overseen by COGCC and agrees that the SAP might benefit from future modifications in response to collected data. Given that available information indicates that the effects of the blast (chimney creation, nuclear fracture extent) were limited to a subsurface volume underlying just a portion of Lot 11, it is not clear that the data collected between ½ and 3 miles from the test point will assist in providing a better understanding of the nature of the blast site.

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6	General CDPHE 6	CDPHE also recommends that DOE define its decision process for reaching a Final Agency Action regarding the exclusion zone surrounding the blast site. The process should include a schedule and a description of the data and data collection efforts required to reach a final decision.	DOE has determined that the current institutional control area consisting of Lot 11 is protective of public health and safety, and that the Path Forward represents the best approach for confirming that production wells outside of Lot 11 will not encounter test-related contamination. DOE developed the Path Forward as a starting point or basis for discussions with the Colorado State regulators and other interested stakeholders in response to increased drilling near the blast site. DOE was not required to develop the Path Forward document and, therefore, did not follow NEPA procedures. The Path Forward is not intended as a Final Agency Action.
7	Rulison Property Owners – General 1	First, we would like to say that you advised our lawyer, Mr. Luke Danielson, when you met with him over 18 months ago that the landowners would have participation in the draft of this document. You said there would be meetings with the DOE staff and transparency as to what was taking place between the DOE, the industry, and the COGCC. Mr. Danielson tried numerous times to contact you by phone and by letters to set up one of these meetings. As far as we know, you never acknowledged any of these contacts. So much for participation and transparency.	DOE has encouraged the participation of all potential stakeholders in Rulison site activities. The presentation of the draft Path Forward and solicitation of comments provide the opportunity for stakeholder input. The comments that you have provided on the draft version of the document are being taken into consideration in development of a final version of the Path Forward. DOE is unaware of any contact from Mr. Danielson that was not acknowledged.
8	Rulison Property Owners – General 2	The DOE and the COGCC have developed a pattern over the years of working behind closed doors, backroom meetings, and private correspondence to conceal vital information, even to the extent of "cover ups" (we have proof), and to get your game plan together to benefit the industry.	Consistent with federal requirements, DOE has made available to the public all information relevant to Rulison site activities (via the website or by contacting the DOE Office of Legacy Management [LM]). DOE is conducting itself in a manner that is consistent with the primary objective of its mission, which is to protect human health and the environment. DOE believes that the steps it is taking are in the interest of all stakeholders.
9	Rulison Property Owners – General 3	The DOE has had to seek support from other Colorado State agencies and Institutions in hopes that "it might buy a little more credibility" (your words) to your model studies and make them more believable. But, if the findings, research, and recommendations do not benefit your cause, they are dismissed. One such recommendation was a safe zone for the Rulison Blast site to be 1/2 mile plus 1500 feet. Now you are recommending drilling to take place right up to the 40-acre lot.	DOE's goal is to keep COGCC, CDPHE, and other stakeholders apprised with regard to DOE activities on the Rulison project. The Office of Legacy Management appreciates the reviews that have been provided on the model to date. DOE believes that the legacy effects of the Rulison test are limited to parts of the Williams Fork Formation that is currently under institutional controls. Therefore, DOE cannot currently support the recommendation of a safe zone of the extent described in

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		Your reasoning being industry can drill until they find contamination.	this comment. DOE believes that the probability of gas developers detecting test-related contamination in wells drilled outside of Lot 11 is very small.
10	Rulison Property Owners – General 4	One landowner, Wesley Kent, did have about a 45 minute conversation with Ms. Judy Miller, your Public Relations personnel, on July 29th. Basically, he was told the Path Forward draft was developed from the industry's findings and had to be relied upon, along with the DOE's findings. Ms. Miller also said unless we had any new information to present to the DOE from our experts, our information was not relevant. The information our expert scientists had presented, and the DOE had reviewed, was editorial findings.	The draft Path Forward was developed incorporating all technical sources (including that of the gas development industry) available. DOE's intent for the Path Forward document was for it to serve as a recommendation for consideration by the agencies and other stakeholders. Comments from all stakeholders are welcomed.
11	Rulison Property Owners – General 5	Where are the DOE's scientific studies of the Rulison site? The DOE's information are "model studies," they are not factual findings on Rulison. The DOE doesn't want to use their funds to find the facts, they want the industry to "play chicken" with our lives, health and welfare, and our lands. Then if "something happens" like a contamination, the DOE will come in and clean it up like they do everywhere else and spend millions of the taxpayers dollars. Does that sound familiar?	DOE has used all available scientific information to develop the Path Forward. As previously discussed, well drilling beneath the footprint of Lot 11 would not add significantly to the information already incorporated by DOE in its approach proposed for the Rulison project. As stated in the response to the comment under Item 1, the area monitored by a single conventional well would be extremely limited due to very low permeability of the rocks penetrated by such a well. In addition, hydrofracturing of a characterization well is not recommended because such an action has the potential to mobilize any contamination that might currently be immobile, potentially spreading test-related radionuclides to currently uncontaminated areas. DOE's goal is to protect human health and the environment at all of its sites. It is DOE's position that the recommended Path Forward (staged, conservative drilling approach by the gas development industry) is protective of human health and the environment and optimizes the use of taxpayer money. Existing knowledge regarding the dimensions of the nuclear test chimney and surrounding test-related fractures indicates that gas production wells drilled in areas surrounding Lot 11 consistent with institutional control conditions should not result in human or environmental exposures to test-related contamination.

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			The purpose of the monitoring supported in the Path Forward is to minimize impacts in the unlikely event that contamination is detected. There would be little, if any, material at land surface present in concentrations requiring remediation. It is important to note that cleanup of test-related contamination from the deeply buried subsurface cavity is technically infeasible; any attempt to remove contamination from the cavity area and bring it to the surface would pose a threat to human health and the environment.
12	Rulison Property Owners – General 6	The DOE's Path Forward document has done nothing to diminish any of our fears. The industry's SAP has done nothing to diminish any of our fears. If anything, over the past four years we have only learned more about how the DOE, the COGCC, and the industry work together to accomplish what benefits each the most at the cost of the taxpayers.	DOE's primary responsibility is to protect human health and safety. DOE is attempting to find solutions to Rulison site issues that are beneficial to all stakeholders, including property owners on or near the site. DOE is also mindful of the fact that its activities and recommendations affect government spending and, therefore, taxpayers.
13	Rulison Property Owners – General 7	This is what the landowners request from the DOE: 1. The **DOE is not permitted**, from this date forward, to have access to the lands of these three landowners for **any purpose** including the purpose of collecting water samples.	DOE fully understands this request and is willing to discuss the issue with the property owners in the interest of working toward a compromise. Note that DOE-sponsored collection of water samples on properties overlying and near the Rulison site is a service provided in the interest of confirming that no contamination is present in the shallow subsurface.

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14	Rulison Property Owners – General 8	(Additional request by property owners) 2. All testing of water, soil, etc. must be conducted by the Environmental Protection Agency.	Under a Long-Term Hydrologic Monitoring Program established by the DOE Office of Environmental Management, the U.S. Environmental Protection Agency (EPA) has traditionally conducted the sampling and analysis of shallow water sources (shallow wells, stream water, springs, etc.) in the vicinity of the Rulison site and surrounding areas. The contractual responsibility for the water sampling was handed over to LM a few years ago, and the samples are collected by highly trained and competent DOE contractors. It should be stressed that EPA still performs all of the analyses of the water samples, and DOE has no influence on the analytical results that EPA produces. The gas and water samples that DOE collects from gas production wells being drilled in the vicinity of the Rulison site are analyzed by DOE-contracted laboratories. DOE is willing to discuss this request further with the property owners in the interest of working toward a solution to their concerns.
15	Rulison Property Owners – General 9	(Additional request by property owners) 3. We request a testing of the topsoil be conducted by the EPA on Lot 11 and the Warren's property for radioactive contamination. Topsoil has been disturbed during the cleanup phase by the DOE in 1994 on Lot 11 from a previous contamination. Topsoil has been disturbed by the oil and gas industry building a road adjoining Lot 11 where the 455 million cubic feet of radioactive gas was flared after the nuclear blast. Topsoil was disturbed and various cables, barrels, and other trash from the work site of the Rulison blast was discovered buried when the Weldons were excavating for the basement of their home. Warrens have had topsoil disturbed due to well pads being established just inside the 3-mile radius which joins their property, pipelines being dug, roads beings established, and large rigs continuously stirring up the dust. A staging area was located on the Warrens property and adjoining the Warrens property while Project Rulison was being conducted. No testing of the soil has been conducted, to our knowledge, of	Surface cleanup at the site, including soils affected by Rulison underground test activities, was completed in 1998, and the CDPHE officially certified that the surface cleanup was complete in that same year. Preceding that activity, there was a detailed site cleanup operation after the gas-testing activities at the site ended. Radioactively contaminated materials and equipment were packaged and removed for burial at a waste facility in Nevada. Concurrent with the facility and equipment decontamination and removal were site radiologic surveys involving sampling and analysis of soil, vegetation, water, and air. The only radionuclide of concern was tritium in surface soil moisture. Concentrations in most cases were negligible, and in no case greater than a fraction of the guideline. The conclusion was that there was nothing to prevent the site from being returned to unrestricted use, subject to the drilling restrictions. Detailed information is available in the *Rulison Site Cleanup Repor*t, 1973, by the

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		any of the soil in this 3-mile area or since the actual flaring of the 455 million cubic feet of radioactive gas on Lot 11 or the 3-mile radius. We would like this done as soon as possible.	US Atomic Energy Commission (AEC) (report NVO-136), which is available on the LM Rulison website. Another report describing the surface cleanup is the *Radiation Contamination Clearance Report*, 1977, by Eberline Instrument Corp. DOE would prefer to discuss with the property owners the concerns that they have regarding soil sampling in the vicinity of the Rulison site. If there are legitimate issues regarding legacy soil contamination in the area, DOE would like to remedy those issues, including resampling of soil if necessary.
16	Rulison Property Owners – General 10	(Additional request by property owners) 4. A written document from the DOE to each individual landowner, not a "blanket document", within the 3-mile radius that can be recorded in the Garfield County records stating that the DOE will be responsible for any damages caused to human health and welfare, the DOE will be responsible for any damages caused to the water supply and soil to these lands, and the DOE will be responsible for any damages caused to the environment within this 3-mile radius. The purpose of this request: A. The AEC, now the DOE, were the responsible agencies who conducted this project in 1969 B. The DOE is the responsible agency who declares information on this site to remain classified C. The DOE is the responsible agency who refuses to conduct scientific studies to obtain factual information before allowing drilling in this area and before **declaring** this area safe to drill D. The DOE will remain the responsible party years after the oil and gas industry have left their ruins This document stating the DOE's responsibility will give the landowners an official document to present a purchaser should they decide to sell their property. If drilling is allowed under the circumstances outlined in the DOE's draft Path Forward, the	DOE has stated on numerous occasions that the federal government would retain ownership and responsibility for contaminants associated with the Rulison detonation. DOE will continue to regularly monitor surface water, water produced from natural gas exploration and development, and natural gas from wells near the Rulison site to ensure protection of public health and the environment. DOE does not intend to send individual letters to landowners stating this position. DOE understands that some of the technical data associated with the Rulison detonation remains classified under directives for national security. As stated in several public meetings, these data have no bearing on either the potential spatial distribution of radionuclides in the subsurface caused by the 1969 blast or any surface contamination related to test activities. DOE has also stated that these data will likely remain classified. Following the detonation, the AEC conducted extensive tests to determine the volume of gas the detonation released from the formation, the amount of contamination in the natural gas and water, and the size of the blast cavity and test-generated fractures. Upon completion of a third and final stage of gas production and flaring from the reentry well, analysis of the gas indicated little to no contamination by radionuclides other than tritium. This

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		landowners couldn't give their property away. Who would want to live on top of a nuclear blast site with hundreds of natural gas wells being fractured within feet of a 1969 nuclear blast site?	meant that (with the exception of tritium), the cavity, chimney, and fractures were being recharged with clean, non-contaminated gas from surrounding rock. During the 40 years following shutdown of the test project, DOE has monitored surrounding groundwater and surface water. In recent years, DOE has also monitored the natural gas and water produced at industry production wells. No Rulison-related contamination has been found in any of the collected samples. The Path Forward recommends continued monitoring of gas production wells as they are drilled and produced, using a conservative technical approach of sequential drilling and extensive sampling. Many landowners with surface rights in the vicinity of the Rulison site purchased their respective properties following the underground test. The owners of subsurface mineral rights have their rights protected by state laws and regulations. The Path Forward has been developed in the interest of protecting all rights of property owners near the site. DOE will provide technical support to COGCC when it begins hearings in response to applications for drilling within the ½-mile hearing zone. This support includes, but is not limited to, presentation of analytical monitoring data, modeling results, updated risk evaluations, and recommendations for the location sequence of new gas wells. DOE will also work to ensure that the rights and concerns of all stakeholders, including property owners, will be addressed during the hearing processes. As part of DOE's commitment to long-term surveillance, this work will include continued monitoring of natural gas, produced water, and groundwater.

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17	Rulison Property Owners – General 11	(Additional request by property owners) 5. A **minimum** no drill zone of one-half mile **plus 1500 feet** established, documented, and recorded in the Garfield County Courthouse. There have been many experts obtained by Garfield County, the landowners, and the lawyers who have stated this is a minimum safe zone. The DOE should compensate the mineral right owners for any minerals within this area.	On the basis of data collected during testing of the Rulison reentry well and many other types of information, including the stipulation that hydrofracturing into Lot 11 will not be allowed, DOE is confident that the institutional control area comprising a subsurface volume below Lot 11 is protective of human health and the environment. The Path Forward is consistent with DOE's assessment of subsurface conditions at the site.
18	Rulison Property Owners – General 12	(Additional request by property owners) 6. Any well dug outside this "safe zone" should be allowed enough time for its natural gas to migrate to the well head from its farthest fracture zone while being monitored in real time before another well is dug within this Lot. As the draft Path Forward is written now, monitoring productions at these well heads at the time of completion of drilling the well is not an accurate reading for a contamination. This monitoring procedure only tests what is brought up immediately from the drill site, not what will be migrating to the well head from fractures caused by the drilling process or what fractures might have been penetrated from the nuclear blast site. An expert in this field could determine a reasonable period of time for this migration.	Agreed. Monitoring of gas and water produced at a well potentially affected by the blast should continue for a period sufficient to analyze fluids located in the farthest portions of the well's hydrofractures. DOE also agrees that experts in the field of gas production and gas reservoir analysis could determine the production time that would be necessary to meet this objective. DOE believes that monitoring at wells over periods of years should be conducted optimally (i.e., it would not make sense to perform long-term [decades], continued monitoring at a well located a mile away from the blast site if one or more producing wells located directly between the site and that well are also being monitored). The Path Forward forms a basis from which concerns regarding future, long-term monitoring of gas production wells can be addressed.
19	Document-Specific by CDPHE 1	In several places DOE emphasizes the lack of vertical movement of contaminants. DOE has commented that surface and groundwater data collection near the blast site supports the conclusion regarding the limitation of vertical movement. However, this data does not support the assumption of the long term integrity of the plugs used in the emplacement and reentry borings. What data exists to support the long term integrity of these plugs?	Microseismic monitoring of hydrofracturing phenomena demonstrates limited vertical movement between sandstone lenses. Accordingly, the gas collected from a particular vertical interval of a perforated well is not expected to originate in overlying or underlying sandstone intervals. Such data and observations explain why a production well completed in Lot 11 above a depth of 6,000 feet, should such a well be constructed, would not be expected to induce upward flow of test-related contamination. It is noteworthy that the cement plugs in the emplacement well are very extensive; about 5,900 vertical feet of cement

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			was used to isolate the emplacement boring, and 7,500 feet of cement was pumped into the reentry well boring above a plug set at a depth of 7,515 feet. COGCC regulations require that the cement plug in an abandoned well extend a minimum of 50 feet above the top of any formation that is to be protected. The cement plug in the reentry well extended from ground surface to about 500 feet below the top of the Williams Fork formation. The cement plug in the emplacement well extended from ground surface to a depth of 5,875 feet. The excessively large weight of cement in each borehole during its plugging would have forced cement far into any perforations or other irregularities in the borehole casing.
20	Document-Specific by CDPHE 2	DOE appears to assume that vitrification of contaminants during and immediately following the blast accounts for the immobilization of a large amount of the contamination not vented. What data exists to support the contention that contaminants will not escape the vitrified material over time, and what data exists regarding the integrity of the vitrified material itself over time?	Numerous studies of underground tests at the Nevada Test Site provide supporting data for DOE's conclusion that most of the radionuclide contamination generated by the nuclear test is entrained in vitrified material at the base of the blast cavity (referred to as a melt glass puddle). Scientific analyses of melt glass do not indicate that the entrained contaminants are completely immobile; gradual dissolution of the material into subsurface water can occur in cases where groundwater (saturated zone water) flows around the melt glass. However, these scientific studies have shown that the rate of dissolution of melt glass is extremely low, which minimizes concentrations of dissolved contaminants. Even in water samples collected from drill holes into cavities and very near cavities, the only radionuclide consistently measured above its maximum contaminant level is tritium. Similarly, predictions of contaminant migration in groundwater over a 1,000-year time frame at the Nevada Test Site find that only nonvitrified radionuclides (principally tritium and carbon-14) are significant. At Rulison, with the William Fork unsaturated (the rock pores contain both gas and water), the water is essentially immobile, effectively eliminating the possibility of dissolution and transport of vitrified material in the foreseeable future.

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			A number of publications can be examined for more information. Three places to start are: (1) Tompson et al (editors), 1999. *Evaluation of the Hydrologic Source Term from Underground Nuclear Tests in Frenchman Flat at the NTS: The Cambric Test*, Lawrence Livermore National Lab, UCRL-ID-132300. (2) Pawloski et al. (editors), 2001. *Evaluation of the Hydrologic Source Term from Underground Nuclear Tests on Pahute Mesa at the Nevada Test Site: The Cheshire Test*, Lawrence Livermore National Lab, UCRL-ID-147023. (3) Zavarin et al., 2004. *Nuclear Melt Glass Dissolution and Secondary Mineral Precipitation at 40 to 200 ºC*, Lawrence Livermore National Lab, UCRL-TR-204870. These also contain many pertinent references themselves, and work continues for the Nevada Test Site on this topic.
21	Document-Specific by CDPHE 3	Section 2.1 notes that more Carbon-14 was released in the production test than was predicted by the pre-blast modeling of the radionuclide production from the blast. At first glance, this appears to indicate that the pre-blast modeling could have underestimated the amount of radionuclides generated by the blast. If so, the calculation of the radionuclide material remaining in the blast zone following the production test could be significantly different from that used in the modeling supporting the current assessment of migration potential.	Table 1 in the Path Forward lists a revised (corrected) estimate of the curies of carbon-14 generated by the test. This value is only slightly less than the observed number of curies removed during production testing. Note that estimates of radionuclide inventories are, by their nature, likely to differ from actual inventories. One of the benefits derived from the post-test gas production and flaring was a more accurate estimate of the amount of each radionuclide produced by the test. The source term used in the DOE model of tritium transport was based on the results of the reentry well testing.
22	Document-Specific by CDPHE 4	Other reviewers expressed the concern that contaminated material from the blast existed at some distance from the blast center, and this distance was not accounted for in the current DOE model. It was stated at a public meeting that “prompt injection” concerns could be discounted since the production test would have pulled the injected material back into the cavity. However, if the original pre-blast model is in error as noted above, the initial amount of material subject to “prompt injection” could have been greater and its retrieval in the production test less assured. The CDPHE has serious	The DOE model effectively accounts for any tritium that may have been placed outside the cavity by prompt injection at the time of the detonation. The maximum distance from the blast center over which prompt injection could have occurred was the radius of test-generated fractures, which reentry well testing indicated was about 2.75 cavity radii, or 209 feet. All simulations conducted with the DOE model show that gaseous diffusion causes the tritium to migrate to the outer edge of the nuclear fractured zone (262 ft in the model due to discretization constraints) within several years from the time of the

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		concerns about the assumptions being made about the behavior of prompt-injection materials.	detonation (zero time). Accordingly, prompt injection effects are appropriately accounted for in simulations extending over several decades. The DOE model is also conservative in that it assumes that pressures in the chimney had returned to pre-production testing levels at zero time in the simulations. In fact, pressures in the chimney are likely to have remained much lower than pressures in areas surrounding the detonation for many years, and may still be lower than pre-test pressures. This pressure sink likely caused any prompt-injection tritium, if any existed, to migrate back toward the chimney, rather than diffuse outward as conservatively simulated in the model.
23	Document-Specific by CDPHE 5	We remain concerned that the narrow focus in the modeling and related risk assessment on tritium ignores radionuclides that could potentially be released over time that would present a greater hazard. Is there long term migration data available from earlier underground testing that could at least partially address this concern?	Text is presented in the Path Forward to provide the rationale for why tritium is the long-term constituent of concern at the Rulison site, as reflected in the modeling efforts. The text incorporates information from available studies of radionuclide transport at underground nuclear test sites on the Nevada Test Site.
24	Document-Specific by Rulison Property Owners 1	Page 7: "DOE is currently developing it (should be its) own sampling and analysis plan (SAP) to supplement the industry plan." Why is the DOE developing a sampling and analysis plan if all of us are suppose to have faith in the industry's SAP that the landowners forced them to implement?	The DOE monitoring plan is designed to be a stand-alone plan but is sufficiently flexible to supplement the industry plan rather than be redundant. DOE's plan proposes to sample more frequently than required in the industry plan and includes a few additional measures of radionuclides. DOE's plan also focuses on areas relatively close to Lot 11. DOE's monitoring validates the results of the industry's plan and, at the same time, demonstrates that the radionuclides monitored by the industry serve as adequate indicators of subsurface conditions in areas closest to Lot 11. This approach increases the utility of the results reported by the industry as indicators of how protective conditions are at the Rulison site relative to ongoing well-drilling activities.
25	Document-Specific by Rulison Property Owners 2	The report on the SAP audit of the first year's monitoring of these wells within the 3-mile radius last March, showed less than 3/4 of their samples were valid and could even be tested. The COGCC hadn't read these report and was not aware of the invalid samples. The scientist reporting didn't have the	DOE is unaware of the invalid samples referred to in this comment, and understands from URS Corporation, who prepared the industry plan, that all samples are valid. DOE is concerned that there may be some confusion about the status of the samples that have been collected and

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		information on invalid samples, he only had information on the valid samples. Does the DOE plan to go on site and test these wells with their "supplemental plan"? If so, will we know the results of these tests?	analyzed, and that this confusion may have led to an erroneous conclusion that many samples were invalid. In particular, radionuclides were reported as below detection limit (non-detects) in many of the samples. It is possible that these non-detects have been misinterpreted as data that are not useful. In fact, constituents may sometimes be present in fluids, but they occur at very low concentrations that are below the detection limits of state-of-the-art analytical laboratory methods and, therefore, are reported as non-detects. Non-detects are valid results and indicate that constituents are not present in concentrations that would be of concern.
26	Document-Specific by Rulison Property Owners 3	Is the reason the DOE is developing its own sampling and analysis plan (SAP) because you have an underlying fear of a contamination, just like we do?	As stated in the response to a previous comment, DOE's monitoring plan supplements the industry plan. Monitoring is an important part of DOE's overall site management strategy. DOE is not relying solely on modeling predictions or institutional controls; it believes monitoring is an important component of responsible management given the uncertainties inherent in predictions of future processes. Long-term site management has three important pillars: scientific predictions, institutional controls, and monitoring.
27	Document-Specific by Rulison Property Owners 4	In general, the terminology is very vague throughout this document. A few statements are very clear. Page ii: Last paragraph: "staged drilling approach...minimizes the **likelihood of encountering contamination".** ..."collecting data from wells outside of the half-mile zone...at low **contamination probability locations** and then moving inward." ...."DOE's recommendation for **drilling while allowing collection of additional data to confirm that contamination is contained within the 40-acre institutional control boundary**." This just tells us the DOE does not know what lies where so let the industry in there and let them drill to confirm what we think **"might"** be true. The people who live in this area, walk on the soil, and drink the water, they will just have to wait and see what the outcome brings.	DOE acknowledges that the current, exact spatial distribution of radionuclide contamination is uncertain. However, analyses of the data that are available (such as the reentry well production data) do indicate that it is contained within the Williams Fork Formation beneath Lot 11.

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28	Document-Specific by Rulison Property Owners 5	Page 11: "Conducting a microseismic survey during the hydrofracturing of **one** of the half-mile wells could be considered to confirm fracture orientation from the dipole sonic logs and to estimate hydrofracture distance." Why not make this a requirement and on more than "one" well? "Collecting rock core from above, within, and below the detonation horizon, at **one** of the half-mile wells could also be considered to show that the formations opposite the detonation depth were not materially affected by the blast." Again, why not make this a requirement and on more than one well? We would think the more information obtained, the better off we all would be.	The combination of a microseismic survey conducted at one well and dipole sonic logs at multiple wells is expected to be more than adequate for determining natural fracture orientation in areas surrounding the Rulison site. The Path Forward does recommend that a microseismic survey be conducted at any well completed beneath either Lot 10 or Lot 12, located, respectively, on the east and west sides of Lot 11.
29	Document-Specific by Rulison Property Owners 6	Page 14: These statements only confirm to us that you know there is risk to drilling around this nuclear blast site. "To ensure that the initial wells are drilled in the **least likely transport direction**, it is also recommended that the natural fracture orientation in the vicinity of the Rulison site be confirmed by the best available technology on at least one of the half-mile wells **before drilling within the half-mile radius is allowed**. Subsequent wells could then be installed in a sequence that gradually approaches the **higher-risk transport direction**, currently **believed** to be **roughly** east-west of the site." These statements really gives us assurance!	These statements acknowledge that, despite the fact that the natural fracture orientation in the Williams Fork Formation of about east-west is observed almost everywhere within the Piceance Basin, which includes the Rulison site, it is a common-sense precaution to test wells like the half-mile wells to confirm that the same fracture orientation is also observed near the site.
30	Document-Specific by Rulison Property Owners 7	The DOE's Path Forward document has done nothing to diminish any of our fears. The industry's SAP has done nothing to diminish any of our fears. If anything, over the past four years we have only learned more about how the DOE, the COGCC, and the industry work together to accomplish what benefits each the most at the cost of the taxpayers.	DOE's objective is to protect human health and the environment, and its intent has always been to provide solutions that are beneficial to all stakeholders (in particular, the Rulison-area property owners, the gas industry, COGCC, and Garfield County). DOE has taken into account all available technical information in developing a science-based and cost-effective approach for the Rulison project.
31	Document Specific by Randy Fricke 1	"Rulison Path Forward" recommends that it is safe to drill for natural gas within close proximity to this nuclear blast site. Suggesting that drilling within three miles of this site is safe is totally ridiculous and extremely irresponsible. It is very upsetting to me and to many other citizens that the Dept. of Energy is promoting gas drilling very close to this nuclear blast site through this document. The Dept. of Energy is using a scientific model only to gauge or estimate the safety of drilling	For the past 40 years following the detonation, DOE has been collecting analytical data from groundwater and surface water. In recent years, DOE has also collected analytical data from drilling fluids, condensed water vapor, and natural gas within the 3-mile notification zone around the Rulison site. Analysis of the various media has not shown any Rulison-related contaminants. DOE and EPA adhered to stringent sampling protocols and used

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		next to the Rulison Blast Site. DOE has gone to great lengths to document their analysis. None of this data or using a computer modeling makes me very warm and fuzzy about gas drilling near a nuclear blast site. The report does not explain clearly what the four production test wells actually performed between October 1970 and August 1971. The reports state that these test wells ".....produced a total of 455 million standard cubic feet of natural gas". The report mentions in the next sentence (Page 2) states "......the volume of gas generated....." So, if 455 million cubic feet of natural gas was generated, where did this radioactive gas go? Where is the accountability here by DOE? The report indicates that actual gas was extracted. Whatever the case, this report is neglible on qualifying the testing that was being performed during that time period. I contend that during this testing procedures and that during other disturbances to this site that radioactive gas escaped into the air. It is this contamination that is causing illnesses and cancer to area residents. There is no accounting in this report of any real physical frequent testing of the air quality or water quality of the blast area and surrounding areas. DOE has been highly negligent in its duty to protect the welfare and lives of United States Citizens living in this area.	independent laboratories to conduct the analyses, and all data collected to date are available on LM's website for review at any time. Current sampling and monitoring is being conducted on new and existing wells by the industry and DOE. These plans specify increased sampling frequencies as drilling activities get closer to the Rulison area. In addition to data, the LM website contains many references to testing of the natural gas produced by Project Rulison. A key document, #378268, *Project Rulison Managers Report, April 1973, HG20*, documents the testing and flaring of the natural gas. Annual monitoring reports are also posted on the LM website.
32	Randy Fricke –- General 1	I recommend that everyone look at the Hiroshima, Japan website and read the descriptions of the devastation that the U.S. Military caused there with this first big nuclear bombing. The website states, "The firestorm eventually engulfed 4.4 square miles of the city, killing anyone who had not escaped in the first minutes of the attack. The website indicates that 70,000 people were killed within this firestorm area. Of course, many thousands died later of radiation exposure and other related illnesses. So, it is well-documented that the Rulison Blast was several times bigger than Hiroshima. Then, since this is the case, the perimeter boundary for gas drilling should be at least doubled to 8.8 square mile area. I am not in favor of drilling this close to the site.	The comparison to Hiroshima is not valid for several reasons. The Rulison device was detonated 8,426 feet below the ground surface in solid rock. Volumetric calculations from the gas produced indicate that the cavity is approximately 76 feet in radius with fractures reaching out approximately 209 feet from the detonation center. At this time, DOE has no evidence that drilling should be restricted beyond the current Institutional control of 40 acres on Lot 11.
33	Randy Fricke –- General 2	Let's not repeat another Hiroshima within the United States. It is very clear that the DOE and our very own Colorado Oil & Gas Conservation Commission have a very nonchalant and careless attitude about letting gas companies drill within a half mile of the blast site. If Noble Energy or any other company	Current drilling practices, increased monitoring of existing and new gas wells, and historical monitoring show that risks from drilling outside Lot 11 but near the site are minimal.

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		makes one mistake in their drilling operations in this area, it will turn into a national disaster in a matter of seconds. What if fracturing into any of these areas near the blast site ruptures a fissure or cracks an area that is directly connected to the radioactive cavern, it could result in harmful radioactive leaks going into underground water sources or cause eruptions of radioactive gas releasing into the outside air. If the COGCC approves gas drilling permits within the three mile perimeter or up to the highly questionable half mile perimeter, this type of behavior and actions on the part of this agency becomes sheer incompetence and extreme irresponsibility.	COGCC has developed a Sampling and Analysis plan that specifies what needs to be tested, and what actions are appropriate if contamination is discovered. Under no circumstances is anyone allowed to drill into or extract material from Lot 11.
34	Randy Fricke –- General 3	I recommend that this report be destroyed and that the information it contains be totally disregarded. The lack of clarity and accountability in this report is obvious. The main fact is that a computer model of this Rulison scenario is fictional. It is not real world testing. The fact that there has been no frequent and consistent testing of the air quality and water quality of the Rulison area makes for further collateral damage. So, based on the lack of real world evidence, I implore the DOE and the COGCC to stop the drilling near or within 20 mile radius of the blast site. Where is the concern by these governmental agencies for the health and welfare of its citizens? I do not see it here.	DOE's Path Forward recommendations are consistent with technical information gathered at the time of the detonation and subsequent monitoring for the past 40 years. DOE is recommending that stakeholders with mineral rights be allowed to exercise their respective options to obtain their natural gas from the area while monitoring continues.
35	Randy Fricke –- General 4	DOE has been terribly neglectful of its duties to physically inspect and monitor this site on a consistent basis. I will speculate that radioactive materials are flowing into underground cracks and crevices as we speak. The intense heat from such a blast could have forced radioactive materials into areas unknown to scientists and geologists. Radioactive materials or gas have probably been leaking into water sources or polluting the air since 1969. The testing on a re-entry well in 1970 and 1971 could have disturbed the radioactive gas and allowed it to escape into unknown pockets or outside of the well. There are too many unanswered questions here, not enough investigations, and no guarantees for the safety of human life at or surrounding this site. This message is for DOE, the Colorado Oil & Gas Conservation Commission, and the Garfield County Commissioners. It is my recommendation that gas drilling near the Rulison Nuclear Blast Site cease immediately and be banned forever.	DOE has tested, monitored, and restored the site following the detonation. Testing at the reentry well showed that, after the third flaring of natural gas from the chimney, mostly uncontaminated gas was being brought to the surface. The CDPHE has given the surface a "clean closure" status following the site cleanup. Analytical data from the past 40 years have shown no Rulison-related contaminants.