



# RIO BLANCO SAMPLING AND ANALYSIS PLAN

---

OPERATIONAL AND ENVIRONMENTAL  
RADIOLOGICAL MONITORING  
WITHIN A TWO-MILE RADIUS  
OF PROJECT RIO BLANCO

---

JULY 2010  
REVISION 1



PREPARED BY:

**URS**

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**REVISION 1**

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- Appendix C Example Field Forms
- Appendix D Radiological Equipment Information
- Appendix E Laboratory Analytical Data Packages
- Appendix F Summary of DOE Analytical Results

## LIST OF ACRONYMS

°C	degrees Celsius
<	less than
%	Percent
<sup>3</sup> H	Tritium
<sup>14</sup> C	carbon-14
<sup>36</sup> Cl	chlorine-36
<sup>37</sup> Ar	argon-37
<sup>39</sup> Ar	argon-39
<sup>40</sup> K	potassium-40
<sup>85</sup> Kr	krypton-85
<sup>90</sup> Sr	strontium-90
<sup>99</sup> Tc	technetium-99
<sup>125</sup> Sb	antimony-125
<sup>129</sup> I	iodine-129
<sup>137</sup> Cs	cesium-137
AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
APD	Application for Permit to Drill
API	American Petroleum Institute
C	Composite sample
CCR	Code of Colorado Regulations
CDH	Colorado Department of Health (predecessor to CDPHE)
CDPHE	Colorado Department of Public Health and Environment
CER	CER Geonuclear Corporation
CFR	Code of Federal Regulations
Ci	Curies
CL	critical level
COC	Chain-of-custody
COGCC	Colorado Oil and Gas Conservation Commission
cpm	counts per minute
cps	counts per second
D	Duplicate sample
DF	Dissolved fraction
DC	drill cuttings
DER	duplicate error ratio
DM	drilling mud sample designation
DMS	data management system
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQI	data quality indicator
DQO	data quality objective
DRI	Desert Research Institute
EDD	electronic data deliverable
EIC	Eberline Instrument Corporation
EPA	U.S. Environmental Protection Agency
FB	flowback fluid sample designation
FCG No. 1	Fawn Creek Government No. 1

**LIST OF ACRONYMS**

ft msl	feet above mean sea level
FW	fracing fluid sample designation
G	Grab sample
gpm	gallons per minute
GPS	global positioning system
GW	Groundwater
IAEA/WMO	International Atomic Energy Agency/World Meteorological Organization
IATA	International Air Transportation Association
J	estimated data qualifier
keV	thousand electron volts
LCS	laboratory control sample
LIMS	Laboratory Information Management System
LP	liquid propane
LSC	liquid scintillation counter
MDA	minimum detectable activity
MeV	million electron volts
mg/L	milligram per liter
micro R/hr	micro Roentgen per hour
MMscf	million standard cubic feet
mV	millivolt
N	tentatively identified data qualifier
NG	natural gas
NIST	National Institute of Standards and Technology
pCi/L	picocuries per liter
pMC	percent modern carbon
PPE	personnel protective equipment
PRG	preliminary remediation goal
psi	pounds per square inch
PW	produced water
QA	quality assurance
QC	quality control
R	unusable (rejected) data qualifier
RB-E-1	device emplacement borehole
RB-AR-2	alternate re-entry borehole
RL	reporting limit
RPD	relative percent difference
RSO	Radiation Safety Officer
RBSAP	Sampling and Analysis Plan
SD	standard deviation
SOP	standard operating procedure
SP	spring
SS	surface soils
SSO	Site Safety Officer
STP	standard temperature and pressure (20°C and 1 atmosphere pressure)
SU	standard uncertainty
SW	surface water
TB	trip blank
TEDE	total effective dose equivalent

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**LIST OF ACRONYMS**

TF	total fraction
TIR	tentatively identified radionuclide
TLD	thermoluminescence dosimeter
TRL	target radionuclide list
TU	tritium unit
U	nondetect data qualifier
U.S.	United States
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

# 1 INTRODUCTION

## 1.1 Sampling and Analysis Plan (RBSAP) Overview

Williams Production RMT (Williams) and other companies (EnCana Oil and Gas (USA) Inc. and Whiting Petroleum Corporation), hereafter collectively referred to as the “Companies,” in consultation with other affected working interest owners, have agreed to voluntarily prepare and submit this consolidated Rio Blanco Sampling and Analysis Plan (RBSAP) for existing and future natural gas wells whose bottom-hole locations are within a 2-mile radius of the site known as Project Rio Blanco located west of Fawn Creek in Rio Blanco County, Colorado. Project Rio Blanco is located about 36 miles northwest of Rifle and about 31 miles southwest of Meeker (Figure 1). Project Rulison, a predecessor to Project Rio Blanco, is located about 35 miles to the southeast.

Project Rio Blanco is the site of a nearly simultaneous subsurface nuclear detonation of three  $30 \pm 3$ -kiloton nuclear devices at depths of 5,838, 6,230, and 6,689 feet below ground on May 17, 1973 by the U. S. Energy Research and Development Administration (ERDA), formerly the U. S. Atomic Energy Commission (AEC), predecessor agencies to the United States Department of Energy (DOE). The test was conducted in partnership with Equity Oil Company (Equity), Continental Oil Company (Conoco), and CER Geonuclear Company (CER). The Rio Blanco nuclear test was conducted in an effort to fracture an approximately 1,300-foot section of low-permeability sandstones in the Paleocene Fort Union Formation and Cretaceous Williams Fork Formation of the Mesaverde Group to stimulate natural gas production.

The Companies, in consultation with other affected working interest owners, have voluntarily initiated development of this RBSAP and understand that implementing this RBSAP will likely become a Condition of Approval for future Applications for Permit to Drill (APDs) issued within a 2-mile radius around Project Rio Blanco. There are approximately 5 existing gas wells whose surface locations are within a 2-mile radius of the Project Rio Blanco monument at surface ground zero. There are currently no operating gas wells within a ½-mile radius of Project Rio Blanco. For RBSAP implementation purposes, radial distances from Project Rio

Blanco are henceforth referenced to the Project Rio Blanco monument at the location of the device emplacement well RB-E-1 at surface ground zero.

The Companies, in consultation with other affected working interest owners, have also voluntarily agreed to a drilling moratorium within the area between the 600-foot DOE exclusion zone and a ½-mile radius of Project Rio Blanco until additional radiological data have been collected outside of this zone to demonstrate that gas drilling, completion, and production can be safely accomplished near Project Rio Blanco. The Companies recognize that a hearing will be required before the COGCC, and COGCC approval granted, before drilling can be performed within the ½-mile radius voluntary drilling moratorium area.

The Companies also propose to include a voluntary drilling exclusion zone around the Fawn Creek Government No. 1 (FCG No. 1) well where radioactively-contaminated water produced from the Rio Blanco test well was injected into an interval between 5,360 and 6,072 feet below the ground surface. The produced water was injected in accordance with a permit issued by the State of Colorado to CER. The voluntary drilling exclusion zone around this well will be maintained until sufficient radiological data have been collected to confirm that radionuclides at the FCG No. 1 well have not migrated to producing gas wells outside this zone. Under the voluntary drilling exclusion zone around FCG No. 1, the Companies propose to limit drilling and gas production within a 600-foot radius of the FCG No. 1 well to a true vertical depth of 6,500 feet below ground surface. FCG No. 1 is also within the ½-mile voluntary drilling moratorium area discussed above. The DOE did not implement a drilling exclusion zone around FCG No. 1.

The monitoring program described in this RBSAP is designed to provide radiological characterization of the area within the Tier I and II monitoring zones and to verify that natural gas operations near Project Rio Blanco are conducted and monitored in a safe and responsible manner, reflective of the environmental health and safety needs of the Companies employees, contractors, and the public. This RBSAP has been reviewed and approved by the primary stakeholder agencies (Colorado Oil & Gas Conservation Commission [COGCC], Colorado Department of Public Health and Environment [CDPHE], the U. S. Department of Energy [DOE], and the U. S. Bureau of Land Management [BLM]) prior to its implementation.

Additionally, the monitoring approach will be reviewed annually (and possibly more frequently, if needed) by the Companies and other affected working interest owners and the primary stakeholder agencies to discuss its implementation, effectiveness, and success based on data collected each year. Modifications will be made based on these reviews, as needed, to improve the implementability and effectiveness of the monitoring approach.

A two-tiered operational and areal environmental monitoring program is presented in this RBSAP. Two operational monitoring tiers, Tiers I and II (Figure 2), are defined based on distance from the Project Rio Blanco monument at surface ground zero in the southeast quarter of the northwest quarter of the northwest quarter (SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ ) of Section 14, Township 3 South, Range 98 West. Each tier zone is divided into 12 equal sectors between the 600-foot DOE exclusion zone and 2-mile radius surrounding Project Rio Blanco, respectively.

The **operational monitoring program** is designed to screen gas drilling, completion, and production activities for the potential presence of identified Project Rio Blanco-related radionuclides within the Tier I and II monitoring zones that might pose a threat to worker safety, public health, or the environment. Because DOE has implemented institutional controls (Figure 3) at the site that prohibit subsurface intrusion within 100 feet of the Project Rio Blanco monument at surface ground zero to a true vertical depth of 1,500 feet and within 600 feet of the monument between true vertical depths of 1,500 and 7,500 feet (DOE 2005), and proposed natural gas drilling will likely occur below 1,500 feet true vertical depth, Tier I monitoring will be conducted at natural gas wells whose bottom-hole locations are between the  $\frac{1}{2}$ -mile voluntary exclusion zone and a 1-mile radius from the Project Rio Blanco monument overlying the device emplacement well RB-E-1 at surface ground zero. Tier II monitoring will be conducted at natural gas wells whose bottom-hole locations are between a 1- and 2-mile radius from the Rio Blanco test monument at surface ground zero.

The **areal environmental monitoring program** is designed to monitor groundwater and surface water quality in the Project Rio Blanco area and involves the collection and analysis of surface water and/or groundwater samples for radiological constituents from permitted water wells, adjudicated springs, or local streams. Sample sites located on private property will only

be sampled with the landowner's permission. Sampling will not be performed if permission is refused.

While performing drilling operations within the Project Rio Blanco monitoring zones (Tiers I and II), the Companies shall comply with all provisions of the most recent COGCC approved revision of the RBSAP. The Companies will also comply with all DOE Office of Legacy Management requests for sampling and analysis of natural gas and other materials associated with drilling, completion, and production.

## 1.2 RBSAP Organization

The following sections of this RBSAP define the monitoring requirements for both the operational and the areal environmental monitoring programs and provide sampling procedures, analytical methods, data quality objectives (DQOs), and quality assurance (QA) and quality control (QC) measures for the analytes monitored. Appendix A provides a Tier I radiological incident management plan that includes incident mitigation, response, and recovery procedures in the unlikely event of a radiological release during natural gas drilling, completion, or production.

This RBSAP is comprised of ten sections, including this introduction. Section 2 provides a brief overview and history of Project Rio Blanco, including a discussion of the more mobile or abundant radionuclides included in the monitoring program. Section 3 provides a brief summary of the historical and current environmental monitoring results. Section 4 summarizes the operational and areal environmental monitoring approach, including a description of the two-tiered, twelve-sector monitoring scheme designed for this RBSAP. Section 5 describes the field sampling methods and procedures. Section 6 discusses the DQOs. Section 7 summarizes the sample handling and custody requirements. Section 8 provides the analytical methods and QC requirements. Section 9 describes the data validation and usability requirements. Section 10 lists the references cited in this RBSAP. Appendix A provides a Tier I Radiological Incident Management Plan. Appendices B, C, and D provide a URS Safe Work Plan, Example Field Forms, and Radiological Equipment Information, respectively. Appendices E and F provide analytical results for produced water and natural gas collected and analyzed at several producing gas wells near Project Rio Blanco in January and February 2009.

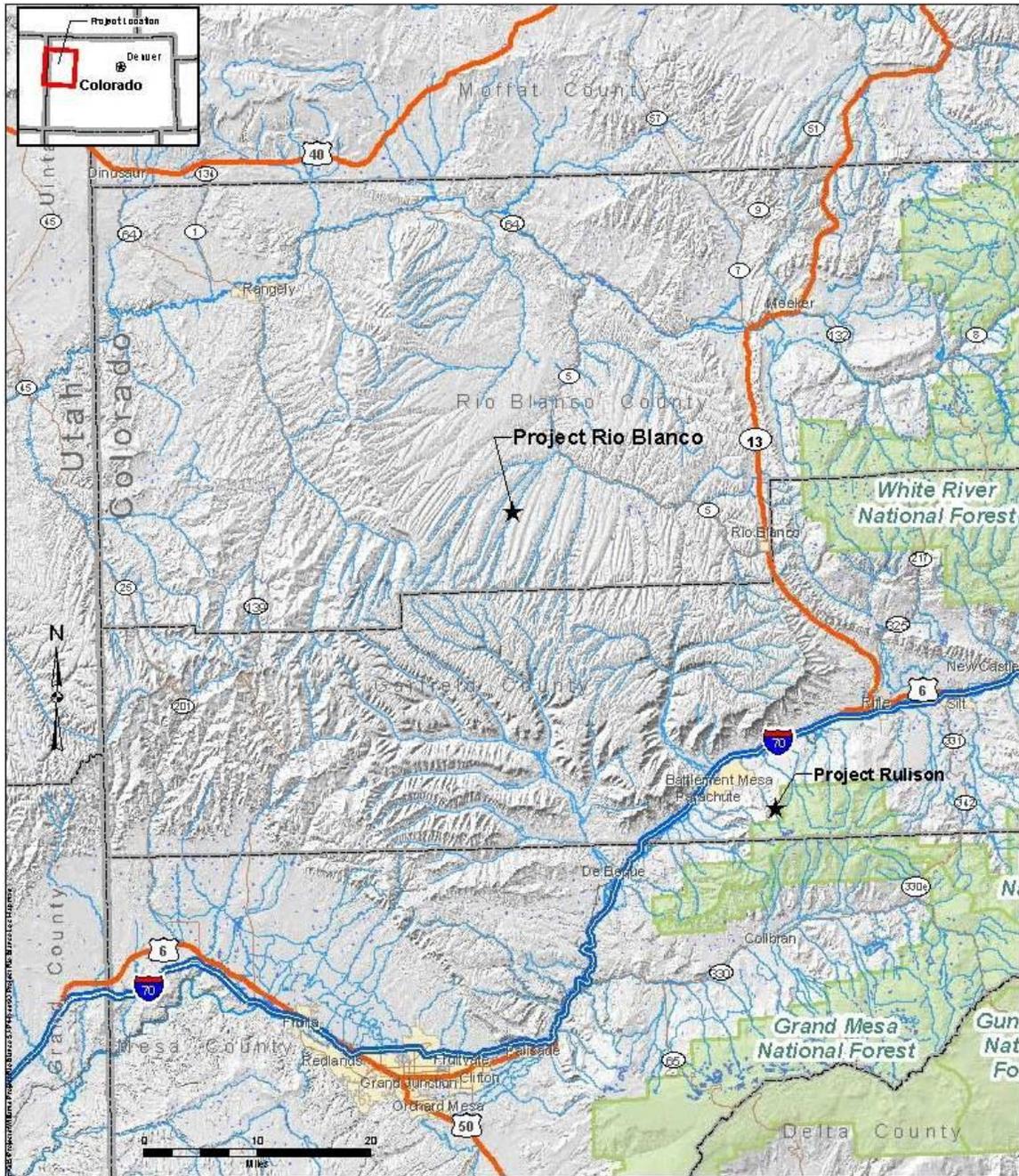
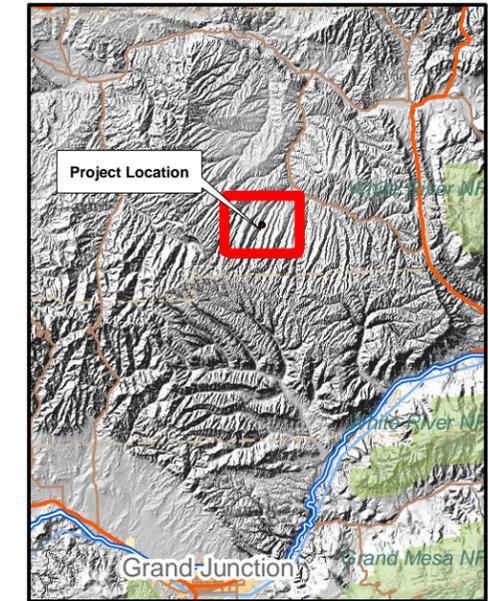
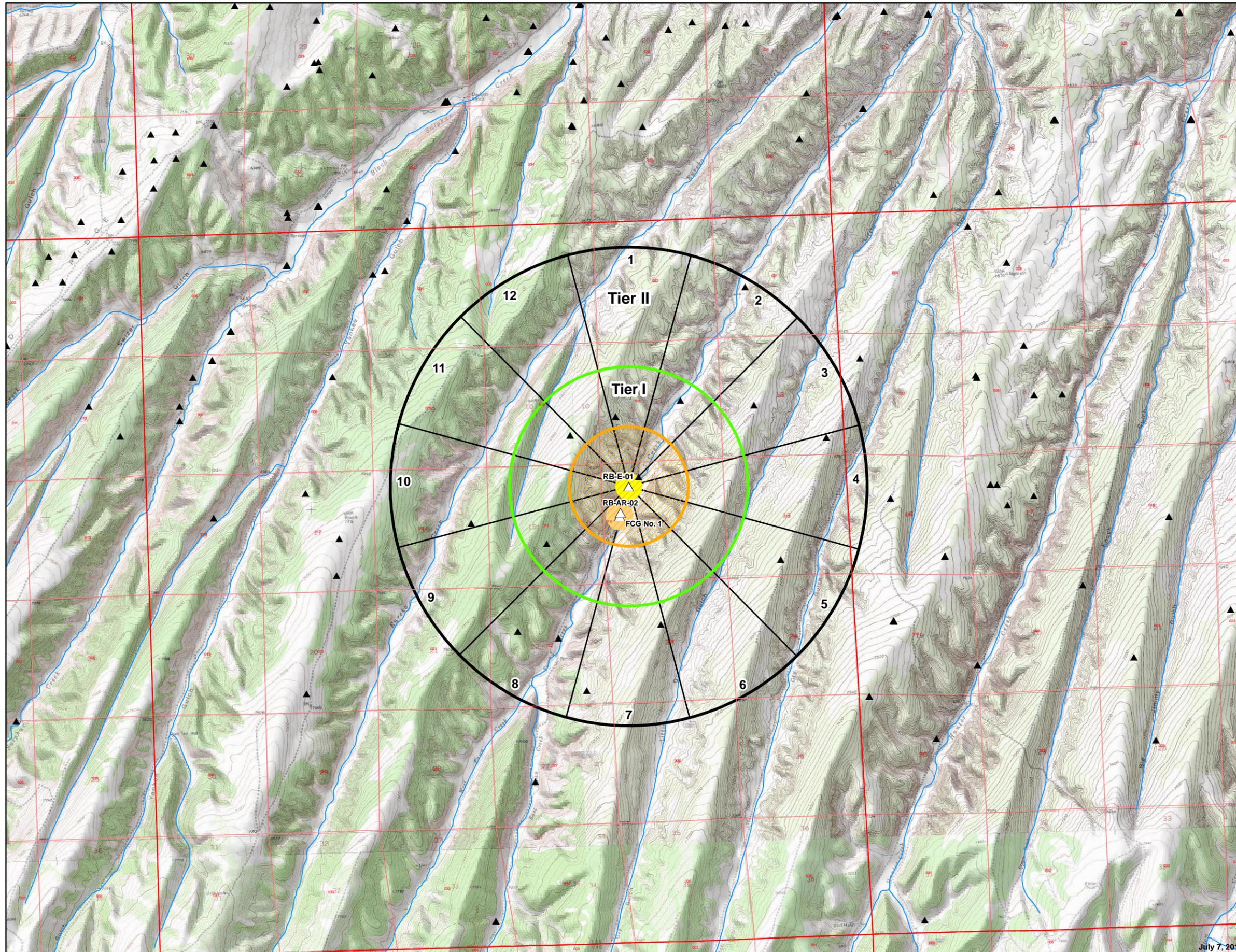
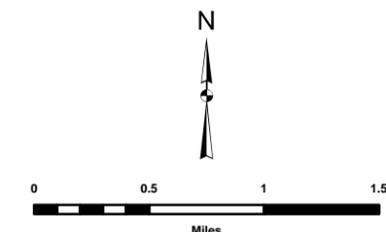


Figure 1. Project Rio Blanco Location Map.



**Legend**

- △ Project Rio Blanco Well
- ▲ Existing or Permitted Gas Well Location
- 600-Foot Radius DOE Drilling Exclusion Zone
- 600-Foot Radius Voluntary Drilling Exclusion Zone
- Half-Mile Radius with Voluntary Drilling Moratorium
- One Mile Radius
- Two-Mile Radius
- Monitoring Sectors



**Figure 2**  
**Tier I and II Monitoring Zones**  
**Project Rio Blanco**  
**Rio Blanco County**  
**Colorado**

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July 7, 2010

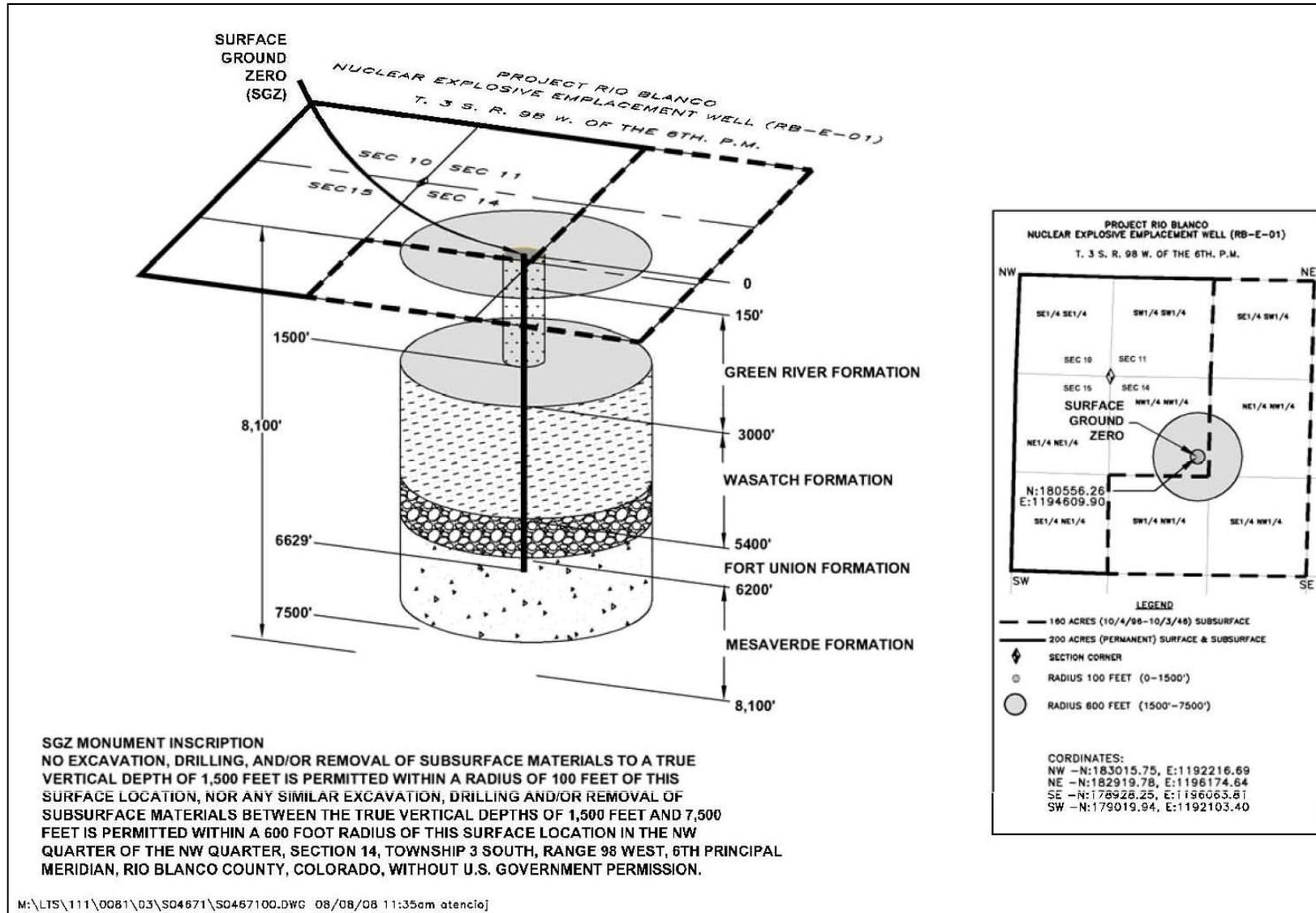


Figure 3. Project Rio Blanco Drilling Exclusion Zones (DOE 2008).

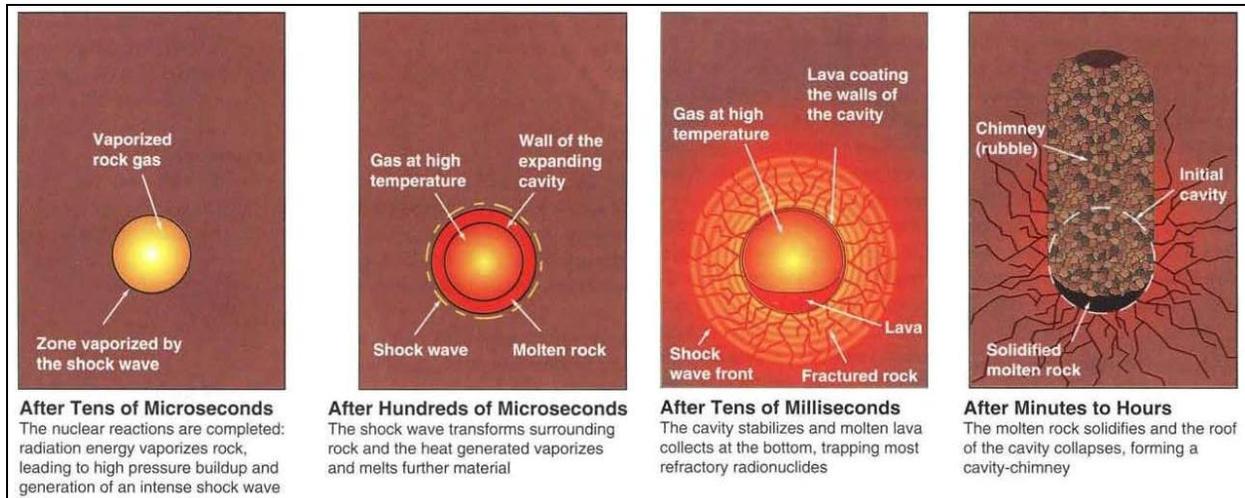
## 2 PROJECT RIO BLANCO BACKGROUND

### 2.1 Project History

Project Rio Blanco was part of a joint industry-government program conducted by the Nevada Operations Office of the ERDA, formerly the AEC, to pursue peaceful uses of nuclear explosives, sometimes referred to as the Plowshare Program. Multiple uses of nuclear explosives were investigated, such as earth moving and excavation or stimulation of natural gas production from low-permeability reservoirs. The concept for gas stimulation was to exploit the large quantity of natural gas known to exist in low-permeability reservoirs in sedimentary basins throughout the Rocky Mountain states. The creation of a large, effective wellbore and fractures in the adjacent formation using a nuclear explosive was proposed as possibly a more efficient method than using chemical explosives or hydraulic fracturing techniques (Rubin et al. 1972).

Three nuclear natural gas stimulation experiments were completed in the western U.S., with others in the planning stages before the end of the Plowshare Program in 1977. The first of the three experiments was the Gasbuggy test in the San Juan Basin in northwestern New Mexico. The second was the Rulison test in northwestern Colorado. The last was the Rio Blanco test, conducted north of Rulison, also located in northwestern Colorado. In all cases, gas production tests were conducted to evaluate the effectiveness of the nuclear stimulation. The natural gas produced, which contained some radioactive byproducts, was flared (burned on site) and was not introduced into any gathering or distribution system or otherwise used.

An underground nuclear explosion generates enormously high pressures and temperatures at the explosion source. The various nuclear explosion phases (Figure 4) occur rapidly over a few tens of milliseconds creating an initial cavity where the rocks are vaporized. As the explosion pressures rapidly subside, the rocks surrounding the cavity subsequently collapse into the underlying cavity and a chimney of rock rubble forms. Pore space within the chimney rubble is initially filled with gases generated during the explosion and is subsequently filled with formation waters and gases as hydrostatic pressures equilibrate over time.



**Figure 4. Sequence of Underground Nuclear Explosion Events (IAEA 1998).**

The industry sponsor for Project Rio Blanco was initially Equity who had gas leases in the project area. Equity engaged CER to conduct a feasibility study (CER 1970) to evaluate the prospects for nuclear stimulation of natural gas production on Equity's properties in the Piceance Basin. Equity subsequently signed a joint venture agreement with CER to proceed with the Rio Blanco project. Lawrence Livermore Laboratory (LLL), a U. S. government laboratory, was responsible for the design, emplacement, and detonation of the nuclear explosives. Conoco subsequently assumed the role of unit operator after the Rio Blanco detonation and conducted the re-entry and testing operations.

Project Rio Blanco was conducted in three phases, pre-detonation, detonation, and post-detonation (Luetkehans et al 1975):

- The pre-detonation phase consisted of drilling a device emplacement well (RB-E-1); performing pre-detonation gas production tests; and conducting geological, hydrological, and other studies for technical and safety considerations. Phase I activities were conducted between April 1970 and February 1973. The AEC removed 360 acres of land from the public domain in 1972 in anticipation of the test, including surface and subsurface rights to 200 acres, and mineral rights to an adjacent 160 acres.

- The detonation phase focused on the emplacement, detonation, and immediate effects of the uranium fission nuclear devices. Beginning on May 3, 1973, three  $30 \pm 3$ -kiloton nuclear devices were placed at depths of 5,838, 6,230, and 6,689 feet below ground in a single emplacement well, RB-E-1, through a 10.75-inch steel casing that was then filled to the surface with stemming materials to isolate the detonations from the surface. Detonation phase activities were conducted between March 1973 and May 1973. The nuclear devices were detonated nearly simultaneously at 10 A.M. on May 17, 1973 (AEC and CER 1973a and 1973b).
  
- The post-detonation phase began in September 1973 and involved drilling a boring into the nuclear chimneys created by the blast in the RB-E-1 well, followed by gas flow testing to determine the cavity sizes, interconnectivity, and post-detonation production characteristics (Woodruff and Guido 1975). The initial re-entry drilling through RB-E-1 occurred four months after the detonation so that the short-lived radioactive materials generated by the detonation decayed prior to re-entry. Drilling was initiated on September 23, 1973 and completed on October 12, 1973. A subsequent re-entry well, RB-AR-2, was drilled approximately 1,260 feet south of RB-E-1 between June and November 1974 to facilitate testing of the lower chimneys. Post-detonation gas production tests were conducted between 1973 and 1974 (ERDA and Conoco 1975). Based on a number of factors, including declining gas pressures, a smaller than predicted blast fracture extent, and isolated chimneys from each of the three detonations, the wells were shut-in and subsequently plugged and abandoned in 1976. Produced water from the re-entry tests was injected into an existing gas well FCG No.1 located approximately 1,328 feet south of surface ground zero near re-entry well RB-AR-2. The produced water was injected into an interval between 5,360 and 6,072 feet below the ground surface that spanned the Fort Union-Williams Fork Formation contact in accordance with a permit issued by the State of Colorado to CER. 23,349 barrels of produced water containing 177.9 Curies (Ci) of tritium, 4.3 milliCuries (mCi) of cesium-137, and 1 mCi of strontium-90 were injected into this zone of the well. During site cleanup, 1,341 more barrels of produced

water containing 68.5 mCi of tritium, 0.7 mCi of cesium-137, and 0.0007 mCi of strontium-90 were injected into the FCG No. 1 well

Site cleanup and restoration was initiated by the ERDA in 1975 and completed in 1976. The emplacement well, re-entry wells, and other test wells were plugged and abandoned. Subsequent site corrective action was initiated by DOE in 2000 and completed in 2003 (DOE 2000; 2000; and 2005). The corrective action investigation concluded that no gamma-emitting radionuclides at activities above background were present in site soils or waters. Risk assessment concluded that no further corrective actions were required and that no surface-use restrictions should be placed on the site. The CDPHE concurred. A permanent monument was placed at the site of surface ground zero (Figure 5) to document the test and drilling restrictions.



**Figure 5. Project Rio Blanco monument at surface ground zero.**

In September 2003, DOE issued Public Land Order 7582 to extend the withdrawal of the original 200 acres of land and 360 acres of mineral rights from the public domain for 50 years. The principal land uses in the area continue to be livestock grazing, recreation, and oil

and gas exploration. No residences exist within the immediate vicinity of the Project Rio Blanco site. The nearest permanent residences are located approximately 6 to 7 miles northeast of the Project Rio Blanco site along County Roads 5 and 26. A temporary man camp and a seasonal residence are located along the Fawn Creek road about 1 and 2 miles north of the monument at surface ground zero, respectively.

## 2.2 Project Setting

Project Rio Blanco is located within the Piceance Creek basin in Rio Blanco County, Colorado. Piceance Creek is a tributary to the White River which occurs along the northern boundary of the drainage basin. The basin is bounded on the east by the Grand Hogback, on the south by the Roan Plateau, and on the west by Cathedral Bluffs. In the area of Project Rio Blanco, the basin is highly dissected by northwest-flowing streams that are flanked by steep rocky upland areas.

The emplacement well, RB-E-01, is located in the Fawn Creek valley, approximately 7 miles southwest of the junction of Rio Blanco County Roads 5 and 26. Fawn Creek is an ephemeral stream that flows northwest approximately 5.4 miles to its confluence with Black Sulphur Creek. Black Sulphur Creek is a tributary to Piceance Creek. Well RB-E-01 at surface ground zero is marked by a concrete monument (Figure 5) located about 500 feet west of the creek at an elevation of approximately 6,636 feet mean sea level (ft msl).

### 2.2.1 Site Climate and Meteorology

The Rio Blanco site climate is semiarid with a mean annual precipitation varying from approximately 12 inches in the northern Piceance Creek valley to approximately 25 inches along the drainage divide to the south (EG&G 1971). About half of the precipitation occurs as snow between December and April. An appreciable part of the remaining precipitation occurs during summer thunderstorms which can produce flash floods and significant erosion. Temperatures vary widely, ranging between winter lows of -40°F and summer highs up to 100°F. Predominant winds are from the west-southwest, but are locally influenced by mountain valley induced circulation patterns that cause the winds to flow up the valleys during the days and down the valleys during the evenings.

2.2.2 Site Geology

The Rio Blanco test site is located in the northern Piceance Basin (Hail and Smith 1994). The Piceance Basin is a large, northwest-trending, asymmetrical structural basin with steeply dipping northern and eastern limbs and gently dipping southern and western limbs. The basin formed as a result of the Laramide Orogeny during the late Cretaceous to Paleocene epochs. The predominant jointing and fracturing directions are oriented northwest and northeast.

In the area of Project Rio Blanco, Quaternary alluvium and colluvium comprised of terrace, floodplain, and fluvial deposits are unconformably underlain by the Tertiary Green River (Evacuation, Parachute Creek, Garden Gulch, and Douglas Creek members), Wasatch, and Fort Union formations. The upper Cretaceous Mesaverde Group and Mancos Shale unconformably underlie the Quaternary and Tertiary formations. The Mesaverde Group contains a thick sequence of natural gas-bearing, low-permeability reservoirs in the Williams Fork and Iles Formations. The Fort Union Formation also contains natural gas reservoirs. Figure 6 is a site geologic cross section that illustrates the subsurface stratigraphy and shows the location of the Project Rio Blanco test intervals.

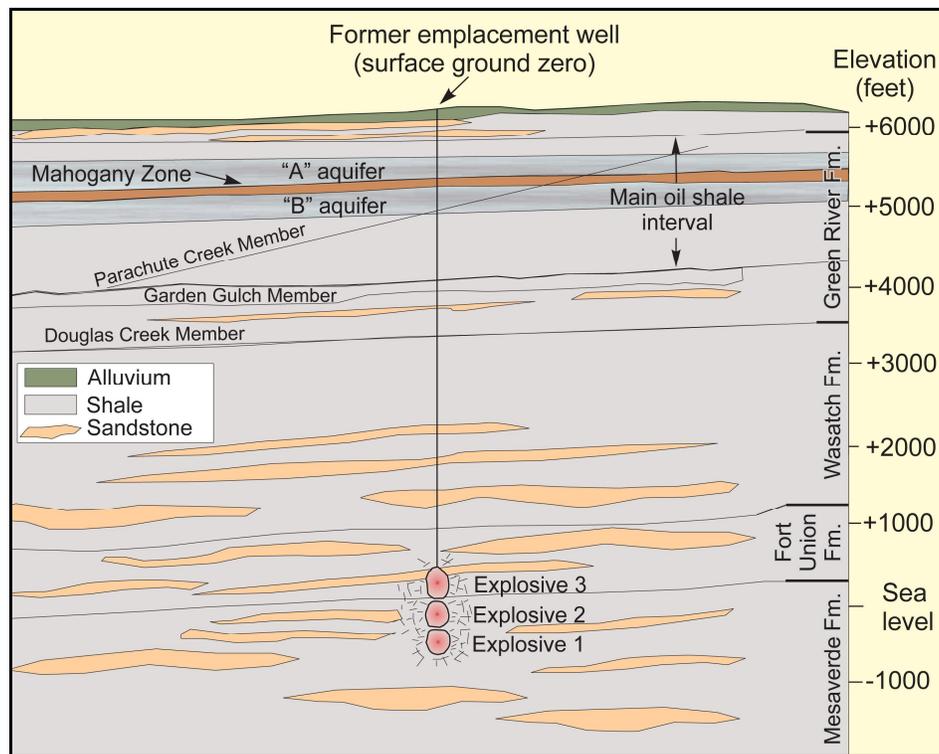


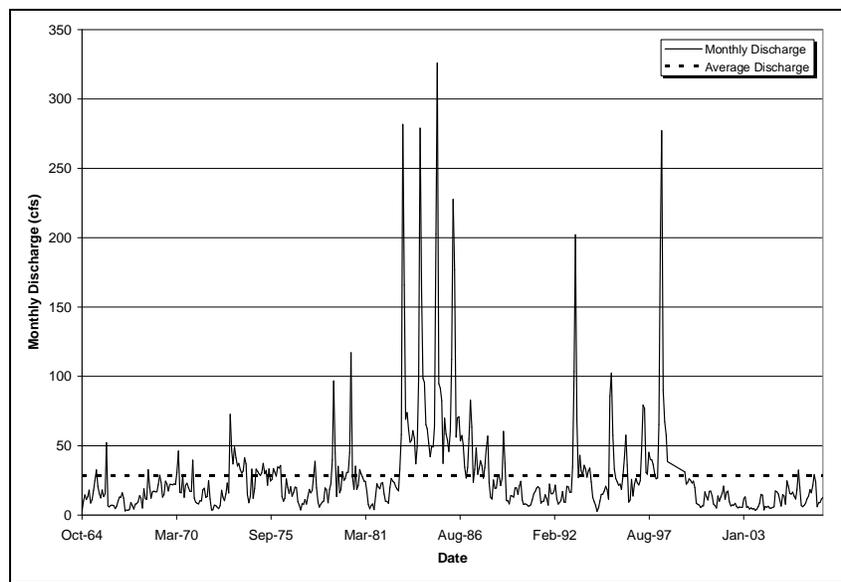
Figure 6 Rio Blanco Geologic Cross Section (DOE 2007).

The Project Rio Blanco test was conducted across the contact of the Paleocene Fort Union Formation and the underlying Mesaverde Group (i.e., Cretaceous Williams Fork Formation). The upper nuclear device was placed at a depth of 5,838 feet near the base of the Fort Union Formation. The second and third nuclear devices were placed at depths of 6,230 and 6,689 feet in the upper portion of the Williams Fork Formation.

### 2.2.3 Surface Water Hydrology

The Project Rio Blanco site is located within the Piceance Creek drainage basin along the ephemeral Fawn Creek, which flows into Black Sulphur Creek, a tributary to Piceance Creek. The basin is about 1,000 square miles in area and provides an estimated annual average water yield to the White River of approximately 26,000 acre feet (Mark et al. 1966). Surface water drainage orientation is largely controlled by the regional northwest-trending joints and fractures in the underlying bedrock. Surface water generally flows from the east, south, and west towards the center of the basin and then flows north to the White River.

Maximum stream flows occur between May and September. Surface water is sourced from melting of winter snowpack and summer rains, augmented by groundwater discharge. Lower flows typically occur during the summer when water is diverted for irrigation. Figure 7 shows the monthly discharge on Piceance Creek below Ryan Gulch (USGS Station 09306200).



**Figure 7. Surface Water Flow Piceance Creek Below Ryan Gulch (USGS 2008).**

The average monthly discharge at this station between 1964 and 2007 is approximately 28 cubic feet per second (cfs). This station is located about 4 miles downstream of the confluence of Piceance Creek and Black Sulphur Creek.

#### **2.2.4 Groundwater Hydrology**

Groundwater occurs in the shallow alluvium along the valley floor streams and in deeper fractured bedrock zones within the Green River Formation (Knutson et al 1973). Two principal bedrock aquifers have been identified starting at a depth of about 1,500 feet in the Parachute Creek Member of the Green River Formation. These two aquifers are designated the “A” (upper) and “B” (lower) groundwater zones. These aquifers are separated by the Mahogany Zone aquitard (Figure 6), a kerogen-rich shale about 170 feet thick. The upper aquifer (“A Zone”) consists of fractured shale and marlstone overlying the Mahogany Zone. The lower aquifer (“B Zone”) consists of fractured shale and marlstone below the Mahogany Zone. Beneath Rio Blanco, the A zone is the more permeable bedrock aquifer.

Recharge to the alluvial aquifer is principally from snowmelt and rainfall, and surface water seepage. Bedrock aquifer recharge largely occurs along the basin margins from infiltration of precipitation. Groundwater in both the alluvium and bedrock generally flows down the valleys towards the central portion of the Piceance Creek basin where it is discharged to Piceance Creek. Water quality data from wells completed within the A (RB-D-02) and B (RB-D-01 and RB-D-03) zones indicate that leaching of soluble minerals in the bedrock formations has increased the total dissolved solids (TDS) concentrations to as much as 60,000 mg/L in the B Zone, sometimes referred to as the leached zone, compared to 2,000 mg/L in the A Zone (Knutson et al 1973).

### **2.3 Project Rio Blanco Test Results**

The Project Rio Blanco test resulted in the formation of three blast cavities (DOE 2005). Drilling into these cavities four months after the detonation revealed that each cavity had an estimated radius of approximately 21 meters (69 feet). Two post-detonation gas production tests indicated that no connection existed between the upper and lower cavities because a tracer incorporated in the center explosive canister was not detected in the produced gas (Toman 1975).

Although the detonations enhanced fracture permeability, only limited data exist to document the actual fracture distance from the blast cavities. Electrical measurements of two coaxial cables installed in RB-E-01 at 50 milliseconds following the detonation indicated that the cables were broken at  $335 \pm 5$  feet and  $152 \pm 5$  feet (AEC and CER 1973a and 1973b), and suggests that fractures may extend about 100 meters from the cavities.

Post-detonation gas calibration and production tests were conducted in the upper cavity on October 25, 1973, November 15 through 21, 1973, and January 28 through February 15, 1974, and in the lowermost cavity on October 22, November 2, and between December 10 and 16, 1974. The estimated gas production from the upper and lower cavities was 98 and 27 million standard cubic feet (MMSCF), respectively (Tewes 1979)

The chemical composition of the gas produced from the cavities (Tewes 1979) primarily included carbon dioxide (CO<sub>2</sub>; 52 to 60%), methane (CH<sub>4</sub>; 28 to 30%), and hydrogen (H<sub>2</sub>; 10 to 15%). The initial activity of gaseous radionuclides detected in the produced gas from the top and bottom cavities included (Tewes 1979):

- Xenon-131m (<sup>131m</sup>Xe; 39,700,000 pCi/L)
- Argon-37 (<sup>37</sup>Ar; 2,820,000 pCi/L)
- Krypton-85 (<sup>85</sup>Kr; 251,000 to 450,000 pCi/L)
- Tritium (<sup>3</sup>H; 29,800 to 37,710 pCi/L)
- Argon-39 (<sup>39</sup>Ar; 320 pCi/L), and
- Carbon-14 (<sup>14</sup>C; 180 to 290 pCi/L).

Tewes (1979) estimated that the initial amounts of radionuclides at time zero (i.e., detonation) in the upper and lower cavities included:

- $4,950 \pm 500$  Curies (Ci) of <sup>37</sup>Ar,  $53.2 \pm 4.7$  Ci of <sup>3</sup>H, and  $0.61 \pm 0.12$  Ci of <sup>14</sup>C in the upper cavity, and

- $57.4 \pm 9.2$  Ci of  $^3\text{H}$ ,  $0.46 \pm 0.09$  Ci of  $^{37}\text{Ar}$ , and  $0.29 \pm 0.06$  Ci of  $^{14}\text{C}$  in the lower cavity.

The  $^3\text{H}$  content of the chimney gas at Project Rio Blanco was approximately 23 times less than that measured at Project Rulison based on data presented in Tewes (1979). The Project Rio Blanco nuclear devices were engineered to produce less  $^3\text{H}$  to minimize the potential for  $^3\text{H}$  in produced natural gas.

## 2.4 Project Rio Blanco-Related Radionuclides

Based on the historic use of the site, and characterization at similar sites, the DOE Rio Blanco Site Environmental Management End State Vision (DOE 2005) indicates that the radionuclides in the subsurface nuclear cavity are expected to include mixed radioactive fission products, plutonium, uranium, and gaseous radionuclides ( $^{85}\text{Kr}$ ,  $^3\text{H}$ , and  $^{14}\text{C}$ ). These gas phase radionuclides are thought to be the most mobile in the subsurface environment. Radionuclide transport in the formation water is thought to be much less significant than gas phase transport because the relative permeability of water in the formations is generally less than gas (Cooper et al. 2005; Cooper et al. 2009).

Table 1 provides a summary of some of the more mobile or abundant Project Rio Blanco-related radionuclides, their half lives, their estimated inventory in the cavity as of June 30, 2010, and the potential exposure medium. To be conservative, the initial activities shown in Table 1 have not been reduced to account for the removal of gaseous radionuclides during gas production testing. The radionuclides listed in Table 1 are those whose half life is greater than 10 years, are a significant inventory component (greater than 1 Curie), and have the potential to migrate from the Project Rio Blanco test cavity in either the gas or formation water. These will be herein referred to as the “identified Project Rio Blanco-related radionuclides” for this project.

Table 1 does not include any radionuclide whose half life is less than 10 years, like antimony-125 (2.8 years) or argon-37 (35 days), because these short-lived radionuclides have decayed sufficiently since the Project Rio Blanco test and no longer pose a threat to human health or the environment. A more exhaustive inventory of short- and long-lived radionuclides

typically found in subsurface nuclear tests is provided as Table 1.1 in the Final Rio Blanco Site Environmental Management End State Vision (DOE 2005).

Borg (1975) and Borg et al. (1976) reported that radionuclides in a below-ground nuclear cavity like Project Rio Blanco may exist in one of four phases: 1) in the nuclear glass melt; 2) in surface deposits on rubble in the cavity chimney; 3) dissolved in water; or 4), or in the gas phase. Most of the fission and activation radionuclides from the detonation are not readily soluble in groundwater, as they are refractory (having low volatility) and are incorporated into the nuclear glass melt. Dissolution of the glass melt is an extremely slow process and many of the leached and dissolved radionuclides will tend to sorb to the formation rock. As a result, most of the radionuclides within the nuclear chimney are not likely to be transported in the subsurface water pathway (Borg et al. 1976). However, these contaminants might pose a risk if materials from the cavity were brought to the surface. The existing 600-foot drilling restriction surrounding the Project Rio Blanco nuclear cavities through perpetuity prevents this potential exposure pathway from occurring (DOE 2008).

Formation water in the Fort Union and Williams Fork Formations is thought to be much less mobile than the gas phase because of the low formation permeability and the significant gas-filled pore space which inhibits water flow. A detailed discussion of two-phase (i.e., gas and water) flow is presented in Cooper et al. (2005). However, considering that formation water is produced along with the gas and the general public concern that a release of radionuclides might occur as a result of gas production, transport of potentially mobile radionuclides in the gas phase and less mobile radionuclides in the liquid phase was considered in developing this RBSAP.

Some of the radionuclides that might be dissolved and transported in subsurface formation water would likely include  $^3\text{H}$ ,  $^{85}\text{Kr}$ , chlorine-36 ( $^{36}\text{Cl}$ ), iodine-129 ( $^{129}\text{I}$ ), technetium-99 ( $^{99}\text{Tc}$ ), cesium-137 ( $^{137}\text{Cs}$ ), and strontium-90 ( $^{90}\text{Sr}$ ) [Smith et al. 1995]. Radionuclides that would more likely be transported in the gas phase include  $^3\text{H}$ ,  $^{85}\text{Kr}$ ,  $^{14}\text{C}$ ,  $^{37}\text{Ar}$ , and  $^{39}\text{Ar}$ . Based on their initial estimated inventories,  $^3\text{H}$  and  $^{85}\text{Kr}$  are likely to be responsible for most of the radioactivity in the gas phase (Holzer 1970) and  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$  and  $^{137}\text{Cs}$  are likely to be responsible for most of the potential Project Rio Blanco-related radioactivity in formation water.

Table 1. Potentially Mobile or Abundant Project Rio Blanco-Related Radionuclides<sup>1</sup>.

Radionuclide	Half-Life <sup>2</sup> (years)	Initial Activity <sup>3</sup> (Curies)	Activity in 2010 <sup>4</sup> (Curies)	Percent Initial Activity Remaining <sup>5</sup>	Potential Exposure Medium	Primary Radiation Emitted	Potential Source <sup>6</sup>
Technetium-99 ( <sup>99</sup> Tc)	211,100	36000	35996	99.99	Cuttings, Produced Water	β-	Nuclear Testing
Cesium-137 ( <sup>137</sup> Cs)	30.07	17000	7222	42.48	Cuttings, Produced Water	β-, γ <sup>7</sup>	Nuclear Testing
Strontium-90 ( <sup>90</sup> Sr)	28.79	14000	5726	40.90	Cuttings, Produced Water	β-	Nuclear Testing
Tritium ( <sup>3</sup> H)	12.33	3000	372	12.40	Gas, Produced Water	β-	Cosmogenic Nuclear Testing
Krypton-85 ( <sup>85</sup> Kr)	10.76	2050	187	9.14	Gas	β-, γ	Cosmogenic Nuclear Testing
Carbon-14 ( <sup>14</sup> C)	5730	22.5	22	99.55	Gas, Produced Water	β-	Cosmogenic Nuclear Testing
Argon-39 ( <sup>39</sup> Ar)	269	20	18	90.87	Gas	β-	Cosmogenic, Nucleogenic Nuclear Testing
Chlorine-36 ( <sup>36</sup> Cl)	301,000	2.82	3	99.99	Gas, Produced Water	β-	Cosmogenic, Nucleogenic Nuclear Testing

<sup>1</sup> A more exhaustive inventory of radionuclides found in subsurface nuclear tests is listed in Table 1.1 (DOE 2005).

<sup>2</sup> Half lives from Lawrence Berkley National Laboratory Table of Isotopes, Version 2.1, January 2004.

<sup>3</sup> The initial activity is obtained from CER (1971b), except for <sup>36</sup>Cl which is from Table 1.1 in DOE (2005).

<sup>4</sup> Activity in 2010 is referenced to June 30, 2010, and assumes a closed system.

<sup>5</sup> Percent initial activity remaining does not account for radionuclide mass removed during gas production testing. Actual activities for <sup>3</sup>H, <sup>85</sup>Kr, <sup>39</sup>Ar, and <sup>14</sup>C are likely less than those calculated because of removal of these isotopes during calibration and production testing.

<sup>6</sup> Cosmogenic – produced in upper atmosphere; nucleogenic – produced in subsurface by natural nuclear reactions.

<sup>7</sup> <sup>137</sup>Cs is a beta emitter; however, its short lived (half life = 2.55 minutes) daughter <sup>137m</sup>Ba emits gamma radiation as it decays to stable <sup>137</sup>Ba.

### **3 BASELINE ENVIRONMENTAL CONDITIONS**

Numerous historical and current environmental monitoring studies have been completed by CER, the Colorado Department of Health (CDH), the DOE, the Desert Research Institute (DRI), the U.S. Environmental Protection Agency (EPA), and Williams were reviewed during the preparation of this RBSAP. A brief summary of these studies is provided in the sections below to define the historical and current environmental conditions near Project Rio Blanco.

#### **3.1 Historical Environmental Data**

A number of historical Project Rio Blanco environmental studies have been completed and are listed in the references cited in Section 10. These studies included sampling and monitoring of environmental media (i.e., milk, air, flora, fauna, soils, sediments, and water) and characterization and cleanup of soils at the Project Rio Blanco site. A brief summary of these studies and their results is provided in the subsections below to provide an understanding of the historical environmental conditions.

##### **3.1.1 CER Geonuclear Corporation Studies**

CER conducted numerous studies to determine the feasibility and baseline environmental conditions prior to conducting the Project Rio Blanco test and monitoring to determine if radionuclides were released to the environment during or following the Project Rio Blanco test (CER 1970, 1971a, 1971b, 1971c, 1971d, 1971e, 1972, 1973a, 1973b, 1973c, 1973d, 1973e, 1974a, 1974b, 1975a, 1975b, and 1975c; Knutson 1973a and 1973b). CER initiated a radiological monitoring program in October 1971 to measure background and environmental radioactivity in the area surrounding the Project Rio Blanco site prior to and after the detonation. The monitoring program was implemented by Eberline Instrument Corporation (EIC) and included precipitation, air particulates, soils, bottom sediments, surface and ground waters, flora and fauna, milk, and radiation dosimetry. The results of these monitoring studies are documented in EIC reports (EIC 1972a, 1972b, 1972c, 1972d, 1973a, 1973b, 1973c, 1974a, 1974b, and 1974c).

The studies found no evidence for any increase in areal radioactivity in any environmental medium resulting from the Project Rio Blanco nuclear test. Radioactivity measured was typical of ambient background radiation ranges for all media.

### **3.1.2 Colorado Department of Health Studies**

The Colorado Department of Health (CDH), predecessor agency to the CDPHE, conducted independent environmental monitoring studies at Project Rio Blanco between January 1971 and December 1976 (CDH 1973 and 1977). Over this monitoring period, CDH collected about 6,862 environmental samples and performed approximately 15,284 radiochemical analyses. The environmental samples included 5,139 air particulate filter samples, 12 compressed air samples, 96 air moisture samples, 49 sediment and soil samples, 44 municipal water supply samples, 698 precipitation and water samples, 122 special well samples, 622 river and stream samples, 39 snow samples, and 41 composite milk samples.

CDH (1973) concluded that the data collected over the period January 1971 through June 1973 found no evidence of a radioactive release from the subsurface nuclear detonation. CDH (1977) further concluded that the only measurable radioactivity found during environmental monitoring conducted between July 1973 and December 1976 was a release of tritium during gas production test flaring on November 19 and 20, 1973. Traces of tritiated methane were also found in compressed air samples collected during flaring. CDH (1977) noted that the flaring of gases caused no detectable increase in radioactivity in air particulates.

### **3.1.3 DOE Studies**

EIC (1978), under contract to the DOE, performed radiological health and safety operations during the cleanup and restoration of the Project Rio Blanco site between July and November 1976. Site cleanup and restoration included plugging and abandonment of RB-E-01 and RB-AR-2, recompletion of Fawn Creek Government Well No. 1, decontamination of surface equipment, removal of contaminated soils and water, and radiological sampling and surveys of the restored site.

EIC noted that all equipment contaminated during gas production test activities was decontaminated to well below applicable release criteria and was released for unrestricted use. EIC collected and analyzed 482 soil samples and found that neither  $^{90}\text{Sr}$  nor  $^{137}\text{Cs}$  was detected above worldwide fallout activities and that only insignificant tritium remained in the surface soil. No radioactive contamination of surface water or groundwater was detected above ambient background. A radiological survey performed after the site was restored indicated that no radiation activities above ambient background remained onsite.

EIC (1978) found that natural gas from Fawn Creek Government Well No. 1, a pre-existing gas well located approximately 1,328 feet south of surface ground zero, did not contain tritium above the detection limit of 3 picoCuries per liter (pCi/L). EIC (1978) reported that radioactively-contaminated water produced from the Rio Blanco test well was injected into the FCG No.1 well within an interval between 5,360 and 6,072 feet below the ground surface. The produced water was injected in accordance with a permit issued by the State of Colorado to CER. 23,349 barrels of produced water containing 177.9 Curies (Ci) of tritium, 4.3 milliCuries (mCi) of cesium-137, and 1 mCi of strontium-90 were injected into this zone of the well. During site cleanup, 1,341 more barrels of produced water containing 68.5 mCi of tritium, 0.7 mCi of cesium-137, and 0.0007 mCi of strontium-90 were injected into the FCG No. 1 well.

EIC (1978) reported that the FCG No. 1 gas well produced very little water, but that the tritium activity in the produced water in February 1977 was approximately 500 picoCuries per milliliter (500,000 picoCuries per liter [pCi/L]). Radioactive decay has reduced the  $^3\text{H}$  activity since 1977. Considering the 12.33 year half life for tritium and the approximately 33 years that has elapsed since February 1977, the present tritium activity at the FCG No. 1 well would be approximately 77,068 pCi/L. This estimate conservatively assumes no dilution by flowing subsurface fluids. The current tritium activity at FGC No. 1 is slightly less than four times the 20,000 pCi/L CDPHE basic groundwater standard for tritium and would result in a minimal external exposure dose if encountered during drilling or production.

The U. S. Department of Energy (DOE) proposed in 1986 (DOE 1986) that a restriction be established on the FCG No. 1 well whereby no excavation, drilling, and/or removal of subsurface materials below a true vertical depth of 5,300 feet be permitted with a 600-foot

radius of this well. The well was plugged and abandoned in June 1986. URS contacted the DOE's Office of Legacy Management in Grand Junction, Colorado on March 22, 2010 to confirm whether this restriction was currently active. DOE confirmed (R. Hutton, personal communication, March 25, 2010) that DOE has no record that the restriction was ever implemented and that no drilling restriction currently exists at the FCG No. 1 well.

EG&G (1994), under contract to the DOE, conducted aerial and ground radiological surveys in June 1993 over a 12 square mile area surrounding Project Rio Blanco to detect any anomalous gamma radiation that may have been released to the environment as a result of the underground nuclear detonation in May 1973 and subsequent production testing. The radiation exposure rates measured using sodium iodide [NaI(Tl)] detectors ranged between about 15 and 23 microRoentgens per hour ( $\mu\text{R/hr}$ ) which are typical of exposure rates resulting from natural background radiation. No evidence of Cs-137 or any other man-made radionuclides were found.

DOE (2002) performed a corrective action investigation at the Project Rio Blanco site between July and September 2000 to evaluate the surface and shallow subsurface soils and groundwater in the alluvium and/or weathered bedrock to a depth of approximately 50 feet. Soils were sampled in the area of surface ground zero at RB-E-01, the alternate re-entry well RB-AR-2 and Fawn Creek Government Well No. 1, the reservoir formation evaluation well RB-U-4, the flare stack, and an upgradient area about 420 feet south of RB-AR-2. Four shallow groundwater monitoring wells were installed and sampled twice. The wells were installed upgradient of RB-AR-2 and in the operational areas of RB-AR-2, RB-E-1, and RB-U-4. The four wells were subsequently plugged and abandoned in September 2002.

The soil sample results indicated that metals, other than lead, total volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), gamma-emitting radionuclides, and tritium did not exceed screening levels. Results for lead and total petroleum hydrocarbons diesel range organics (TPH DRO) were above screening levels in one or more samples. However, a risk assessment demonstrated that these compounds posed no significant human health risks. All valid groundwater results were below applicable screening levels for metals, total VOCs, SVOCs, TPH DRO, gamma-emitting radionuclides, and tritium.

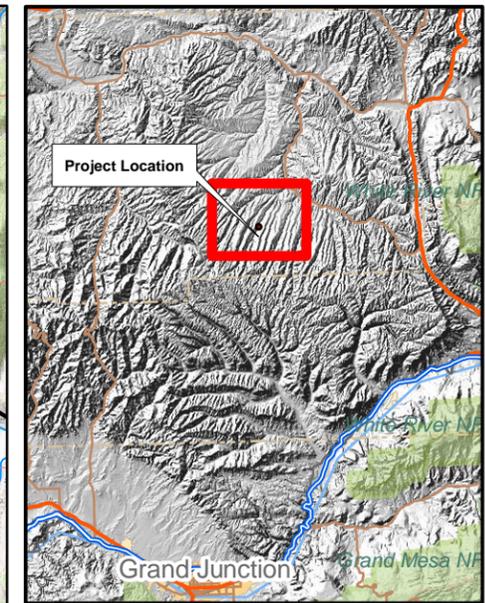
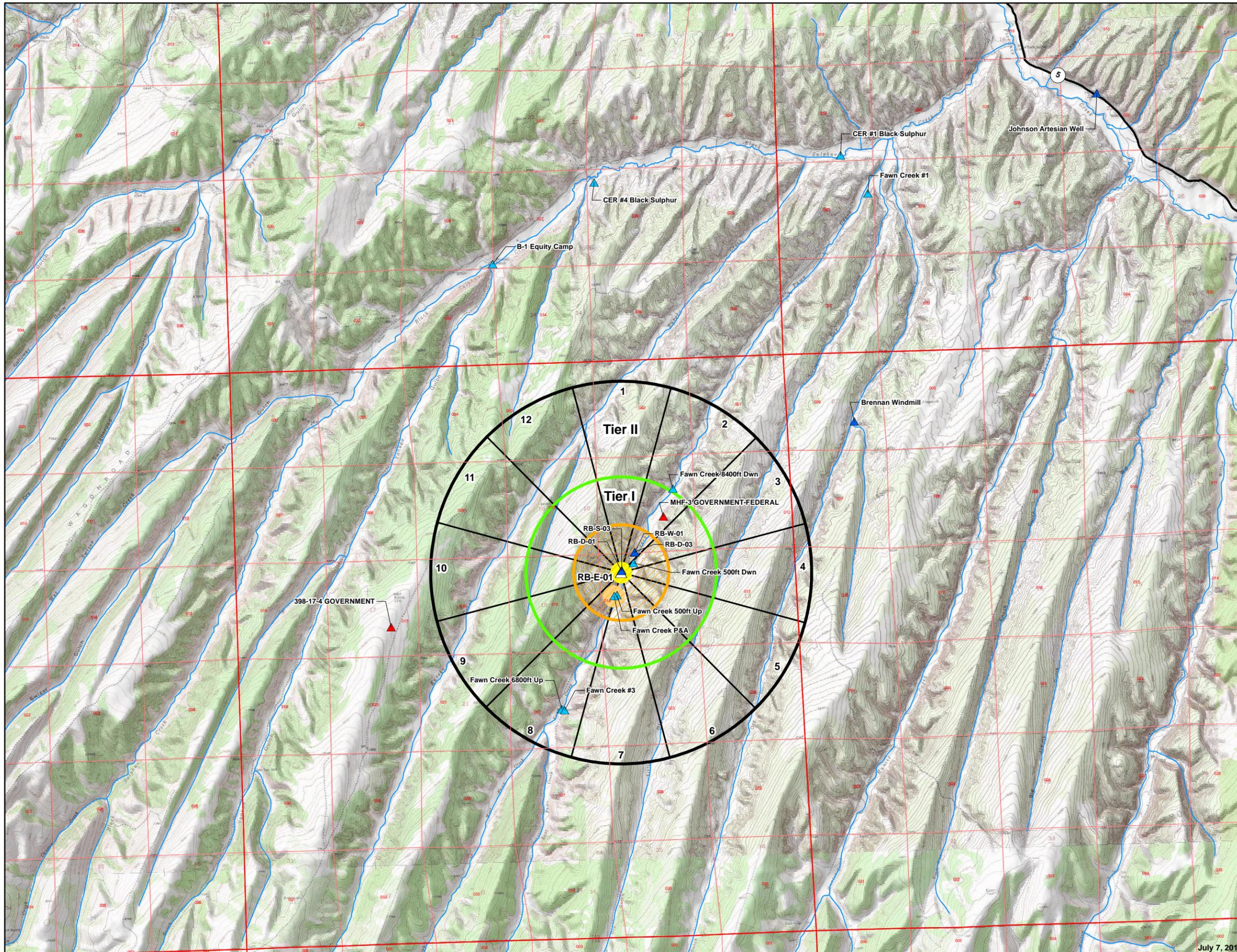
DOE (2008) made a presentation at the Northwest Colorado Oil and Gas Forum in Rifle, Colorado on September 4, 2008. They provided an overview of DOE project activities and subsurface interests at the Rulison and Rio Blanco sites. DOE indicated that the federal government would continue to maintain exclusion boundaries around the Rulison and Rio Blanco test sites that protect human health and the environment. DOE is continuing to study radionuclide migration at both sites in an effort to determine an appropriate exclusion zone.

#### 3.1.4 DRI Studies

The Desert Research Institute (DRI), under contract to the DOE, sampled natural gas in two producing gas wells that were proximate to the Project Rio Blanco site in January 2004 (Cooper and Shirley 2004). The wells sampled included Government-Federal MHF-3 and Government 398-17-4 (Figure 8) which were operated by Riata Energy, Inc at the time of sampling. These wells are located approximately  $\frac{3}{4}$  and  $2\frac{1}{2}$  miles from Project Rio Blanco and were drilled in December 1980 and August 1979, respectively. The gas samples were analyzed by Isotech Laboratories of Champaign, Illinois who determined the gas composition, methane  $\delta^{13}\text{C}$ , and methane  $^{14}\text{C}$  and  $^3\text{H}$  activities.

$^3\text{H}$  or  $^{14}\text{C}$  were not detected in methane above their respective reporting limits in either of the gas samples. The reporting limits for  $^3\text{H}$  were 10 and 12.4 tritium units (TU) and 0.3 and 0.4 percent modern carbon (pMC) for  $^{14}\text{C}$ .  $^{14}\text{C}$  is reported as pMC which is set by convention as 13.56 decays per minute per gram of carbon (Kazemi et al. 2006), or 100 pMC.  $^{14}\text{C}$  results less than 2 pMC indicate that modern  $^{14}\text{C}$  is not present and that the natural gas has been isolated from sources of modern  $^{14}\text{C}$  that would have been contributed by the Project Rio Blanco test. These results indicate that  $^3\text{H}$  or  $^{14}\text{C}$  from the Project Rio Blanco test have not migrated into the area of these gas production wells.

Chapman et al (1996) performed an initial simulation of the potential for radionuclides to migrate in groundwater from the Project Rio Blanco test site using a solute flux screening model. Cooper et al (2005) subsequently evaluated the potential for gaseous  $^3\text{H}$  and  $^{85}\text{Kr}$  to migrate from the Rio Blanco chimney cavities to a producing gas well at 292 meters (958 feet) using a three-dimensional multiphase transport code. The results of the modeling suggest



### Legend

- ▲ DOE Sampled Gas Well
- ▲ DOE Groundwater Well
- ▲ DOE Surface Water Station
- 600-Foot Radius DOE Drilling Exclusion Zone
- 600-Foot Radius Voluntary Drilling Exclusion Zone
- Half-Mile Radius with Voluntary Drilling Moratorium
- One-Mile Radius
- Two-Mile Radius
- Monitoring Sectors



**Figure 8**  
**DOE (EPA) Sampling Locations**  
**Project Rio Blanco**  
**Rio Blanco County**  
**Colorado**

that  $^3\text{H}$  is transported a maximum distance ranging between 100 and 150 meters (328 and 492 feet) from the edge of the chimney depending on the applied pressure gradients and liquid saturation. The tritium concentrations in the producing gas well were essentially equal to background in this model.

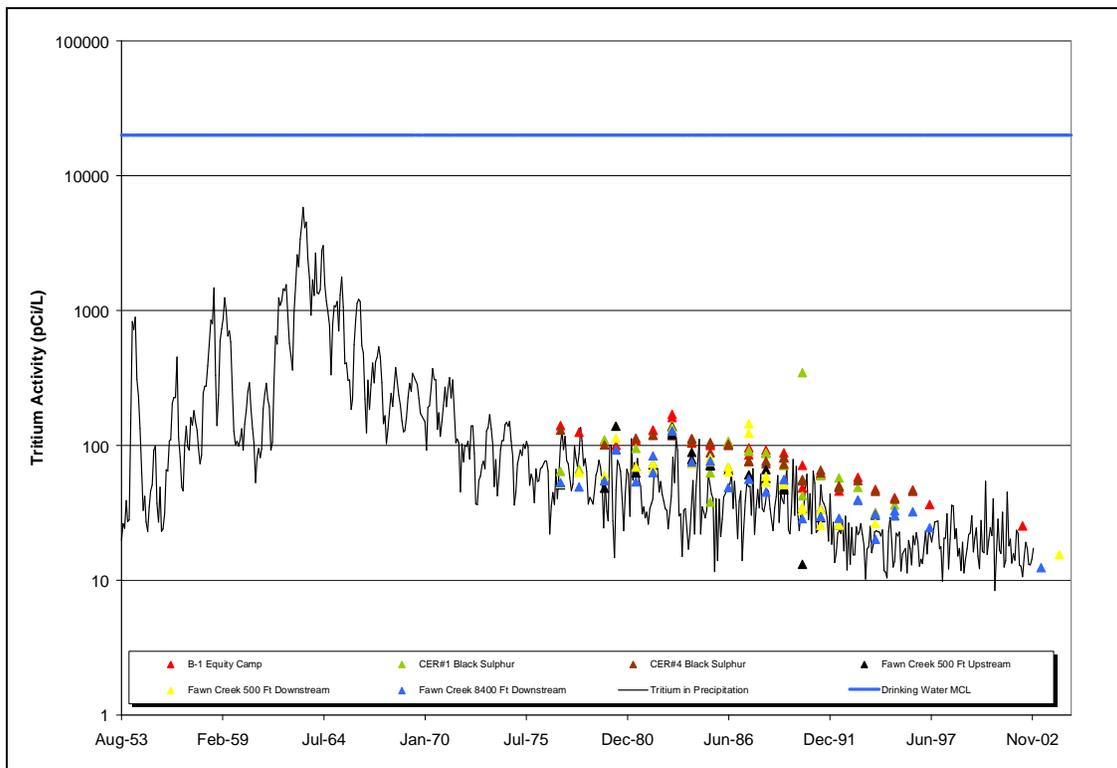
### 3.1.5 EPA Studies

EPA (1995) evaluated the abundances of man-made and naturally occurring radionuclides at the Project Rio Blanco site and determined their contributions to total radiation exposure rates.  $^{137}\text{Cs}$  was the only man-made radionuclide found. Its activity is consistent with radiocesium fallout concentrations found in other parts of the United States. Naturally occurring radionuclides included  $^{40}\text{K}$ ,  $^{232}\text{Th}$ , and  $^{238}\text{U}$ . The total exposure rate, including cosmic rays, ranged between 16.5 and 18.0  $\mu\text{R/hr}$ , which is typical of background in the area. These exposure rates are similar to those determined by EG&G in 1994 which ranged from 15 to 23  $\mu\text{R/hr}$ .

Beginning in 1972, the EPA has been performing annual water sampling at 14 well, spring, or stream locations (Figure 8) in the area of Project Rio Blanco on behalf of the DOE (EPA 1998, 1999, and 2004). These locations have typically included 4 springs, 4 surface water locations, and 6 groundwater wells, 4 of which (RB-D-01, RB-D-03, RB-S-03, and RB-W-01) are located near surface ground zero. Water samples collected from these locations are routinely analyzed for  $^3\text{H}$  and gamma-emitting radionuclides by spectroscopy. The EPA results have detected measurable  $^3\text{H}$  activities (Figure 9) but have found no man-made, gamma-emitting radionuclides above their minimum detectable activity (MDA).

Most of the tritium found in present day groundwater and surface water is largely derived from the atmospheric testing of nuclear weapons in the 1950's and 1960's. Figure 9 shows the  $^3\text{H}$  activities in precipitation (black line) at Ottawa, Ontario, that are considered representative of regional precipitation. A large increase in  $^3\text{H}$  in precipitation occurred in 1963 because of the increase in atmospheric testing of nuclear weapons during this time period. However, natural radioactive decay and a relatively short half life for  $^3\text{H}$  (12.3 years) resulted in a decrease in  $^3\text{H}$  activities in precipitation after the cessation of most of the atmospheric nuclear weapons testing in 1963 to the present day activity of 50 pCi/L or less. Figure 9 also shows the

tritium activities in surface water samples collected and analyzed by EPA for DOE at some of the locations in the Project Rio Blanco area after the detonation. The  $^3\text{H}$  activities detected in these surface water samples are consistent with the activities found in worldwide precipitation (Figure 9).  $^3\text{H}$  activities in both precipitation and Rio Blanco surface waters have always been less than the EPA drinking water 20,000 pCi/L MCL for  $^3\text{H}$  (blue line on Figure 9).



**Figure 9.  $^3\text{H}$  Activity in Precipitation at Ottawa, Ontario and in Surface Water at Project Rio Blanco (Ottawa data from IAEA; Rio Blanco data from DOE 2008).**

The EPA concluded (EPA 2004) that tritium concentrations in water samples collected onsite and offsite are consistent with those of past studies at the Project Rio Blanco test site. In general, the current level of tritium in shallow wells at the Project Rio Blanco site cannot be distinguished from the rain-out of naturally produced tritium augmented by, perhaps, a small amount of residual global ‘fallout tritium’ remaining from nuclear testing in the 1950s and 1960s. Gamma-emitting radionuclide activities are below the minimum detectable activity. No radioactive materials attributable to the Project Rio Blanco test have been detected in any of the wells, springs, or streams tested by EPA.

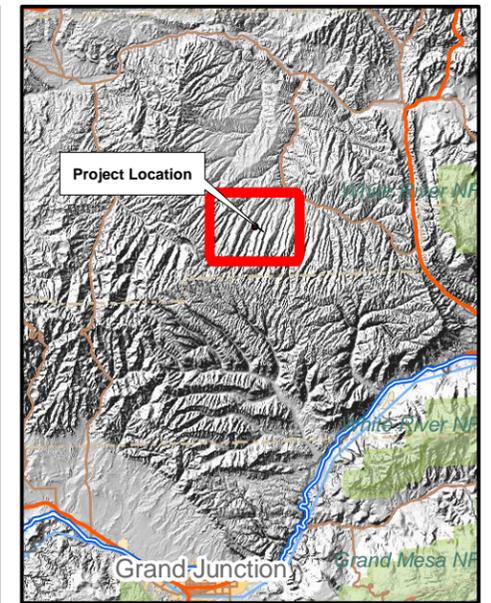
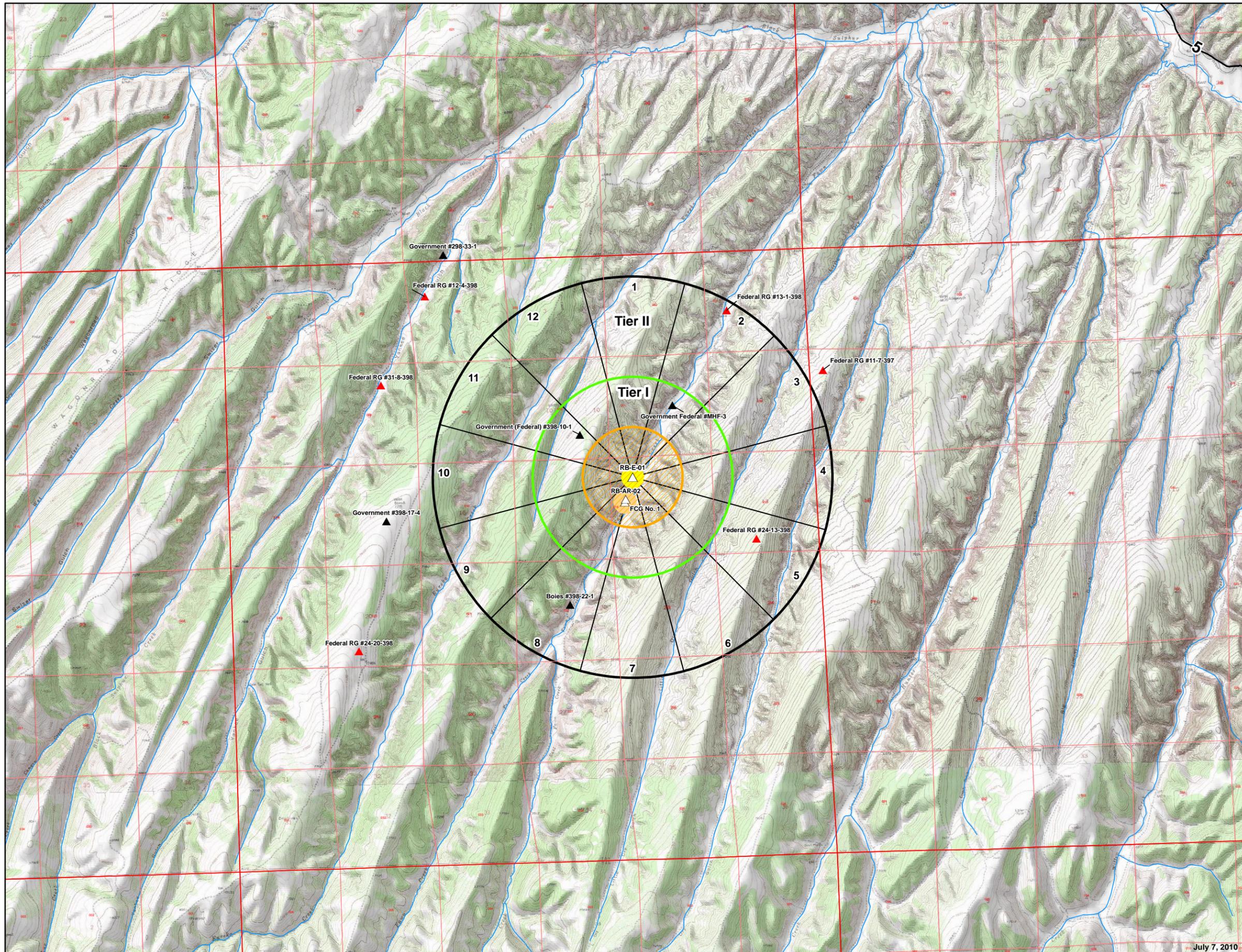
### 3.1.6 COGCC Studies and Policies

The COGCC has not performed any studies or established any regulatory policies for gas wells drilled near the Project Rio Blanco test site to date. However, it is the Companies understanding that the COGCC, DOE, and U. S. Bureau of Land Management (BLM) have had preliminary discussions concerning gas well drilling near Project Rio Blanco and intend to require a sampling and analysis plan that is similar to the plan developed for the Project Rulison area (URS 2008). DOE recently made a presentation at the Northwest Energy Forum on September 4, 2008 confirming their future intentions regarding monitoring of gas well drilling near the Project Rio Blanco site.

## 3.2 Current Environmental Data

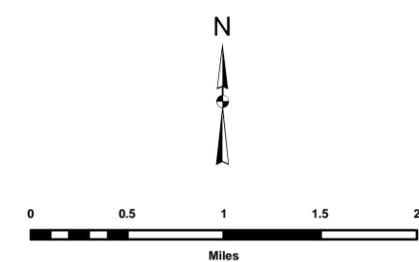
Williams sampled produced water and natural gas at six of its producing gas wells near Project Rio Blanco on January 7 and February 12, 2009. The wells sampled included Federal RG 11-7-397, Federal RG 12-4-398, Federal RG 13-1-398, Federal RG 24-13-398, Federal RG 24-20-398, and Federal RG 31-8-398 (Figure 10). These wells are located between approximately 1½ and 3 miles from Project Rio Blanco. Sampling was conducted by URS Corporation. The samples were collected following the sampling procedures in the Rulison Sampling and Analysis Plan, Revision 2 (URS 2008). The samples were analyzed for non-radionuclides by Paragon Analytics of Fort Collins, Colorado and radionuclides by GEL Laboratories of Charleston, South Carolina and Isotech Laboratories Inc. of Champaign, Illinois. The produced water samples were analyzed for  $^3\text{H}$ , gross alpha, gross beta,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ ,  $^{36}\text{Cl}$ , and gamma-emitting radionuclides by spectroscopy. The natural gas samples were analyzed for  $^3\text{H}$  and  $^{14}\text{C}$ . The laboratory results were independently validated by URS. The results of the validated laboratory analyses are summarized in Tables 2 through 5. The laboratory data packages are provided on compact disk (CD) in Appendix E.

DOE collected duplicate samples on January 7, 2009 at well locations Federal RG 13-1-398 and Federal 24-13-398. The analytical results for their samples are consistent with those discussed below. A summary of the DOE results is provided in Appendix F.



**Legend**

- ▲ Existing Gas Well
- ▲ Sampled Gas Well
- △ Project Rio Blanco Well
- 600-Foot Radius DOE Drilling Exclusion Zone
- 600-Foot Radius Voluntary Drilling Exclusion Zone
- Half-Mile Radius with Voluntary Drilling Moratorium
- One-Mile Radius
- Two-Mile Radius
- Monitoring Sectors



**Figure 10**  
**Gas Sampling Locations**  
**January-February 2009**  
**Project Rio Blanco**  
**Rio Blanco County**  
**Colorado**

Y:\GIS\Projects\Williams Project Rio Blanco SAP\kx\fig10 Gas Well Locations Project Rio Blanco 11x17.mxd

### 3.2.1 Gross Alpha/Beta in Produced Water

Gross alpha, a screening analysis for non-volatile alpha-emitting radionuclides, was not detected above its reporting activities in produced water (Table 2). The gross alpha reporting activities ranged between less than 10.6 and less than 44.8 pCi/L. Gross alpha activity was generally reported at an elevated reporting activity because of the high total dissolved solids (TDS) concentration of the produced waters. The high TDS concentrations resulted in the evaporation of a smaller sample volume during analysis because the gross alpha analytical method limits the residue after evaporation to 100 milligrams or less.

Gross beta, a screening analysis for non-volatile beta-emitting radionuclides, was detected in produced water at activities ranging between  $36 \pm 11.4$  and  $175 \pm 28$  pCi/L (Table 2). Gross beta activity in the produced water is related to naturally-occurring potassium-40 ( $^{40}\text{K}$ ; ANL 2005b) and radium-228 ( $^{228}\text{Ra}$ ) in the subsurface formation fluids.  $^{40}\text{K}$  activities in produced water ranged between  $61 \pm 39$  and  $215 \pm 56$  pCi/L. The highest gross beta and  $^{40}\text{K}$  activities occurred at the Federal RG 12-4-398 gas well.  $^{228}\text{Ra}$  was only detected in produced water at Federal RG 11-7-397.

### 3.2.2 $^{99}\text{Tc}$ , $^{90}\text{Sr}$ , and $^{36}\text{Cl}$ in Produced Water

$^{99}\text{Tc}$  and  $^{90}\text{Sr}$ , two of the most abundant radionuclides in the Project Rio Blanco inventory, were not detected above their reporting activities in produced water. The  $^{99}\text{Tc}$  and  $^{90}\text{Sr}$  reporting activities ranged between less than 38.4 and less than 48.7 pCi/L, and less than 0.70 and less than 1.22 pCi/L, respectively (Table 2).

$^{36}\text{Cl}$ , one of the less abundant radionuclides in the Project Rio Blanco inventory, was not detected above its reporting activities in produced water. The  $^{36}\text{Cl}$  reporting activities ranged between less than 182 and less than 305 pCi/L (Table 2).

### 3.2.3 Gamma-Emitting Radionuclides in Produced Water

Most of the gamma-emitting radionuclides, including cesium-137 ( $^{137}\text{Cs}$ ), were not detected above their reporting activities in produced water (Table 2).  $^{137}\text{Cs}$  is one of the most

abundant radionuclides in the Project Rio Blanco inventory. The only gamma-emitting radionuclides detected were those that naturally occur in the subsurface formation fluids and rocks of the Fort Union and Williams Fork Formations.

Naturally-occurring gamma-emitting radionuclides detected in produced water included actinium-228 ( $^{228}\text{Ac}$ ;  $16.3 \pm 11.4$  pCi/L) and radium-228 ( $^{228}\text{Ra}$ ;  $16.3 \pm 11.4$  pCi/L) at Federal RG 11-7-397 and  $^{40}\text{K}$  at all of the wells sampled.  $^{40}\text{K}$  activities in produced water ranged between  $61 \pm 39$  and  $215 \pm 56$  pCi/L. The highest  $^{40}\text{K}$  activity in produced water occurred at the Federal RG 12-4-398 gas well.  $^{228}\text{Ac}$  and  $^{228}\text{Ra}$  are decay products of naturally-occurring thorium-232 ( $^{232}\text{Th}$ ). The  $^{232}\text{Th}$  decay series is shown as Figure 11.  $^{40}\text{K}$  naturally occurs in the clays and feldspars found in the subsurface rock formations.

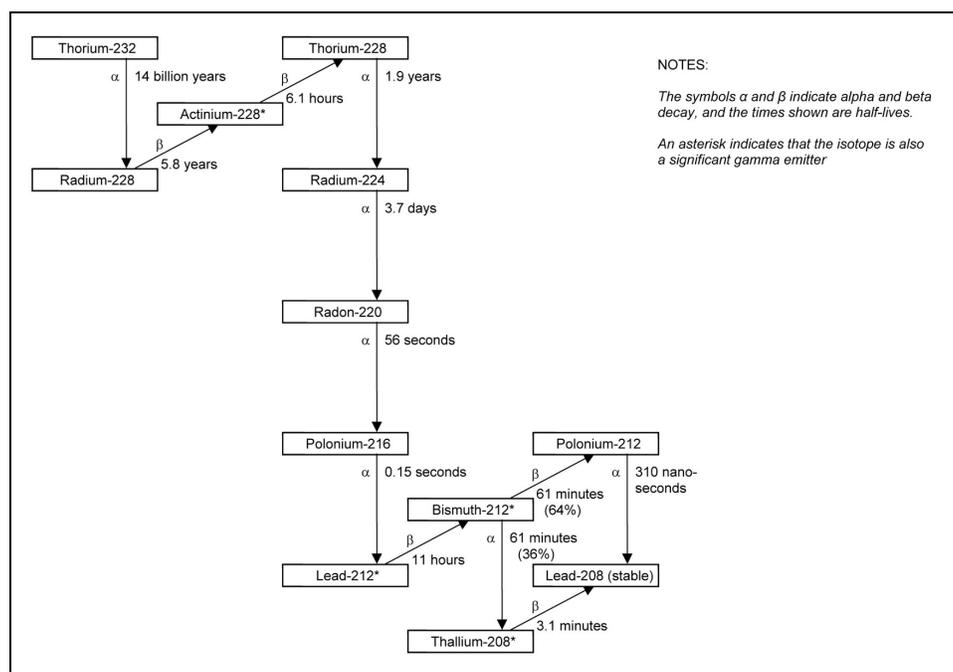


Figure 11.  $^{232}\text{Th}$  Decay Series (modified from ANL 2005a)

### 3.2.4 Tritium in Produced Water

$^3\text{H}$ , the most mobile radionuclide in the inventory at Project Rio Blanco, was not detected above the reporting concentration in any of the produced water samples (Table 2). The  $^3\text{H}$  reporting concentrations ranged between less than 10.0 and less than 10.6 tritium units (TU).

One TU equals 1 tritium atom per  $10^{18}$  hydrogen atoms or approximately 3.19 pCi/L in water (Kazemi et al. 2006). Thus, the  $^3\text{H}$  activities in these fluid samples ranged between less than 32 to less than 34 pCi/L. The CDPHE basic ground water standard for  $^3\text{H}$  is 20,000 pCi/L (CDPHE 2008).

### 3.2.5 Tritium and $^{14}\text{C}$ in Natural Gas Results

$^3\text{H}$  was not detected above the reporting concentration in the natural gas methane fraction in any of the samples (Table 2).  $^3\text{H}$  reporting concentrations ranged between less than 10.0 and less than 12.5 TU (Table 2). One TU equals 1 tritium atom per  $10^{18}$  hydrogen atoms or approximately 3.19 pCi/L<sub>water</sub> (Kazemi et al. 2006). For  $^3\text{H}$  analysis, methane is combusted to produce carbon dioxide and water. At 20°C and one atmosphere, it takes approximately 621 liters of combusted methane to produce one liter of water. To convert the reported methane tritium results to pCi/L<sub>methane</sub>, a conversion factor of  $1.61\text{E-}3 \text{ L}_{\text{water}}/\text{L}_{\text{methane}}$  is used. Thus, the  $^3\text{H}$  activities in these natural gas samples ranged between less than 0.05 and less than 0.06 pCi/L<sub>methane</sub>.

$^{14}\text{C}$  concentrations in the methane fraction of the natural gas samples ranged between not detected ( $< 0.2$ ) and  $0.5 \pm 0.1$  percent modern carbon (pMC) as shown in Table 2.  $^{14}\text{C}$  is reported as pMC which is set by convention as 13.56 decays per minute per gram of carbon (Kazemi et al. 2006), or 100 pMC.  $^{14}\text{C}$  results less than 1 pMC indicate that modern  $^{14}\text{C}$  is not present in the gas and that the natural gas has been isolated from sources of modern  $^{14}\text{C}$  such as Project Rio Blanco.

### 3.2.6 Major Cation and Trace Metal Results

Major cation and trace metal results for produced water indicate that these metals are detected at varying concentrations. The results of the major cation and trace metal analyses are summarized in Table 3.

Sodium and potassium are the dominant major cations in produced water. The mean sodium and potassium concentrations detected are 4,100 milligrams per liter (mg/L) and 263 mg/L, respectively. Calcium and magnesium in these fluids are found at significantly lower

concentrations compared to sodium and potassium. The mean calcium and magnesium concentrations are 100 mg/L and 10.8 mg/L, respectively.

Barium, iron, strontium, boron, lithium, and manganese are the dominant trace metals in produced water. Mean barium, iron, strontium, lithium, boron, and manganese concentrations in produced water are 29,483, 18,150, 15,483, 10,850, 4,767, and 297  $\mu\text{g/L}$ , respectively. Mean concentrations of trace metals in produced water include chromium (65  $\mu\text{g/L}$ ), arsenic (6.15  $\mu\text{g/L}$ ), mercury (6.02  $\mu\text{g/L}$ ), uranium (0.89  $\mu\text{g/L}$ ), lead (0.31  $\mu\text{g/L}$ ), cadmium (0.19  $\mu\text{g/L}$ ), and selenium (less than 1  $\mu\text{g/L}$ ).

### 3.2.7 Major and Minor Anion and pH Results

Major and minor anions and pH results for produced water indicate that these constituents are detected at varying concentrations. The results of the major cation and trace metal analyses are summarized in Table 4. Chloride is the dominant major anion in produced water. The mean chloride concentration is 6,633 milligrams per liter (mg/L). Chloride is the primary anion comprising the mean total dissolved solids (TDS) concentration (12,383 mg/L). The next most abundant major anion in produced water is bicarbonate (as  $\text{CaCO}_3$ ) whose mean concentration is 1,330 mg/L. Bicarbonate is the primary anion comprising the mean total alkalinity (as  $\text{CaCO}_3$ ) of 1,330 mg/L. The mean pH for produced water, fracing water, flowback fluid, dewatered drilling mud fluid is 6.60, which is consistent with bicarbonate being the dominant carbonate component in these fluids.

Bromide, sulfate, and orthophosphate (as P) are the predominant minor anions in produced water with mean concentrations of 41, 20, and 11 mg/L, respectively. Nitrate (as N) was detected at a mean estimated (J) concentration of 2.75 mg/L. Carbonate (as  $\text{CaCO}_3$ ), fluoride, and nitrite (as N) were not detected above their reporting limits in produced water.

### 3.2.8 Natural Gas Composition Results

Natural gas composition results (Table 5) indicate that methane is the predominant component of the gas. The mean methane gas component comprises 83 percent. Ethane (7.66 percent), carbon dioxide (5.61 percent), and propane (2.26 percent) comprise the next most

abundant natural gas components. These four constituents comprise approximately 99 percent of the natural gas. The remaining 1 percent is comprised of iso-butane (0.52 percent), n-butane (0.46 percent), C6+ (0.21 percent), iso-pentane (0.18 percent), n-pentane (0.13 percent), nitrogen (0.11 percent), and oxygen (0.02 percent). Trace amounts of helium (0.003 percent) and hydrogen (0.003 percent) are also present. Argon, carbon monoxide, ethylene, and hydrogen sulfide were not detected above their reporting limits.

The mean heating value at base conditions (14.696 pound per square inch atmosphere and 60 degrees Fahrenheit [ $^{\circ}$ F]; ASTM 2003) is 1,088 British thermal units per cubic foot (BTU/Ft<sup>3</sup>). The mean relative gas density (calculated as the ratio of natural gas density to air density,  $\rho_g/\rho_a$ ) is 0.693.

### 3.3 Conclusions

Review of the results of the various monitoring studies completed by CER, CDH, DOE, DRI, EPA, and Williams shows that no known release of identified Project Rio Blanco radionuclides has occurred, except during the natural gas calibration flaring and production tests following re-entry into the nuclear chimney. Monitoring by CER and others during these test activities indicated that <sup>3</sup>H and <sup>85</sup>Kr were significantly below regulated levels during the gas calibration and production tests. Residual radionuclides released during re-entry drilling were excavated and shipped off-site as part of the site cleanup efforts in 1976. During 2000, the site surface and shallow subsurface was characterized and determined to require no further action. No further action was subsequently approved by the CDPHE.

Overall, the monitoring performed prior to, during, and after the Project Rio Blanco test has demonstrated that radionuclide activities within environmental media sampled over the 35-year period since the test are generally within background ranges for naturally-occurring radionuclides that are commonly found in the geologic formations or man-made radionuclides that have been atmospherically deposited (i.e., as fallout) over the region. These monitoring studies have also demonstrated that gas production has not resulted in the migration of identified Project Rio Blanco-related radionuclides outside of the test cavities to producing gas wells near the test site since the detonation.

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-11-7-397		02/12/09	NG	SA	14C1	0.5	± 0.1	0.2	pMC		Yes
FE-RG-12-4-398		01/07/09	NG	SA	14C1	0.2	----	0.2	pMC	U	No
FE-RG-13-1-398	Tier II	01/07/09	NG	SA	14C1	0.3	----	0.3	pMC	U	No
FE-RG-24-13-398	Tier II	01/07/09	NG	SA	14C1	0.2	----	0.2	pMC	U	No
FE-RG-24-20-398		01/07/09	NG	SA	14C1	0.2	----	0.2	pMC	U	No
FE-RG-31-8-398		01/07/09	NG	SA	14C1	0.2	----	0.2	pMC	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ac-228	16.3	11.4	8.46	pCi/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ac-228	16.5	10.8	16.7	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ac-228	1.98	7.89	13.2	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ac-228	-5.1	8	12.2	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ag-110m	-1.22	1.47	2.35	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Ag-110m	-0.966	1.81	2.89	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ag-110m	1.27	1.94	3.41	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Ag-110m	0.971	1.84	3.24	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ag-110m	0.273	1.7	2.85	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ag-110m	0.598	1.55	2.68	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Am-241	0.697	13.1	19.2	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Am-241	4.15	11.7	17.2	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Am-241	-17.8	10.4	16	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Am-241	5.01	11.6	17.9	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Am-241	-4.68	11.6	18.1	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Am-241	2.01	13.1	19.6	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ba-133	-0.861	2.5	3.54	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Ba-133	0.791	2.92	4.29	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ba-133	0.636	2.99	4.52	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Ba-133	-0.185	2.89	4.15	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ba-133	-1.05	2.6	3.81	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ba-133	-0.639	2.73	4.07	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ba-140	4.5	7.25	12.6	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Ba-140	2.67	8.65	15	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ba-140	-4.39	8.72	13.7	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Ba-140	-1.88	9.54	16	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ba-140	-1.63	9.24	15.2	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ba-140	2.97	8.53	14.7	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Be-7	10.1	14.8	25	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Be-7	-4.05	15.4	25.7	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Be-7	-19.9	16.4	24.7	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Be-7	8.67	16	28.6	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Be-7	5.79	16	27.8	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Be-7	4.05	16.4	28.2	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Bi-212	3.18	18.5	23.2	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Bi-212	16.1	15.6	28.4	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Bi-212	4.59	15.1	25.7	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Bi-212	14.5	15.1	27.4	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Bi-212	1.81	15.8	23.3	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Bi-212	5.66	16.7	25.5	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Bi-214	8.53	6.11	8.67	pCi/L	UJ, D-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Ce-139	0.247	1.62	2.78	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Ce-139	-0.857	1.74	2.86	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ce-139	1.02	1.93	3.27	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Ce-139	-0.497	1.83	3.11	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ce-139	-0.0641	1.75	2.96	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ce-139	-0.86	1.7	2.8	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ce-141	4	3.4	5.35	pCi/L	UJ, D-I	No
FE-RG-12-4-398		01/07/09	PW	SA	Ce-141	-0.22	3.24	5.49	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ce-141	-0.969	3.7	6.08	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Ce-141	1.1	3.37	5.74	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ce-141	-0.0122	3.32	5.66	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ce-141	-2.42	3.31	5.44	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ce-144	-1.4	12.3	20.4	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Ce-144	3.65	12.7	21.8	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ce-144	9.79	13.5	23.2	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Ce-144	-3.27	13.7	21.8	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ce-144	7.56	12.9	22.5	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ce-144	7.01	12.9	22.6	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Cl-36	166	130	214	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Cl-36	24.6	104	182	pCi/L	UJ, D-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Cl-36	48.2	109	188	pCi/L	UJ, D-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Cl-36	97.2	114	191	pCi/L	UJ, D-I	No
FE-RG-24-20-398		01/07/09	PW	SA	Cl-36	88.9	179	305	pCi/L	UJ, D-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Cl-36	64.6	120	206	pCi/L	UJ, D-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Co-56	0.328	1.53	2.61	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Co-56	1.35	1.96	3.47	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Co-56	-0.5	1.94	3.23	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Co-56	-0.347	2.08	3.37	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Co-56	-0.235	1.77	2.99	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Co-56	1.89	1.69	3.24	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Co-57	0.734	1.5	2.62	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Co-57	-0.0479	1.6	2.73	pCi/L	UJ, D-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Co-57	-1.13	1.78	2.88	pCi/L	UJ, D-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Co-57	-1.61	1.81	2.81	pCi/L	UJ, D-I	No
FE-RG-24-20-398		01/07/09	PW	SA	Co-57	-0.2	1.66	2.83	pCi/L	UJ, D-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Co-57	0.606	1.62	2.84	pCi/L	UJ, D-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Co-58	0.872	1.5	2.63	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Co-58	-1.37	1.83	2.76	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Co-58	-0.363	2.14	3.16	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Co-58	0.187	2.21	3.2	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Co-58	1.12	1.79	3.27	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Co-58	-0.00319	1.62	2.78	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Co-60	-0.837	1.53	2.46	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Co-60	1.74	2.08	3.86	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Co-60	-0.464	2.07	3.35	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Co-60	-0.549	2.13	2.85	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Co-60	-0.0637	1.88	3.07	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Co-60	0.681	1.98	3.43	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Cr-51	3.63	14.9	25.1	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Cr-51	-4.86	17.9	28.8	pCi/L	UJ, D-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Cr-51	-10.4	18.3	30.3	pCi/L	UJ, D-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Cr-51	30.4	18.9	34.5	pCi/L	UJ, D-I	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-24-20-398		01/07/09	PW	SA	Cr-51	-18.6	18.4	27.3	pCi/L	UJ, D-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Cr-51	-3.22	19	30.3	pCi/L	UJ, D-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Cs-134	0.147	2.05	3.46	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Cs-134	0.248	2.43	4.08	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Cs-134	0.366	2.3	3.86	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Cs-134	-0.676	2.87	3.97	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Cs-134	-0.86	2.12	3.49	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Cs-134	0.628	2.01	3.57	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Cs-136	-0.718	2.66	4.28	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Cs-136	1.11	3.46	6.13	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Cs-136	-1.36	3.84	6.26	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Cs-136	-0.691	3.51	5.82	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Cs-136	1.22	3.23	5.7	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Cs-136	-0.374	3.48	5.77	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Cs-137	-1.16	2.27	2.77	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Cs-137	-1.27	2.21	3.35	pCi/L	UJ, D-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Cs-137	-0.94	1.99	3.13	pCi/L	UJ, D-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Cs-137	-3.5	2.38	3.17	pCi/L	UJ, D-I	No
FE-RG-24-20-398		01/07/09	PW	SA	Cs-137	0.169	1.93	3.22	pCi/L	UJ, D-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Cs-137	1.21	1.86	3.28	pCi/L	UJ, D-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Eu-152	3.26	5.31	8.41	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Eu-152	-3.38	5.5	8.59	pCi/L	UJ, D-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Eu-152	2.76	6.5	10.8	pCi/L	UJ, D-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Eu-152	4.91	5.47	9.64	pCi/L	UJ, D-I	No
FE-RG-24-20-398		01/07/09	PW	SA	Eu-152	-3.26	5.37	8.93	pCi/L	UJ, D-I	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-31-8-398		01/07/09	PW	SA	Eu-152	-3.67	5.34	8.83	pCi/L	UJ, D-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Eu-154	-0.718	4.46	7.5	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Eu-154	-1.57	5.56	9.05	pCi/L	UJ, D-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Eu-154	-1.08	5.49	8.94	pCi/L	UJ, D-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Eu-154	-3.94	5.5	8.21	pCi/L	UJ, D-I	No
FE-RG-24-20-398		01/07/09	PW	SA	Eu-154	-1.53	5.36	8.46	pCi/L	UJ, D-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Eu-154	-3.05	5.52	8.33	pCi/L	UJ, D-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Eu-155	2.62	6.52	11.4	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Eu-155	4.66	6.82	12	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Eu-155	-1.12	7.58	12.6	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Eu-155	-1.13	8.08	12.3	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Eu-155	-0.421	7.26	12.6	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Eu-155	-2.41	6.7	11.4	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Fe-59	-1.68	3.19	4.98	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Fe-59	-2.64	3.56	5.48	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Fe-59	2.69	3.52	6.53	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Fe-59	-3.8	4.14	6.24	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Fe-59	-0.556	3.45	5.64	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Fe-59	1.9	3.18	5.78	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Gross Alpha	14.6	22.6	38.9	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Gross Alpha	7.44	17.2	30.8	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Gross Alpha	11	25.7	44.8	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Gross Alpha	6.77	10.6	18.3	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Gross Alpha	13.8	9.36	14.2	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Gross Alpha	2.43	5.93	10.6	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-11-7-397		02/12/09	PW	SA	Gross Beta	74.2	18.1	25.5	pCi/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Gross Beta	175	28	40.2	pCi/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Gross Beta	115	29.5	45.9	pCi/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Gross Beta	66.5	14.6	22	pCi/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Gross Beta	69.2	14.8	22.3	pCi/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Gross Beta	36	11.4	18.1	pCi/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Hg-203	0.263	1.85	3.12	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Hg-203	-1.07	2.09	3.34	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Hg-203	0.195	2.19	3.78	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Hg-203	0.732	2.2	3.76	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Hg-203	0.786	2.07	3.48	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Hg-203	0.711	2.06	3.46	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ir-192	-0.451	1.61	2.64	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Ir-192	0.799	1.92	3.25	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ir-192	1.21	1.84	3.28	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Ir-192	-0.867	1.97	3.18	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ir-192	0.83	2.06	3.43	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ir-192	0.0916	1.83	2.98	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	K-40	172	54.6	26.9	pCi/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	K-40	215	56.3	28.3	pCi/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	K-40	179	51.3	37.5	pCi/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	K-40	154	50.8	29.9	pCi/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	K-40	110	39.2	30.3	pCi/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	K-40	60.9	39.4	32.4	pCi/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Kr-85	-1700	479	699	pCi/L	UJ, D-I	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-12-4-398		01/07/09	PW	SA	Kr-85	-1170	557	830	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Kr-85	-1580	623	891	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Kr-85	-1690	631	922	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Kr-85	-1220	597	883	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Kr-85	-1300	581	845	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Mn-54	-0.599	1.67	2.73	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Mn-54	-1.03	2.1	3.31	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Mn-54	-1.2	2.19	2.98	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Mn-54	0.942	1.97	3.42	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Mn-54	-0.443	1.74	2.9	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Mn-54	0.736	1.71	3.05	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Na-22	-0.256	1.59	2.67	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Na-22	-0.535	1.99	3.24	pCi/L	UJ, D-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Na-22	-0.412	1.95	3.17	pCi/L	UJ, D-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Na-22	-1.48	1.95	2.89	pCi/L	UJ, D-I	No
FE-RG-24-20-398		01/07/09	PW	SA	Na-22	-0.623	1.9	2.98	pCi/L	UJ, D-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Na-22	-1.14	1.96	2.94	pCi/L	UJ, D-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Nb-94	-0.859	1.53	2.49	pCi/L	UJ, D-I	No
FE-RG-12-4-398		01/07/09	PW	SA	Nb-94	0.64	1.81	3.13	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Nb-94	-1.03	1.9	2.97	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Nb-94	1.58	1.72	3.12	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Nb-94	0.837	1.58	2.76	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Nb-94	-2.02	1.73	2.46	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Nb-95	1.7	1.82	3.24	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Nb-95	0.973	2.05	3.57	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Nb-95	0.98	2.17	3.74	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Nb-95	0.253	2.09	3.52	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Nb-95	0.483	1.96	3.28	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Nb-95	-0.289	2.27	3.65	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Nd-147	-9.37	13.8	22.6	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Nd-147	0.43	17	29	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Nd-147	17.5	19.4	34.7	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Nd-147	-7.14	18.2	29.9	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Nd-147	-4.07	19.1	31.5	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Nd-147	1.2	17.3	29.2	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Np-239	-1.34	11.5	19.8	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Np-239	2.1	11.9	20.6	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Np-239	2.02	13.6	22.9	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Np-239	2.76	13.6	22.4	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Np-239	-3.32	13.1	22.4	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Np-239	-1.53	12.4	21.2	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Pb-210	118	335	558	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Pb-210	-35.8	320	456	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Pb-210	79	281	358	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Pb-210	-194	338	482	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Pb-210	233	423	600	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Pb-210	-78.6	420	564	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Pb-212	4.63	5.85	6.35	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Pb-212	4.98	4.81	6.66	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Pb-212	3.71	5.39	8.11	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Pb-212	5.38	6.7	7.02	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Pb-212	1.43	4.01	5.89	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Pb-212	3.33	5.87	6.51	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Pb-214	7.56	6.92	7.97	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Pb-214	7.33	7.39	9.38	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Pb-214	7.05	7.21	8.2	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Pb-214	6.21	5.49	7.96	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Pm-144	-1.75	2.04	2.48	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Pm-144	0.144	1.67	2.82	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Pm-144	-0.502	1.91	3.08	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Pm-144	0.291	1.69	2.88	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Pm-144	1.45	1.77	3.15	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Pm-144	-0.559	1.77	2.81	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Pm-146	-0.573	2.22	3.58	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Pm-146	1.17	2.45	4.33	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Pm-146	0.192	2.44	4.14	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Pm-146	0.816	2.52	4.44	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Pm-146	1	2.36	4.14	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Pm-146	-1.66	2.31	3.69	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ra-228	16.3	11.4	8.46	pCi/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ra-228	16.5	10.8	16.7	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ra-228	1.98	7.89	13.2	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ra-228	-5.1	8	12.2	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Ru-106	-10.9	14.4	23.4	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Ru-106	3.05	17.6	30.1	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Ru-106	-10.4	17.8	27.9	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Ru-106	-8.04	16.9	27.2	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Ru-106	-8.29	17	26.8	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Ru-106	-0.0963	15.3	25.3	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Sb-124	-4.53	3.48	4.76	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Sb-124	0.0859	4.64	7.73	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Sb-124	-0.714	5.24	8.46	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Sb-124	-0.365	3.9	6.52	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Sb-124	-2.04	4.55	7.09	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Sb-124	0.686	4.07	7.06	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Sb-125	2.67	4.46	7.55	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Sb-125	-2.52	5.9	8.46	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Sb-125	0.404	5.48	9.33	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Sb-125	0.0483	5.54	9.06	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Sb-125	2.52	5.15	9.1	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Sb-125	-0.84	4.9	8.26	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Sn-113	-0.139	2.02	3.32	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Sn-113	-0.419	2.42	3.9	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Sn-113	-2.6	2.46	3.85	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Sn-113	-2.27	2.58	3.93	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Sn-113	-1.19	2.24	3.7	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Sn-113	-1.05	2.27	3.77	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Sr-90	-0.286	0.485	0.898	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Sr-90	0.0202	0.55	1.01	pCi/L	UJ, MS-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Sr-90	-0.715	0.598	1.22	pCi/L	UJ, MS-I	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Sr-90	0.344	0.59	1.03	pCi/L	UJ, MS-I	No
FE-RG-24-20-398		01/07/09	PW	SA	Sr-90	0.0199	0.358	0.695	pCi/L	UJ, MS-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Sr-90	-0.292	0.442	0.901	pCi/L	UJ, MS-I	No
FE-RG-11-7-397		02/12/09	PW	SA	Tc-99	-10.1	25.6	45.3	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Tc-99	-18.3	25.3	44.7	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Tc-99	-13.5	27.8	48.7	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Tc-99	7.87	27.2	46.5	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Tc-99	-9.59	22	38.4	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Tc-99	-10.1	23.9	41.7	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Th-230	1030	6630	1360	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Th-230	-227	1700	1260	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Th-230	-420	2790	1310	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Th-230	883	5700	1250	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Th-230	330	2300	1440	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Th-230	920	5950	1330	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Th-234	27.6	143	175	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Th-234	25.3	123	138	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Th-234	-13.5	99	160	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Th-234	78.2	129	180	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Th-234	-94.5	121	187	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Th-234	16.7	128	152	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Tl-208	1.1	2.41	3.81	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Tl-208	2.38	2.78	4.43	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Tl-208	0.468	2.97	3.87	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Tl-208	2.28	2.49	3.87	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-31-8-398		01/07/09	PW	SA	TI-208	3.23	2.37	4.08	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Total Uranium	-0.00366	0.00134	0.533	ug/L	UJ, D-I	No
FE-RG-12-4-398		01/07/09	PW	SA	Total Uranium	0.583	0.0559	0.267	ug/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Total Uranium	1.81	0.132	0.267	ug/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Total Uranium	0.692	0.0667	0.267	ug/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Total Uranium	1.09	0.074	0.267	ug/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Total Uranium	0.651	0.0491	0.267	ug/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Tritium	10	-----	10	TU	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Tritium	10	-----	10	TU	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Tritium	10.6	-----	10.6	TU	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Tritium	10.5	-----	10.5	TU	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Tritium	10	-----	10	TU	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Tritium	10	-----	10	TU	U	No
FE-RG-11-7-397		02/18/09	NG	SA	TritiumC1	10	-----	10	TU	U	No
FE-RG-12-4-398		01/07/09	NG	SA	TritiumC1	10	-----	10	TU	U	No
FE-RG-13-1-398	Tier II	01/07/09	NG	SA	TritiumC1	10	-----	10	TU	U	No
FE-RG-24-13-398	Tier II	01/07/09	NG	SA	TritiumC1	10	-----	10	TU	U	No
FE-RG-24-20-398		01/07/09	NG	SA	TritiumC1	12.5	-----	12.5	TU	U	No
FE-RG-31-8-398		01/07/09	NG	SA	TritiumC1	10	-----	10	TU	U	No
FE-RG-11-7-397		02/12/09	PW	SA	U-235	11.2	18.9	20.8	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	U-235	-20.3	15.8	22	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	U-235	-22.5	17	24.6	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	U-235	-4.46	16.6	22.4	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	U-235	-13.3	16	22.3	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	U-235	-3.81	15.8	22.9	pCi/L	U	No

Table 2. Summary of 2009 Radiological Analytical Results

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
FE-RG-11-7-397		02/12/09	PW	SA	U-238	27.6	143	158	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	U-238	25.3	123	138	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	U-238	-13.5	99	160	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	U-238	78.2	129	159	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	U-238	-94.5	121	187	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	U-238	16.7	128	152	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Y-88	1.15	1.8	3.23	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Y-88	1.85	2.12	4	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Y-88	0.234	1.82	3.18	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Y-88	-1.7	1.91	2.62	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Y-88	-1.42	2.13	3.11	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Y-88	-1.23	1.78	2.51	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Zn-65	1.34	3.76	5.58	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Zn-65	-3.44	4.35	6.77	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Zn-65	-4.07	4.57	6.94	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Zn-65	-1.41	4.39	7.16	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Zn-65	-0.735	4.5	7.09	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Zn-65	0.315	4.13	6.66	pCi/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Zr-95	-1.12	2.85	4.67	pCi/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Zr-95	-0.451	3.29	5.41	pCi/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Zr-95	-1.75	3.55	5.52	pCi/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Zr-95	-0.756	3.3	5.36	pCi/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Zr-95	-1.54	2.88	4.33	pCi/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Zr-95	2.01	3.17	5.56	pCi/L	U	No

**Table 2. Summary of 2009 Radiological Analytical Results**

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Activity or Concentration	Counting Error	Reporting Limit	Units	Flag	Detected ?
<p><b>Notes:</b> PW = produced water, NG = natural gas; SA = primary sample; pCi/L = picoCuries per liter; µg/L = micrograms per liter; pMC = percent modern carbon; TU = tritium units; U = analyte was analyzed but was not detected above the minimum detectable activity (MDA); UJ = the analyte was analyzed for but was not detected above the MDA, the reported result is an estimate; D = result was qualified as estimated because the duplicate error ratio criterion was not met; MS = result was qualified as estimated because of a low matrix spike recovery; I = bias in sample result is indeterminant; TritiumC1 = tritium in water derived from the combustion of natural gas; the tritium activity per liter of methane = <math>TU * 3.19 * 1.6E-3 = pCi/L_{\text{methane}}</math>.</p>											

Table 3. Summary of 2009 Metals Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-11-7-397		02/12/09	PW	SA	Arsenic	3.6	2	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Arsenic	15	2	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Arsenic	1.2	2	µg/L	J, SQL-I	Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Arsenic	2.2	2	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Arsenic	10	2	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Arsenic	4.9	2	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Barium	65000	1000	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Barium	50000	1000	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Barium	18000	1000	µg/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Barium	23000	1000	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Barium	7900	1000	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Barium	13000	1000	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Boron	14000	1000	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Boron	8500	1000	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Boron	12000	1000	µg/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Boron	13000	1000	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Boron	11000	1000	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Boron	6600	1000	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Cadmium	0.3	0.3	µg/L	U, MB-I	No
FE-RG-12-4-398		01/07/09	PW	SA	Cadmium	0.056	0.3	µg/L	J, SQL-I	Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Cadmium	0.099	0.3	µg/L	J, SQL-I	Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Cadmium	0.1	0.3	µg/L	J, SQL-I	Yes
FE-RG-24-20-398		01/07/09	PW	SA	Cadmium	0.3	0.3	µg/L	U, CCB-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Cadmium	0.3	0.3	µg/L	U	No

Table 3. Summary of 2009 Metals Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-11-7-397		02/12/09	PW	SA	Calcium	180000	10000	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Calcium	130000	10000	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Calcium	170000	10000	µg/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Calcium	60000	10000	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Calcium	28000	10000	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Calcium	34000	10000	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Chromium	100	100	µg/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Chromium	100	100	µg/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Chromium	100	100	µg/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Chromium	22	100	µg/L	J, CCB, SQL-I	Yes
FE-RG-24-20-398		01/07/09	PW	SA	Chromium	10	100	µg/L	J, CCB,SQL-I	Yes
FE-RG-31-8-398		01/07/09	PW	SA	Chromium	58	100	µg/L	J, SQL-I	Yes
FE-RG-11-7-397		02/12/09	PW	SA	Iron	12000	1000	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Iron	4400	1000	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Iron	62000	1000	µg/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Iron	8400	1000	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Iron	7100	1000	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Iron	15000	1000	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Lead	0.5	0.5	µg/L	U, MB-I	No
FE-RG-12-4-398		01/07/09	PW	SA	Lead	0.5	0.5	µg/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Lead	0.075	0.5	µg/L	J, SQL-I	Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Lead	0.55	0.5	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Lead	0.16	0.5	µg/L	J, SQL-I	Yes
FE-RG-31-8-398		01/07/09	PW	SA	Lead	0.095	0.5	µg/L	J, SQL-I	Yes
FE-RG-11-7-397		02/12/09	PW	SA	Lithium	7400	100	µg/L		Yes

Table 3. Summary of 2009 Metals Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-12-4-398		01/07/09	PW	SA	Lithium	4300	100	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Lithium	4800	100	µg/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Lithium	5600	100	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Lithium	3400	100	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Lithium	3100	100	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Magnesium	21000	10000	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Magnesium	15000	10000	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Magnesium	16000	10000	µg/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Magnesium	5900	10000	µg/L	J, SQL-I	Yes
FE-RG-24-20-398		01/07/09	PW	SA	Magnesium	2800	10000	µg/L	J, SQL-I	Yes
FE-RG-31-8-398		01/07/09	PW	SA	Magnesium	3800	10000	µg/L	J, SQL-I	Yes
FE-RG-11-7-397		02/12/09	PW	SA	Manganese	300	2	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Manganese	120	2	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Manganese	990	20	µg/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Manganese	160	2	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Manganese	84	2	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Manganese	130	2	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Mercury	0.24	0.2	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Mercury	0.2	0.2	µg/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Mercury	0.2	0.2	µg/L	U, MB-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Mercury	3.2	0.2	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Mercury	32	20	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Mercury	0.25	0.2	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Potassium	390000	10000	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Potassium	370000	10000	µg/L		Yes

Table 3. Summary of 2009 Metals Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Potassium	330000	10000	µg/L	J, DL-H	Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Potassium	200000	10000	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Potassium	150000	10000	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Potassium	140000	10000	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Selenium	1	1	µg/L	U, MB-I	No
FE-RG-12-4-398		01/07/09	PW	SA	Selenium	1	1	µg/L	U, MB-I	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Selenium	1	1	µg/L	U, MB-I	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Selenium	1	1	µg/L	U, MB-I	No
FE-RG-24-20-398		01/07/09	PW	SA	Selenium	1	1	µg/L	U, MB-I	No
FE-RG-31-8-398		01/07/09	PW	SA	Selenium	1.3	1	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Sodium	6000000	100000	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Sodium	4700000	100000	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Sodium	4800000	100000	µg/L	J, DL-H	Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Sodium	3700000	100000	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Sodium	3000000	100000	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Sodium	2400000	10000	µg/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Strontium	33000	100	µg/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Strontium	18000	100	µg/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Strontium	20000	100	µg/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Strontium	12000	100	µg/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Strontium	4700	100	µg/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Strontium	5200	100	µg/L		Yes

Notes: PW = produced water; SA = primary sample; µg/L = micrograms per liter; U = analyte was analyzed but was not detected above the reporting limit; J = the reported analytical result is estimated below the practical quantitation limit.; SQL = analysis meets all quantitative identification criteria, but the measured concentration is less than the reporting limit; MB = method blank contamination; CCB = calibration blank contamination; I = bias in sample result is indeterminate; DL = serial dilution results did not meet evaluation criteria; H = bias in sample result is likely to be high.

Table 4. Summary of 2009 Inorganic Parameter Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-11-7-397		02/12/09	PW	SA	Bicarbonate (as CaCO <sub>3</sub> )	1100	50	MG/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Bicarbonate (as CaCO <sub>3</sub> )	1400	100	MG/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Bicarbonate (as CaCO <sub>3</sub> )	900	100	MG/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Bicarbonate (as CaCO <sub>3</sub> )	980	100	MG/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Bicarbonate (as CaCO <sub>3</sub> )	2000	100	MG/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Bicarbonate (as CaCO <sub>3</sub> )	1600	100	MG/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Bromide	58	10	MG/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Bromide	49	4	MG/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Bromide	54	4	MG/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Bromide	39	4	MG/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Bromide	21	2	MG/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Bromide	22	2	MG/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Carbonate (as CaCO <sub>3</sub> )	50	50	MG/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Carbonate (as CaCO <sub>3</sub> )	100	100	MG/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Carbonate (as CaCO <sub>3</sub> )	100	100	MG/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Carbonate (as CaCO <sub>3</sub> )	100	100	MG/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Carbonate (as CaCO <sub>3</sub> )	100	100	MG/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Carbonate (as CaCO <sub>3</sub> )	100	100	MG/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Chloride	9600	200	MG/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Chloride	8500	100	MG/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Chloride	9100	100	MG/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Chloride	6200	100	MG/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Chloride	3400	100	MG/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Chloride	3000	100	MG/L		Yes

Table 4. Summary of 2009 Inorganic Parameter Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-11-7-397		02/12/09	PW	SA	Fluoride	5	5	MG/L	UJ, MS-L	No
FE-RG-12-4-398		01/07/09	PW	SA	Fluoride	2	2	MG/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Fluoride	2	2	MG/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Fluoride	1.6	2	MG/L	J, SQL-I	Yes
FE-RG-24-20-398		01/07/09	PW	SA	Fluoride	1	1	MG/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Fluoride	1	1	MG/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Nitrate (as N)	10	10	MG/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Nitrate (as N)	1.6	4	MG/L	J, SQL-I	Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Nitrate (as N)	1.5	4	MG/L	J, SQL-I	Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Nitrate (as N)	1.6	4	MG/L	J, SQL-I	Yes
FE-RG-24-20-398		01/07/09	PW	SA	Nitrate (as N)	0.82	2	MG/L	J, SQL-I	Yes
FE-RG-31-8-398		01/07/09	PW	SA	Nitrate (as N)	1	2	MG/L	J, SQL-I	Yes
FE-RG-11-7-397		02/12/09	PW	SA	Nitrite (as N)	5	5	MG/L	UJ, MS-L	No
FE-RG-12-4-398		01/07/09	PW	SA	Nitrite (as N)	2	2	MG/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Nitrite (as N)	2	2	MG/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Nitrite (as N)	2	2	MG/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Nitrite (as N)	1	1	MG/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Nitrite (as N)	1	1	MG/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	Orthophosphate (as P)	25	25	MG/L	U	No
FE-RG-12-4-398		01/07/09	PW	SA	Orthophosphate (as P)	10	10	MG/L	U	No
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Orthophosphate (as P)	10	10	MG/L	U	No
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Orthophosphate (as P)	10	10	MG/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Orthophosphate (as P)	5	5	MG/L	U	No
FE-RG-31-8-398		01/07/09	PW	SA	Orthophosphate (as P)	5	5	MG/L	U	No
FE-RG-11-7-397		02/12/09	PW	SA	pH	7.09	0.1	PH	J, HT-I	Yes

Table 4. Summary of 2009 Inorganic Parameter Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-12-4-398		01/07/09	PW	SA	pH	6.43	0.1	PH	J, HT-I	Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	pH	6.25	0.1	PH	J, HT-I	Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	pH	6.57	0.1	PH	J, HT-I	Yes
FE-RG-24-20-398		01/07/09	PW	SA	pH	6.63	0.1	PH	J, HT-I	Yes
FE-RG-31-8-398		01/07/09	PW	SA	pH	6.64	0.1	PH	J, HT-I	Yes
FE-RG-11-7-397		02/12/09	PW	SA	Sulfate	25	50	MG/L	J, SQL-I	Yes
FE-RG-12-4-398		01/07/09	PW	SA	Sulfate	13	20	MG/L	J, SQL-I	Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Sulfate	26	20	MG/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Sulfate	20	20	MG/L	U	No
FE-RG-24-20-398		01/07/09	PW	SA	Sulfate	26	10	MG/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Sulfate	12	10	MG/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Total Alkalinity (as CaCO <sub>3</sub> )	1100	50	MG/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Total Alkalinity (as CaCO <sub>3</sub> )	1400	100	MG/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Total Alkalinity (as CaCO <sub>3</sub> )	900	100	MG/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Total Alkalinity (as CaCO <sub>3</sub> )	980	100	MG/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Total Alkalinity (as CaCO <sub>3</sub> )	2000	100	MG/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Total Alkalinity (as CaCO <sub>3</sub> )	1600	100	MG/L		Yes
FE-RG-11-7-397		02/12/09	PW	SA	Total Dissolved Solids	18000	1000	MG/L		Yes
FE-RG-12-4-398		01/07/09	PW	SA	Total Dissolved Solids	14000	400	MG/L		Yes
FE-RG-13-1-398	Tier II	01/07/09	PW	SA	Total Dissolved Solids	15000	400	MG/L		Yes
FE-RG-24-13-398	Tier II	01/07/09	PW	SA	Total Dissolved Solids	11000	400	MG/L		Yes
FE-RG-24-20-398		01/07/09	PW	SA	Total Dissolved Solids	8700	400	MG/L		Yes
FE-RG-31-8-398		01/07/09	PW	SA	Total Dissolved Solids	7600	200	MG/L		Yes

Notes: PW = produced water; SA = primary sample; mg/L = milligrams per liter; U = analyte was analyzed but was not detected above the reporting limit; J = the reported analytical result is estimated; UJ = The analyte was analyzed for, but was not detected. The reported value is an estimate and may be inaccurate or imprecise; SQL = analysis meets all quantitative identification criteria, but the measured concentration is less than the reporting limit; MS = matrix spike recovery outside acceptance range; I = bias in sample result is indeterminate; HT = holding time requirement was not met.

Table 5. Summary of 2009 Natural Gas Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-11-7-397		2/18/2009	NG	SA	Argon	0		%	U	No
FE-RG-12-4-398		1/7/2009	NG	SA	Argon	0		%	U	No
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Argon	0		%	U	No
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Argon	0		%	U	No
FE-RG-24-20-398		1/7/2009	NG	SA	Argon	0		%	U	No
FE-RG-31-8-398		1/7/2009	NG	SA	Argon	0		%	U	No
FE-RG-11-7-397		2/18/2009	NG	SA	BTU	1059		BTU/Ft <sup>3</sup>		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	BTU	1109		BTU/Ft <sup>3</sup>		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	BTU	1085		BTU/Ft <sup>3</sup>		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	BTU	994		BTU/Ft <sup>3</sup>		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	BTU	1153		BTU/Ft <sup>3</sup>	U	No
FE-RG-31-8-398		1/7/2009	NG	SA	BTU	1130		BTU/Ft <sup>3</sup>		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	C6+	0.219		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	C6+	0.214		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	C6+	0.202		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	C6+	0.1		%		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	C6+	0.252		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	C6+	0.257		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Carbon Dioxide	4.63		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Carbon Dioxide	5.13		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Carbon Dioxide	4.71		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Carbon Dioxide	7.27		%		Yes

Table 5. Summary of 2009 Natural Gas Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-24-20-398		1/7/2009	NG	SA	Carbon Dioxide	5.71		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Carbon Dioxide	6.23		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Carbon Monoxide	0		%	U	No
FE-RG-12-4-398		1/7/2009	NG	SA	Carbon Monoxide	0		%	U	No
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Carbon Monoxide	0		%	U	No
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Carbon Monoxide	0		%	U	No
FE-RG-24-20-398		1/7/2009	NG	SA	Carbon Monoxide	0		%	U	No
FE-RG-31-8-398		1/7/2009	NG	SA	Carbon Monoxide	0		%	U	No
FE-RG-11-7-397		2/18/2009	NG	SA	Ethane	5.56		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Ethane	8.95		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Ethane	7.02		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Ethane	4.16		%		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	Ethane	10.54		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Ethane	9.73		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Ethylene	0		%	U	No
FE-RG-12-4-398		1/7/2009	NG	SA	Ethylene	0		%	U	No
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Ethylene	0		%	U	No
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Ethylene	0		%	U	No
FE-RG-24-20-398		1/7/2009	NG	SA	Ethylene	0		%	U	No
FE-RG-31-8-398		1/7/2009	NG	SA	Ethylene	0		%	U	No
FE-RG-11-7-397		2/18/2009	NG	SA	Helium	0.0023		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Helium	0.0028		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Helium	0.003		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Helium	0.0024		%		Yes

Table 5. Summary of 2009 Natural Gas Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-24-20-398		1/7/2009	NG	SA	Helium	0.0027		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Helium	0.0027		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Hydrogen	0.0051		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Hydrogen	0.0029		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Hydrogen	0.0042		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Hydrogen	0.0024		%		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	Hydrogen	0.0023		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Hydrogen	0.0024		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Hydrogen Sulfide	0		%	U	No
FE-RG-12-4-398		1/7/2009	NG	SA	Hydrogen Sulfide	0		%	U	No
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Hydrogen Sulfide	0		%	U	No
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Hydrogen Sulfide	0		%	U	No
FE-RG-24-20-398		1/7/2009	NG	SA	Hydrogen Sulfide	0		%	U	No
FE-RG-31-8-398		1/7/2009	NG	SA	Hydrogen Sulfide	0		%	U	No
FE-RG-11-7-397		2/18/2009	NG	SA	Iso-Butane	0.342		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Iso-Butane	0.555		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Iso-Butane	0.459		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Iso-Butane	0.165		%		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	Iso-Butane	0.832		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Iso-Butane	0.762		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Iso-Pentane	0.138		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Iso-Pentane	0.186		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Iso-Pentane	0.167		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Iso-Pentane	0.0512		%		Yes

Table 5. Summary of 2009 Natural Gas Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-24-20-398		1/7/2009	NG	SA	Iso-Pentane	0.275		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Iso-Pentane	0.26		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Methane	87.22		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Methane	81.81		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Methane	84.92		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Methane	87.45		%		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	Methane	77.59		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Methane	78.05		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	n-Butane	0.285		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	n-Butane	0.494		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	n-Butane	0.395		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	n-Butane	0.105		%		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	n-Butane	0.761		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	n-Butane	0.731		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Nitrogen	0.097		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Nitrogen	0.049		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Nitrogen	0.049		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Nitrogen	0.015		%		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	Nitrogen	0.077		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Nitrogen	0.35		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	n-Pentane	0.0869		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	n-Pentane	0.126		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	n-Pentane	0.108		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	n-Pentane	0.0302		%		Yes

Table 5. Summary of 2009 Natural Gas Analytical Results.

Well Number	Well Type	Sample Date	Medium	Sample Type	Parameter	Concentration	Reporting Limit	Units	Flag	Detected ?
FE-RG-24-20-398		1/7/2009	NG	SA	n-Pentane	0.207		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	n-Pentane	0.2		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Oxygen	0.0092		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Oxygen	0.0051		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Oxygen	0		%	U	No
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Oxygen	0		%	U	No
FE-RG-24-20-398		1/7/2009	NG	SA	Oxygen	0.0062		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Oxygen	0.0738		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Propane	1.41		%		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Propane	2.48		%		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Propane	1.96		%		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Propane	0.648		%		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	Propane	3.74		%		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Propane	3.35		%		Yes
FE-RG-11-7-397		2/18/2009	NG	SA	Specific Gravity	0.658		$\rho_g/\rho_a$		Yes
FE-RG-12-4-398		1/7/2009	NG	SA	Specific Gravity	0.698		$\rho_g/\rho_a$		Yes
FE-RG-13-1-398	Tier II	1/7/2009	NG	SA	Specific Gravity	0.675		$\rho_g/\rho_a$		Yes
FE-RG-24-13-398	Tier II	1/7/2009	NG	SA	Specific Gravity	0.659		$\rho_g/\rho_a$		Yes
FE-RG-24-20-398		1/7/2009	NG	SA	Specific Gravity	0.735		$\rho_g/\rho_a$		Yes
FE-RG-31-8-398		1/7/2009	NG	SA	Specific Gravity	0.732		$\rho_g/\rho_a$		Yes

Notes: NG = natural gas; SA = primary sample; % = percent; BTU/Ft<sup>3</sup> = British Thermal Units per cubic foot at 14.696 psia and 60 °F;  $\rho_g/\rho_a$  = relative density (ratio of natural gas density to air density) at 14.696 psia and 60 °F; U = analyte was analyzed but was not detected above the reporting limit.

## 4 MONITORING APPROACH

The Companies have developed a two-tiered (Tier I and II) operational and areal environmental monitoring program to support gas exploration and production within a 2-mile radius of Project Rio Blanco. The objectives of the monitoring program are to monitor the drilling, completion, production, and abandonment operations and the local water quality so that workers, the public, and the environment are protected from an unlikely radiological release during natural gas exploration and production in the area surrounding Project Rio Blanco.

The two operational monitoring tiers (Figure 2) are defined based on distance from Project Rio Blanco and are divided into 12 equal sectors. The areal environmental monitoring includes permitted wells, adjudicated springs, and streams both within and outside of the operational monitoring tiers. This RBSAP defines the monitoring requirements for both the operational and areal environmental monitoring programs and provides sampling procedures, analytical methods, and quality assurance/quality control (QA/QC) requirements for selected analytes that will be used to screen for identified Project Rio Blanco-related radionuclides. The specifics of each monitoring component are discussed below and summarized on Table 6.

The **operational monitoring program** is designed to verify that no identified Project Rio Blanco-related radionuclides are present in natural gas or produced water from any of the existing gas wells within the Tier I or Tier II monitoring zones (Figure 2) once this RBSAP is approved. It is also designed to screen future gas drilling, completion, production, and abandonment activities for identified Project Rio Blanco-related radionuclides within the Tier I and II monitoring zones (Figure 2) to protect workers, the public, and the environment. For the purposes of this RBSAP, an identified Project Rio Blanco-related radionuclide is a radionuclide that is:

- characteristic of a nuclear fission detonation
- whose half life is greater than 10 years
- whose activity is above background, and
- whose presence is determined to be valid.

**Table 6. Tier I and II Sampling and Analysis Scheme for Gas Wells within a Two-Mile Radius of Project Rio Blanco.**  
*(To Be Reviewed Annually)*

Monitoring Activity	Tier I Zone (Between 1/2-mile voluntary exclusion zone and 1-Mile Radius of Project Rio Blanco)	Tier II Zone (Between 1- and 2-Mile Radius of Project Rio Blanco)
Drilling (new wells)	<ul style="list-style-type: none"> <li>• A one-time background radiation survey will be performed at the well pad after grading but prior to drilling the <b>closest</b> designated gas well within each Tier I monitoring sector.</li> <li>• Ambient radiation dosimetry will be performed during drilling of the <b>closest</b> designated gas well within each Tier I monitoring sector.</li> <li>• Continuous, real-time gamma screening of drill cuttings and fluids will be conducted at the <b>closest</b> designated gas well within each Tier I monitoring sector.</li> <li>• Sampling and analysis of drilling mud for the radiological analytes listed in Table 7 will be conducted prior to introduction into the well bore at the <b>closest</b> designated gas well within each Tier I monitoring sector.</li> <li>• Two composite samples of drill cuttings will be collected from selected intervals approximately equivalent to the Project Rio Blanco test intervals at the <b>closest</b> designated gas well within each Tier I monitoring sector. These samples will be analyzed for the radiological analytes listed in Table 7. Sample results shall be reviewed by a third-party consultant independent of the Companies. The cuttings can be transported, re-used, or disposed without approval from the COGCC if identified Project Rio Blanco-related radionuclides are less than the screening level. If identified Project Rio Blanco-related radionuclides are greater than the screening level, the cuttings can not be transported, re-used, or disposed without prior written approval from the COGCC. A Notice of Intent to transport, re-use, or dispose of drill cuttings with identified Project Rio Blanco-related radionuclides equal to or greater than the screening level shall be submitted to the COGCC for approval.</li> </ul>	<ul style="list-style-type: none"> <li>• If a Tier II well is the <b>closest</b> designated gas well in a monitoring sector (i.e., no Tier I well), collect two composite drill cuttings samples from selected intervals approximately equivalent to the Project Rio Blanco test interval. The samples will be analyzed for the radiological analytes listed in Table 7. Sample results shall be reviewed by a third-party consultant independent of the Companies. The cuttings can be transported, re-used, or disposed without approval from the COGCC if identified Project Rio Blanco-related radionuclides are less than the screening levels. If identified Project Rio Blanco-related radionuclides are equal to greater than the screening levels, the cuttings can not be transported, re-used, or disposed without prior written approval from the COGCC. A Notice of Intent to transport, re-use, or dispose of drill cuttings with identified Project Rio Blanco-related radionuclides equal to or greater than the screening level shall be submitted to the COGCC for approval.</li> <li>• If a Tier II well is the <b>closest</b> designated gas well in a monitoring sector (i.e., no Tier I well), review open- or cased-hole gamma logs through the Fort Union and Williams Fork Formations for evidence of elevated gamma radiation that might be related to Project Rio Blanco.</li> <li>• If a Tier II well is the <b>closest</b> designated well in a monitoring sector (i.e., no Tier I well) or is projected to be laterally within 200 feet of the Tier I boundary (1-mile radius), perform a high accuracy gyroscopic directional wellbore survey after reaching total well depth but prior to commencing perforation and completion activities for wells. Alternatively, a magnetic survey may be performed in lieu of a gyroscopic survey as long as Tier I monitoring is performed for the respective well.</li> </ul>

**Table 6. Tier I and II Sampling and Analysis Scheme for Gas Wells within a Two-Mile Radius of Project Rio Blanco (continued).**

<b>Monitoring Activity</b>	<b>Tier I Zone (Between ½-mile voluntary exclusion zone and 1-Mile Radius of Project Rio Blanco)</b>	<b>Tier II Zone (Between 1- and 2-Mile Radius of Project Rio Blanco)</b>
Drilling (new wells)	<ul style="list-style-type: none"> <li>• Review open- or cased-hole gamma logs through the Fort Union and Williams Fork Formations for evidence of gamma radiation that might be related to Project Rio Blanco.</li> <li>• Perform a high accuracy gyroscopic directional wellbore survey after reaching total well depth but prior to commencing perforating and completion activities for all Tier I gas wells whose bottom-hole location is projected to be laterally within 200 feet of the ½-mile radius to verify that the wellbore did not penetrate the ½-mile boundary.</li> </ul>	
Completion (new wells)	<ul style="list-style-type: none"> <li>• Ambient radiation dosimetry during fracing at the <b>closest</b> designated gas well within each Tier I monitoring sector</li> <li>• Sampling and analysis of fracing fluids at the <b>closest</b> designated gas well within each Tier I monitoring sector. Samples will be analyzed for <sup>3</sup>H and reported to the COGCC in the quarterly monitoring reports.</li> <li>• Sampling and analysis of flowback fluids at the <b>closest</b> designated gas well within each Tier I monitoring sector. Samples will be analyzed for <sup>3</sup>H. Flowback fluid results shall be reviewed by a third-party consultant independent of the Companies. Flowback fluids can be transported, re-used, or disposed without approval from the COGCC if <sup>3</sup>H is less than the screening level. If <sup>3</sup>H is equal to or greater than the screening level, flowback fluid results shall be reviewed and approved by the COGCC before the fluids can be transported, re-used, or disposed. A Notice of Intent to transport, re-use, or dispose of flowback fluid with <sup>3</sup>H equal to or greater than the screening level shall be submitted to the COGCC for approval.</li> </ul>	<ul style="list-style-type: none"> <li>• If a Tier II well is the <b>closest</b> designated gas well in a monitoring sector (i.e., no Tier I well), sampling and analysis of fracing fluids. Samples will be analyzed for <sup>3</sup>H and reported to the COGCC in the quarterly monitoring reports.</li> <li>• If a Tier II well is the <b>closest</b> designated gas well in a monitoring sector (i.e., no Tier I well), sampling and analysis of flowback fluids. Samples will be analyzed for <sup>3</sup>H. Flowback fluid results shall be reviewed by a third-party consultant independent of the Companies. Flowback fluids can be transported, re-used, or disposed without approval from the COGCC if <sup>3</sup>H is less than the screening level. If <sup>3</sup>H is equal to or greater than the screening level, flowback fluid results shall be reviewed and approved by the COGCC before the fluids can be transported, re-used, or disposed. A Notice of Intent to transport, re-use, or dispose of flowback fluid with <sup>3</sup>H equal to or greater than the screening level shall be submitted to the COGCC for approval.</li> </ul>

**Table 6. Tier I and II Sampling and Analysis Scheme for Gas Wells within a Two-Mile Radius of Project Rio Blanco (continued).**

Monitoring Activity	Tier I Zone (Between ½-mile voluntary exclusion zone and 1-Mile Radius from Project Rio Blanco)	Tier II Zone (Between 1-and 2-Mile Radius of Project Rio Blanco)
Production (new and existing wells)	<ul style="list-style-type: none"> <li>• For all <b>new</b> Tier I gas wells, one-time sampling and analysis of produced water and natural gas for the radiological analytes listed in Table 7 shall be conducted as soon as possible after fracing but no later than 30 days after the first gas delivery, as long as the site is safely accessible.</li> <li>• During the first year of production, produced water and natural gas at all <b>new</b> gas wells shall be sampled and analyzed quarterly for one year <b>regardless of whether they are the closest designated well</b>. The samples will be analyzed for the radiological analytes listed in Table 7.</li> <li>• For the <b>closest</b> designated gas well in each monitoring sector, sampling and analysis of produced water and natural gas for the radiological analytes listed in Table 7 will be conducted quarterly during Year 1, semiannually during Years 2 and 3, and annually thereafter.</li> </ul>	<ul style="list-style-type: none"> <li>• For all <b>new</b> Tier II gas wells, one-time sampling and analysis of produced water and natural gas for the radiological analytes listed in Table 7 shall be conducted as soon as possible after fracing but no later than 30 days after the first gas delivery, as long as the site is safely accessible.</li> <li>• If a Tier II well is the closest well in a monitoring sector (i.e., no Tier I well), sampling and analysis of produced water and natural gas for the radiological analytes listed in Table 7 shall be conducted quarterly during Year 1, semiannually during Years 2 and 3, and annually thereafter. The first quarterly sample shall be collected within 180 days of first gas delivery.</li> <li>• Additional Tier II testing may be performed contingent on identified Project Rio Blanco-related radionuclide detection in Tier I wells.</li> </ul>
Plugging and Abandonment (new and existing wells)	<ul style="list-style-type: none"> <li>• P&amp;A monitoring requirements will be determined on a case-by-case basis by the Companies and the COGCC based on available analytical data.</li> </ul>	<ul style="list-style-type: none"> <li>• P&amp;A monitoring requirements will be determined on a case-by-case basis by the Companies and the COGCC based on available analytical data.</li> </ul>
Baseline (existing wells)	<ul style="list-style-type: none"> <li>• Produced water and natural gas at all Tier I gas wells that exist at the time this RBSAP is approved shall be sampled and analyzed once for the radiological analytes listed in Table 7 within 120 days of the RBSAP approval.</li> </ul>	<ul style="list-style-type: none"> <li>• Produced water and natural gas at all Tier II gas wells that exist at the time this RBSAP is approved shall be sampled and analyzed once for the radiological analytes listed in Table 7 within 120 days of the RBSAP approval.</li> </ul>
Areal Environmental Monitoring	<ul style="list-style-type: none"> <li>• Annual sampling and analysis of selected groundwater and surface water locations will be conducted for the radiological analytes listed in Table 7.</li> <li>• Additional testing contingent on verified Project Rio Blanco-related radionuclides within Tier I gas wells.</li> </ul>	<ul style="list-style-type: none"> <li>• Annual sampling and analysis of selected groundwater and surface water locations near Project Rio Blanco will be conducted for the radiological analytes listed in Table 7.</li> <li>• Additional testing contingent on verified Project Rio Blanco-related radionuclides within Tier II gas wells.</li> </ul>

Table 7. Radiological Analyte List.

Sample Medium	Gross Alpha	Gross Beta	Gamma-Emitting Radionuclides (includes <sup>85</sup> Kr and <sup>137</sup> Cs)	Tritium ( <sup>3</sup> H)	Carbon-14 ( <sup>14</sup> C)	Strontium-90 ( <sup>90</sup> Sr)	Technetium-99 ( <sup>99</sup> Tc)
Natural Gas	----	----	----	X	X <sup>8</sup>	----	----
Produced Water	X	X	X	X	----	X	X
Groundwater	X	X	X	X	----	X	X
Surface Water	X	X	X	X	----	X	X
Drilling Mud	X	X	X	X	----	X	X
Drill Cuttings	X	X	X	----	----	X	X
Fracing Fluid	----	----	----	X	----	----	----
Flowback Fluid	----	----	----	X	----	----	----

<sup>8</sup> The methane analyzed is separated using molecular sieves from other hydrocarbon and gas (e.g., CO<sub>2</sub>) constituents that naturally occur in the natural gas. The separated methane is combusted to form carbon dioxide (CO<sub>2</sub>) that is captured for <sup>14</sup>C analysis.

Tier I monitoring will be conducted at gas wells whose bottom-hole locations are between the ½-mile voluntary exclusion zone and a 1-mile radius from the Project Rio Blanco monument at surface ground zero. Tier II monitoring will be conducted at gas wells whose bottom-hole locations are between a 1- and 2-mile radius from the Project Rio Blanco monument at surface ground zero. At present, there are 5 producing gas wells within the Tier I and Tier II zones according to publically available COGCC records.

The **areal environmental monitoring program** is designed to monitor local water quality in groundwater and streams (i.e., permitted water wells, adjudicated springs, and local streams) for identified Project Rio Blanco-related radionuclides to protect local water supplies and the environment. The monitoring program involves the collection and analysis of surface water and groundwater from yet to be identified locations within and outside Tiers I and II (Figure 2). Sample sites located on private property will only be sampled with the landowner's permission. If permission is refused, sampling will not be performed.

#### 4.1 Tier I Monitoring

Tier I operational monitoring will be conducted at gas wells whose bottom hole locations are between the ½-mile voluntary exclusion zone and a 1-mile radius from the Project Rio Blanco monument at surface ground zero. Tier I monitoring is designed to screen for the presence of identified Project Rio Blanco-related radionuclides that may be encountered during gas drilling, completion, production, and abandonment operations within the Tier I monitoring zone (Figure 2). The selected radionuclide analytes for various media are listed in Table 7. The radiological analytes were selected because they provide a comprehensive set of screening analytes for some of the potentially more mobile or abundant Project Rio Blanco-related radionuclides that might be transported in the subsurface fluids.

Tier I monitoring includes:

- Baseline monitoring
- Drilling monitoring
- Completion monitoring

- Production monitoring
- Plugging and abandonment (P&A) monitoring

Specifics of each of these monitoring activities are discussed below.

#### 4.1.1 Tier I Baseline Produced Water and Natural Gas Monitoring

One time baseline produced water and natural gas sampling and analysis will be performed at each **existing** producing gas well within the Tier I zone within 120 days after this RBSAP is approved to document the initial radiological conditions within Tier I. For existing Tier I gas wells that are not currently in production, sampling and analysis will be performed if the well resumes production. Produced water and natural gas will be analyzed for the radiological analytes listed in Table 7.

#### 4.1.2 Tier I Drilling Monitoring

Tier I drilling monitoring will be conducted at the **closest** designated gas well in each Tier I monitoring sector to screen for the presence of identified Project Rio Blanco-related radionuclides that might be encountered during gas drilling operations. The closest designated well is defined as the closest well within each Tier I sector whose bottom hole location is nearest the Project Rio Blanco monument overlying the device emplacement well RB-E-1 at surface ground zero. If a new gas well is drilled within a Tier I monitoring sector that is closer than a previously drilled well, then the new, closer well within that sector will be monitored.

A 200-foot horizontal bottom hole location variance relative to the distance from Project Rio Blanco is allowed in determining whether a well is deemed the closest designated well within each monitoring sector. Thus, if the bottom hole locations of two or more wells are within 200 horizontal feet or less relative to their distance from Project Rio Blanco monument at surface ground zero, the Companies can specify any one of these wells as the closest well to streamline drilling operations and to minimize excessive monitoring requirements for wells whose bottom hole locations are a similar distance from the Project Rio Blanco site.

To allow the Companies to streamline drilling operations, such as batch drilling and cementing surface casings prior to drilling a Tier I production hole, Tier I drilling monitoring will be implemented at a vertical distance of at least 3,000 feet above the top of the Fort Union Formation. This will facilitate establishing background radiation levels prior to entering the Fort Union Formation while providing some degree of flexibility in planning drilling patterns. In practice, it is assumed that once production drilling is initiated, the Tier I monitoring activities discussed below will be implemented at the closest designated well.

Tier I drilling monitoring activities include:

- A one-time background radiation survey shall be performed at each new Tier I well pad within each monitoring sector after it is graded but prior to drilling the **closest** designated gas well. The background radiation survey will be performed in accordance with the procedures outlined in Section 5.3.2.2.
- Ambient radiation monitoring shall be performed at the **closest** designated Tier I gas well within each monitoring sector using dosimetry to measure ambient radiation in personnel work areas that could conceivably be released during drilling. Passive or electronic radiation dosimeters will be placed at the well pad prior to drilling the production hole and remain until the borehole reaches total depth. The dosimeters will be placed in work areas or near drilling fluid and cuttings discharge locations on the well pad to measure cumulative radiation intensities to which personnel could be exposed. One dosimeter will be placed in a location away from the drilling activities on the well pad to measure background radiation dose. A minimum of four Quantum Products Instadose™ dosimeters or Mirion Technologies DMC 2000XB electronic dosimeters (Appendix D), or equivalent, will be deployed at the well pad. The Instadose™ dosimeters are based on a Mirion Technologies ionization chamber and a direct ion storage technology (Appendix D). The dosimeters will be weatherproofed as necessary for outdoor use. The dosimeters are sensitive enough to provide accurate reporting to 1 mrem or less ( $10^{-3}$  Roentgen-Equivalent Man). The dosimeters will be periodically retrieved and processed as needed to determine the accumulated

dose. At a minimum, the accumulated dose on each dosimeter will be recorded prior to and immediately following deployment. The dosimeters will be handled and placed in accordance with the procedures in Section 5.4. Personnel occupancy times at the well pad will be logged so that, in the event of a radiation incident, personnel doses can be estimated.

- Continuous, real-time gamma screening of drill cutting and fluid returns at their outfall shall be performed to address concerns about radionuclides other than  $^3\text{H}$  that could conceivably be encountered during drilling of the **closest** designated gas well within each Tier I monitoring sector. Monitoring shall be conducted during drilling of the Green River Formation (to establish background) as well as in the Fort Union and Williams Fork Formations. Continuous, real-time gamma screening will be performed using a ICX Technologies Stride Series 200 real-time gamma spectrometry system equipped with a 3-inch diameter NaI(Tl) scintillation probe, or an equivalent system, to determine and verify whether gamma radiation encountered during drilling could be related to Project Rio Blanco. The gamma screening system will be operated in exposure mode ( $\mu\text{R/hr}$ ) and calibrated to a National Institute of Standards and Technology (NIST) traceable  $^{137}\text{Cs}$  standard. To the extent possible, the real-time gamma screening equipment will be linked directly to computers in the drilling control station so that the gamma radiation exposure can be recorded and reviewed in real time. The gamma radiation screening equipment will be equipped with an alarm to notify personnel of gamma screening and action levels. The gamma screening and action levels will be set at background  $\pm 5$  standard deviations and background  $\pm 10$  standard deviations, respectively (Appendix A, Table A-1). These screening or action levels may be adjusted once the equipment is in the field and background gamma levels have been determined.

If the gamma radiation screening or action level alarm is triggered, the drilling supervisor or his designated representative will temporarily stop drilling and call the RSO identified in the Tier I Radiological Incident Management Plan (Appendix A, Table A-2) for review and guidance. If the gamma alarm is verified

by the RSO, the drilling supervisor, or his designated representative, will suspend all work immediately and wait for further direction from Company management and the RSO. The Companies will immediately inform the COGCC, CDPHE, and DOE of any verified Project Rio Blanco-related radiation incident.

- Samples of drilling mud shall be collected prior to their introduction into the **closest** designated Tier I borehole in each monitoring sector for laboratory analysis of the radiological analytes listed in Table 7. The results of these analyses will be used to determine whether any radiological constituents detected may have been introduced during drilling.
- Two composite samples of drill cuttings shall be collected from **each new gas well until cuttings from a minimum of eight new gas wells have been sampled** within the Tier I or II monitoring zones. After eight wells have been sampled, composite drill cuttings samples will only be collected at the **closest** designated Tier I gas well within each monitoring sector whose bottom hole location is closest to the Project Rio Blanco monument at surface ground zero. The drill cuttings will be collected from selected formation intervals approximately equivalent (corrected for dip and distance) to the Project Rio Blanco test intervals. The composite samples will be collected by the Companies field representative in accordance with the procedures described in Section 5.7 and analyzed for the radiological analytes listed in Table 7. The two sampled intervals will include:
  - An approximate 500-foot interval extending from approximately 750 feet to 250 feet above the approximate top of the Project Rio Blanco test interval; and
  - An approximate 1,500-foot interval extending from approximately 250 feet above to 250 feet below the Project Rio Blanco test interval.
- Drill cuttings from the **closest** designated well location in each monitoring sector shall be analyzed for the radiological constituents listed in Table 7 to confirm compliance with the RBSAP. Sample results shall be reviewed by a third-party consultant independent of the Companies. The cuttings can be transported, re-used, or disposed without approval from the COGCC if identified Project Rio

Blanco-related radionuclides are less than the screening levels in Table 8. A letter, including the data validation report and qualified data sheets, along with a Sundry Notice Form 4 shall be submitted to the COGCC to document the drill cuttings results and demonstrate compliance with the RBSAP. If identified Project Rio Blanco-related radionuclides are equal to or greater than the screening levels, the drill cuttings can not be transported, re-used, or disposed without prior written approval from the COGCC. A Notice of Intent to transport, re-use, or dispose of drill cuttings with identified Project Rio Blanco-related radionuclides equal to or greater than the screening level (Table 8) shall be submitted to the COGCC for approval. The Notice of Intent shall include a letter, including the data validation report and qualified data sheets, that summarizes and discusses the results as an attachment.

- A closed loop mud system, or equivalent, shall be used to contain all drilling fluids that have been in contact with downhole strata and fluids in the **closest** designated gas well in each Tier I monitoring sector. If reserve pits are used to manage drilling fluids they will be lined. Stormwater best management practices (BMPs), such as surface contouring, drains, etc., will be employed, as necessary, to ensure containment and overall site integrity
- Open- or cased-hole gamma-ray logs will be run through the Fort Union and Williams Fork Formation intervals after each hole is completed and reviewed to determine whether Project Rio Blanco-related gamma radiation was encountered in the hole, its depth, and activity. A gamma radiation measurement greater than 500 American Petroleum Institute (API) gamma log units or any other gamma readings that appear to be anomalously high will be noted and immediately reported to the RSO and Company management for review and guidance.
- A high accuracy gyroscopic directional wellbore survey shall be run after reaching the total wellbore depth but prior to commencing perforation and completion activities for wells whose bottom-hole location is projected to be laterally within 200 feet of the ½-mile monitoring radius to verify that the

wellbore did not penetrate the ½-mile boundary. A copy of the directional drilling survey report, including a map view and a vertical profile view showing the wellbore trajectory and the distance from the ½ mile Project Rio Blanco monitoring radius, along with a Sundry Notice Form 4 shall be submitted to the COGCC. The operator shall obtain approval in writing from the COGCC prior to commencing casing perforation and other completion activities at these wells.

#### 4.1.3 Tier I Completion Monitoring

Tier I completion monitoring shall be conducted at the **closest** designated well in each Tier I monitoring sector to screen for the presence of identified Project Rio Blanco-related radionuclides that might be encountered in flowback fluids (i.e., produced waters) during gas well completion operations. Flowback fluids shall be contained in tanks only. The Companies shall submit a secondary and tertiary containment plan via Sundry Notice Form 4 for the tanks. If the COGCC has not objected to or requested additional information within 10 business days of a Company's filing of a Sundry Notice Form 4, the Company may proceed with fracing and flowback operations.

Ambient radiation monitoring shall be performed using dosimetry in personnel work areas to measure ambient radiation that could conceivably be released during fracing at the **closest** designated Tier I gas well in each monitoring sector. Passive or electronic radiation dosimeters will be placed at the well pad prior to fracing and remain until flowback is completed. The dosimeters will be placed near the well(s) undergoing fracing and near fluid discharge locations on each well pad to measure cumulative radiation intensities to which personnel may be exposed. One dosimeter will be placed in a location away from the drilling activities on the well pad to measure the background radiation dose. The dosimetry will be performed as discussed in Sections 4.1.2 and 5.4.

Samples of introduced fracing fluids (prior to use) and recovered flowback fluids will be collected for laboratory analysis of  $^3\text{H}$ . The samples will be collected in accordance with the procedures described in Section 5.8. The fracing and flowback fluids will only be analyzed for  $^3\text{H}$  to screen for the most likely Project Rio Blanco-related radionuclide in these fluids. The

results of the analyses will be used to determine whether  $^3\text{H}$  may have been introduced during fracing or to determine whether  $^3\text{H}$  is present in the recovered flowback fluids.

Flowback fluid results shall be reviewed by a third-party consultant independent of the Companies, prior to transport, re-use, or disposal. Flowback fluids may be transported, re-used, or disposed without written approval from the COGCC if  $^3\text{H}$  is less than the screening level provided in Table 8. A letter, including the data validation report and qualified data sheets, along with a Sundry Notice Form 4 shall be submitted to the COGCC to document the flowback fluid results and demonstrate compliance with the RBSAP. If  $^3\text{H}$  is equal to or greater than the screening level (Table 8), flowback fluid results shall be reviewed and approved in writing by the COGCC before the flowback fluids can be transported, re-used, or disposed.

A Notice of Intent to transport, re-use, or dispose of flowback fluids with identified Project Rio Blanco-related radionuclides equal to or greater than the screening level (Table 8) shall be submitted to the COGCC for approval. The Notice of Intent shall include a letter, including the data validation report and qualified data sheets, that summarizes and discusses the results as an attachment.

Once flowback fluids from the closest designated well within a monitoring sector have been demonstrated to contain  $^3\text{H}$  at concentrations less than the screening level, all subsequent flowback fluids generated in outlying wells within that monitoring sector can be transported, disposed, or re-used without additional laboratory analyses.

#### 4.1.4 Tier I Production Monitoring

Tier I production monitoring will be conducted at the **closest** designated well within each Tier I monitoring sector to screen for the presence of identified Project Rio Blanco-related radionuclides in natural gas or produced water in existing or new gas wells. Tier I production monitoring activities include:

- One time sampling of produced water and natural gas will be performed at **all new** Tier I gas wells as soon as possible after fracing but no later than 30 days after the first gas delivery, as long as the site is safely accessible. The samples will

be collected in accordance with the procedures described in Sections 5.9 and 5.10. The produced water and natural gas samples will be analyzed for the radiological analytes listed in Table 7.

- Following the initial (30 day) sampling, produced water and natural gas at **all new** Tier I gas wells will be sampled and analyzed quarterly during the first year of production for identified Project Rio Blanco-related radionuclides (Table 7) **regardless of whether they are the closest designated well**. The samples will be collected in accordance with the procedures described in Sections 5.9 and 5.10.
- For the **closest** designated gas well within each Tier I monitoring sector, sampling and analysis of produced water and natural gas will be performed quarterly during Year 1, semiannually during Years 2 and 3, and annually thereafter. The sampling frequency is based on the anticipated annual gas production at a well, which declines rapidly during the first few years of a well's life. The specified sampling frequency is essentially monitoring approximately 5-percent increments of cumulative gas production over a well's 20- to 30-year anticipated life span. Monitoring is more frequent on a time basis during the early years of production when gas volumes are larger. In the out years, monitoring is less frequent on a time basis but more frequent on a volume basis, because the gas volumes are considerably less. The samples will be collected in accordance with the procedures in Sections 5.9 and 5.10. The produced water and natural gas samples will be analyzed for the radiological analytes listed in Table 7.

If an identified Project Rio Blanco-related radionuclide is detected in a Tier I well above its screening level, Tier I wells within that sector and the two adjacent sectors will be sampled to determine whether identified Project Rio Blanco-related radionuclides exist in other wells. The well in question will be temporarily shut-in pending further evaluation of the radionuclide activities.

#### 4.1.5 Tier I Plugging and Abandonment Monitoring

Requests to abandon a well within the boundaries of the Project Rio Blanco monitoring program will be evaluated on a case by case basis, with specific requirements detailed as conditions of approval for the Form 6 (Notice of Intent to Abandon). Monitoring of fluids and/or solids may be required by COGCC during abandonment of a well if identified Project Rio Blanco-related radionuclides were detected during drilling, completion and/or production monitoring. Similarly if drilling, completion and production activities at a well pre-date the monitoring requirements set forth in the RBSAP, sampling of fluids and/or solids may be required by COGCC during abandonment activities to demonstrate that identified Project Rio Blanco-related radionuclides are not present prior to disposal of any media derived from the subsurface during well abandonment.

### 4.2 Tier II Monitoring

Tier II monitoring will be conducted at gas wells whose bottom hole locations are between a 1- and 2-mile radius from the Project Rio Blanco monument at surface ground zero (Figure 2). Tier II monitoring is designed to screen for the presence of identified Project Rio Blanco-related radionuclides that may be encountered during gas drilling, completion, production, and abandonment operations within the Tier II monitoring zone (Figure 2). Tier II monitoring includes:

- Baseline Monitoring
- Drilling monitoring
- Completion monitoring
- Production monitoring
- Plugging and abandonment (P&A) monitoring

#### 4.2.1 Tier II Baseline Monitoring

One time baseline produced water and natural gas sampling and analysis will be performed at each **existing** producing gas well within the Tier II zone within 120 days after this RBSAP is approved to document the initial radiological conditions within Tier II. For existing Tier II gas wells that are not currently in production, sampling and analysis will be performed if the well resumes production. The samples will be collected in accordance with the procedures described in Sections 5.9 and 5.10. Produced water and natural gas will be analyzed for the radiological analytes listed in Table 7.

Additional produced water and natural gas sampling within Tier II will be contingent upon the detection of identified Project Rio Blanco-related radionuclides within produced water or gas at other Tier I or Tier II gas wells.

#### 4.2.2 Tier II Drilling Monitoring

Because existing sampling data and the recent DOE modeling (Cooper et al. 2005) indicate that Project Rio Blanco-related radionuclides are not expected to be encountered outside of the exclusion zone, which has been removed from the public domain, the Companies have established a limited Tier II drilling monitoring program to screen for identified Project Rio Blanco-related radionuclides that might be unexpectedly encountered during gas well drilling, completion, production, and abandonment operations within the Tier II monitoring zone.

Tier II drilling monitoring activities include:

- Review open- or cased-hole gamma-ray logs through the Fort Union or Williams Fork Formation intervals for **existing and new** Tier II wells for evidence of above normal gamma-ray signatures that might be related to Project Rio Blanco. A gamma radiation measurement greater than 500 API gamma units or any other gamma readings that appear to be anomalously high will be noted by the drilling supervisor or his designated representative and immediately reported to the RSO and Company management for review and guidance.

- Two composite samples of drill cuttings will be collected from each new gas well until cuttings from a minimum of eight new gas wells have been sampled within the Tier I or II monitoring zones. After eight wells have been sampled, composite drill cuttings samples will only be collected at the closest designated Tier II gas well within each monitoring sector if a Tier I gas well is not present.
- If a Tier II well is the **closest** designated gas well in a monitoring sector (i.e., no Tier I well), two composite drill cuttings samples shall be collected from selected intervals approximately equivalent to the Project Rio Blanco test interval. The drill cuttings will be collected from selected formation intervals approximately equivalent (corrected for dip and distance) to the Project Rio Blanco test intervals. The composite samples will be collected by the Companies field representative in accordance with the procedures described in Section 5.7 and analyzed for the radiological analytes listed in Table 7. The two sampled intervals will include:
  - An approximate 500-foot interval extending from approximately 750 feet to 250 feet above the approximate top of the Project Rio Blanco test interval; and
  - An approximate 1,500-foot interval extending from approximately 250 feet above to 250 feet below the Project Rio Blanco test interval.
- If drill cuttings are sampled at a Tier II well location, the cuttings shall be analyzed for the radiological constituents listed in Table 7 to confirm compliance with the RBSAP. Sample results shall be reviewed by a third-party consultant independent of the Companies. The cuttings can be transported, re-used, or disposed without approval from the COGCC if identified Project Rio Blanco-related radionuclides are less than the screening levels in Table 8. A letter, including the data validation report and qualified data sheets, along with a Sundry Notice Form 4 shall be submitted to the COGCC to document the drill cuttings results and demonstrate compliance with the RBSAP. If identified Project Rio Blanco-related radionuclides are equal to or greater than the screening levels in Table 8, the drill cuttings can not be transported, re-used, or disposed without prior written approval from the COGCC. A Notice of Intent to transport, re-use, or dispose of drill cuttings with identified Project Rio Blanco-related

radionuclides equal to or greater than the screening levels (Table 8) shall be submitted to the COGCC for approval. The Notice of Intent shall include a letter, including the data validation report and qualified data sheets, that summarizes and discusses the results as an attachment.

- If a Tier II well is the **closest** designated well in a monitoring sector (i.e., no Tier I well) and is projected to be laterally within 200 feet of the Tier I boundary (1-mile monitoring radius), perform high accuracy gyroscopic directional wellbore survey after reaching the total wellbore depth but prior to commencing perforation and completion activities to verify that the wellbore did not penetrate the 1-mile boundary. Alternatively, a magnetic survey may be performed in lieu of a gyroscopic survey as long as Tier I monitoring is performed for the respective well. A copy of the directional drilling survey report, including a map view and a vertical profile view showing the wellbore trajectory and the distance from the 1-mile Project Rio Blanco monitoring radius, along with a Sundry Notice Form 4 shall be submitted to the COGCC. The operator shall obtain approval in writing from the COGCC prior to commencing casing perforation and other completion activities.

#### 4.2.3 Tier II Completion Monitoring

If a Tier II well is the **closest** designated gas well within a monitoring sector (i.e., no Tier I well), completion monitoring will be conducted to screen for the presence of  $^3\text{H}$  in flowback fluids (i.e., produced waters) during gas well completion operations. Flowback fluids shall be contained in tanks only. The Companies shall submit a secondary and tertiary containment plan via Sundry Notice Form 4 for the tanks. If the COGCC has not objected to or requested additional information within 10 business days of a Company's filing of a Sundry Notice Form 4, the Company may proceed with fracing and flowback operations.

If a Tier II well is the closest designated well within a monitoring sector (i.e., no Tier I well), samples of introduced fracing fluids (prior to use) and recovered flowback fluids will be collected for laboratory analysis of  $^3\text{H}$ . The samples will be collected in accordance with the procedures described in Section 5.8. The fracing and flowback fluids will only be analyzed for

$^3\text{H}$  to screen for the most likely Project Rio Blanco-related radionuclide in these fluids. The results of the analyses will be used to determine whether  $^3\text{H}$  may have been introduced during fracturing or to determine whether  $^3\text{H}$  is present in the recovered flowback fluids.

Flowback fluid results shall be reviewed by a third-party consultant independent of the Companies, prior to transport, re-use, or disposal. Flowback fluids may be transported, re-used, or disposed without written approval from the COGCC if  $^3\text{H}$  is less than the screening level provided in Table 8. A letter, including the data validation report and qualified data sheets, along with a Sundry Notice Form 4 shall be submitted to the COGCC to document the flowback fluid results and demonstrate compliance with the RBSAP. If  $^3\text{H}$  is equal to or greater than the screening level (Table 8), flowback fluid results shall be reviewed and approved in writing by the COGCC before the flowback fluids can be transported, re-used, or disposed.

A Notice of Intent to transport, re-use, or dispose of flowback fluids with verified Project Rio Blanco-related radionuclides equal to or greater than the screening level (Table 8) shall be submitted to the COGCC for approval. The Notice of Intent shall include a letter, including the data validation report and qualified data sheets, that summarizes and discusses the results as an attachment.

Once flowback fluids from the closest designated well within a monitoring sector have been demonstrated to contain  $^3\text{H}$  at concentrations less than the screening level, all subsequent flowback fluids generated in outlying wells within that monitoring sector can be transported, disposed, or re-used without additional laboratory analyses.

#### 4.2.4 Tier II Production Monitoring

Tier II production monitoring will be conducted to screen for Project Rio Blanco-related radionuclides in natural gas and produced water in new gas wells. Tier II production monitoring activities include:

- One-time sampling of produced water and natural gas at **all new** gas wells as soon as possible after fracturing but no later than 30 days after the first gas delivery, as long as the site is safely accessible. The samples will be collected in accordance

with the procedures in Sections 5.8 and 5.9. The produced water and natural gas samples will be analyzed for the radiological analytes listed in Table 7.

- If a Tier II well is the **closest** designated producing gas well in a monitoring sector (i.e., no Tier I well) to the Project Rio Blanco monument at surface ground zero, sampling and analysis of produced water and natural gas will be performed quarterly during Year 1, semiannually during Years 2 and 3, and annually thereafter. For a new Tier II well, that is the closest well within the sector, the first quarterly sample will be collected approximately 180 days after initial gas delivery. The samples will be collected in accordance with the procedures in Section 5.9 and 5.10. The produced water and natural gas samples will be analyzed for the radiological analytes listed in Table 7.
- Additional radiological monitoring of produced water and natural gas within Tier II will be contingent upon the detection of identified Project Rio Blanco-related radionuclides within Tier I or Tier II zone gas wells, or as requested by the primary stakeholder agencies.

If an identified Project Rio Blanco-related radionuclide in a Tier II well is equal to or greater than its screening level (Table 8), Tier I and/or Tier II wells within that sector will be sampled to determine whether identified Project Rio Blanco-related radionuclides exist in other wells. The well in question will be temporarily shut-in pending further evaluation of the radionuclide activities.

#### **4.2.5 Tier II Plugging and Abandonment Monitoring**

Requests to abandon a well within the boundaries of the Project Rio Blanco monitoring program will be evaluated on a case by case basis, with specific requirements detailed as conditions of approval for the Form 6 (Notice of Intent to Abandon). Monitoring of fluids and/or solids may be required by COGCC during abandonment of a well if identified Project Rio Blanco-related radionuclides were detected during drilling, completion and/or production monitoring. Similarly if drilling, completion and production activities at a well pre-date the monitoring requirements set forth in the RBSAP, sampling of fluids and/or solids may

be required by COGCC during abandonment activities to demonstrate that identified Project Rio Blanco-related radionuclides are not present prior to disposal of any media derived from the subsurface during well abandonment.

### **4.3 Areal Environmental Groundwater and Surface Water Monitoring**

Areal environmental groundwater and surface water (i.e., permitted water wells, adjudicated springs, and local streams) radiological monitoring will be performed annually to document the local groundwater and surface water quality within the Project Rio Blanco area. The areal environmental monitoring may include sampling of selected groundwater and surface water monitoring locations that will be determined by consensus with the primary stakeholder agencies.

Although environmental monitoring of the shallow alluvial aquifer and streams by both the DOE and previous operators has not detected any identified Project Rio Blanco-related radionuclides and no pathway for radionuclides to migrate from the Project Rio Blanco cavities to the shallow subsurface has been recognized, the Companies have elected to perform this monitoring, as necessary, at the request of the primary stakeholder agencies to adequately demonstrate that no threat exists to local water supplies.

The samples will be collected in accordance with the procedures described in Sections 5.5 and 5.6. The groundwater and surface water samples will be analyzed for the radiological analytes listed in Table 7. These analytes are selected because they provide a comprehensive screening suite of some of the potentially mobile or abundant identified Project Rio Blanco-related radionuclides identified in previous studies. Sample sites that may be located on private property will only be sampled with the landowner's permission. If permission is refused, sampling will not be performed.

### **4.4 Monitoring Schedule Variances**

The COGCC expects the Companies to implement the RBSAP version as approved while accounting for the safety of their personnel and equipment. COGCC understands that access to gas well sample sites during adverse weather conditions may not be safely accomplished, and in those situations, some of the schedules in this RBSAP may not be met.

Where a task can not be safely completed as specified in the RBSAP because of adverse weather conditions or any other conditions outside of the Company's control, the Company shall notify the COGCC and provide a written explanation that justifies the exception. The COGCC expects the Companies to perform a postponed task as soon as it can be safely accomplished. Successive schedule extensions may be necessary and will be considered by the COGCC on a case-by-case basis.

New gas wells are occasionally brought on-line, and subsequently taken off-line within the 30-day first gas sales time period, to perform well workover activities, frac additional intervals within the well, or to frac other wells on the same pad. Where a task, such as 30-day first gas sales sampling, can not be completed as specified in the RBSAP because of these operational activities, the Company shall notify the COGCC and provide a written explanation that justifies the exception. The COGCC expects the Companies to perform a postponed task as soon as it can be reasonably accomplished. Successive schedule extensions may be necessary and will be considered by the COGCC on a case-by-case basis.

## **4.5 Radionuclide Screening and Action Levels**

Radionuclide screening and action levels for the various media that are being monitored under this RBSAP are listed in Table 8. These screening and action levels were developed to provide a measure against which radionuclide activities in natural gas, produced water, drill fluids or cuttings, groundwater, and surface water can be compared to determine the exposure of workers, individual members of the public, or the environment to a potential release of identified Project Rio Blanco-related radionuclides.

### **4.5.1 Development of Radionuclide Screening and Action Levels**

The screening and action levels were developed based on the most likely exposure scenarios to workers, individual members of the public, or the environment. The approach used to determine the screening and action levels for each sample medium is discussed below. The Companies recognize that the primary stakeholder agencies may request that the screening or action levels be modified once a sufficient quantity of background data are collected for each medium.

### Natural Gas

The natural gas screening and action levels shown in Table 8 are based on the air effluent inhalation concentration values provided in the Colorado Standards for Protection Against Radiation 6 CCR 1007-1 Part 4, Appendix 4B, Table 4B2. The air effluent value is the activity (in pCi/L) of a specific radionuclide ( $^3\text{H}$  or  $^{14}\text{C}$ ) in methane gas, which if inhaled continuously over the course of a year, would produce a total effective dose equivalent (TEDE) to an individual member of the public or the environment of 50 millirem. The TEDE is exclusive of the dose contributions from natural background radiation, medical tests, or sanitary sewerage. The Colorado TEDE for individual members of the public is 100 millirem (mrem) per year. The natural gas action level is set at 75% of the air effluent activity for  $^3\text{H}$  and  $^{14}\text{C}$  (6 CCR 1007-1 Part 4, Appendix 4B, Table 4B2). The natural gas screening level is set at 10 percent of the action level.

$^3\text{H}$  in the methane (C1) fraction of natural gas is analyzed and reported by Isotech Laboratories as a  $^3\text{H}$  concentration (in TU) in water. One TU equals 1 tritium atom per  $10^{18}$  hydrogen atoms or approximately 3.19 pCi/L in water (pCi/L<sub>water</sub>; Kazemi et al. 2006). For  $^3\text{H}$  analysis of natural gas, water in the gas is removed using a molecular sieve and the dry methane is subsequently combusted to produce carbon dioxide and water. At 20°C and one atmosphere, it takes approximately 621 liters of combusted methane to produce one liter of water. To convert the reported methane tritium results to pCi/L methane gas (pCi/L<sub>methane</sub>), a conversion factor of  $1.61\text{E-}3 \text{ L}_{\text{water}}/\text{L}_{\text{methane}}$  is used. Thus, for a reported  $^3\text{H}$  concentration of 10 TU in water (or approximately 32 pCi/L<sub>water</sub>), the concentration of  $^3\text{H}$  in the methane fraction of the natural gas would be approximately 0.05 pCi/L<sub>methane</sub>.

### Produced Water

The produced water screening and action levels shown in Table 8, except for gross alpha and beta, are based on the water effluent concentration values provided in 6 CCR 1007-1 Part 4, Appendix 4B, Table 4B2 or Colorado Basic Standards for Groundwater (5 CCR 1002-41), where available. Although produced water is contained on site and is not likely to be ingested by either a worker or the public, the action level is established at 75 percent of either the basic groundwater standard (i.e.,  $^3\text{H}$  and  $^{90}\text{Sr}$ ) or the water effluent concentration for specific radionuclides (Table 4B2), which if ingested at the concentrations (in pCi/L) specified in the

regulations continuously over the course of a year, would produce a TEDE to an individual member of the public of 50 mrem. The produced water screening level is set at 10 percent of the action level, except for  $^3\text{H}$  where the screening level is set at 10 times the minimum detectable activity (MDA) and  $^{90}\text{Sr}$  where the screening level is set at 50 percent of the action level. The gross alpha and beta screening and action levels are determined as background  $\pm 2$  standard deviations and background  $\pm 3$  standard deviations, respectively.

### **Drill Cuttings**

Drill cuttings screening and action levels shown in Table 8 are calculated for a residential soil scenario for an exposure frequency of 350 days and an exposure duration of 1 year. The residential soil scenario accounts for the combined effects of inhalation, ingestion, and external exposure to soils containing a specific radionuclide. The action level is calculated for a conservative carcinogenic risk value of 1 in 1,000,000 (1E-6). The action levels were calculated using the preliminary remediation goal (PRG) equation for the residential soil exposure scenario presented on the Risk Assessment Information System web page at [http://www.rais.ornl.gov/cgi-bin/prg/PRG\\_search](http://www.rais.ornl.gov/cgi-bin/prg/PRG_search). Default values provided on the web page were used in the action level calculations. The action level for drill cuttings is set at 75 percent of the risk-based concentrations. The drill cutting screening levels are set at 10 percent of the action level.

### **Groundwater and Surface Water**

The groundwater and surface water screening and action levels shown in Table 8 are established for an individual member of the public that might consume (i.e., drink) either of these media. The action levels are set at 75 percent of the Colorado Basic Standards for Groundwater (5 CCR 1002-41) for specific radionuclides, except for gross alpha and beta which are set at the standard or screening level. The 50 pCi/L gross beta screening level is specified in 40 CFR 141.26(b)(1)(i). 40 CFR 141.26(b)(5) suggests that for gross beta activities greater than 50 pCi/L, a subsequent water sample will be analyzed (as necessary) to determine potential beta-emitting species that are contributing to the gross beta activity. The derived activities for the 4 millirem/year standard for beta and photon emitters were obtained from EPA (2002). With the exception of alpha particle activity, beta and photon emitters,  $^3\text{H}$  and  $^{90}\text{Sr}$ , groundwater and surface water screening levels are set at 10 percent of the action level. The screening levels for

alpha particle activity, beta and photon emitters, and <sup>90</sup>Sr are set at 50 percent of the action level. The screening level for <sup>3</sup>H is established at 10 times the MDA.

**4.5.2 Application of Radionuclide Screening and Action Levels**

Radionuclide screening and action levels will be applied as follows:

Analyte Result	Required Action
Radionuclide analyte is not detected	No action required
Radionuclide analyte is detected but is less than the screening level	Verify the analytical result and determine its validity either through discussion with the analytical laboratory, re-analysis of existing sample, or resample and analyze; if verified, review previous and subsequent analytical results to determine if there is a statistically significant increasing trend; continue to monitor; if the radionuclide is verified and exhibits a statistically significant increasing trend, contact the primary stakeholder agencies to discuss subsequent actions.
Radionuclide analyte is detected and its activity is equal to or greater than the screening level but less than the action level	Verify the analytical result and determine its validity either through discussion with the analytical laboratory, re-analysis of existing sample, or resample and analyze. If the radionuclide is verified, the closest wells within that sector and the two adjacent sectors shall be sampled to determine whether Project Rio Blanco-related radionuclides exist in other wells. The well in question will be temporarily shut-in pending further evaluation of the radionuclide activities. The Company shall contact the primary stakeholder agencies within 1 week or less to discuss subsequent actions.

Analyte Result	Required Action
Radionuclide analyte is detected and its activity is equal to or greater than the action level	Verify the analytical result and determine its validity either through discussion with analytical laboratory, re-analysis of existing sample, or resample and analyze. If the radionuclide is verified, the closest wells within that sector and the two adjacent sectors shall be sampled to determine whether Project Rio Blanco-related radionuclides exist in other wells. The well in question will be temporarily shut-in pending further evaluation of the radionuclide activities. The Company shall contact the primary stakeholder agencies within 48 hours or less to discuss subsequent actions.

#### 4.6 Records Retention

Records, except for medical records, generated under this RBSAP will be reported in the quarterly monitoring reports (Section 4.8). Personnel, field, and laboratory records will be retained a minimum of three years from their date of generation. After the retention date has passed, the records may continue to be retained or destroyed, depending on the individual Companies' record retention policy. All non-personnel and non-proprietary records selected for disposal will be offered to the COGCC, CDPHE, or DOE for archiving prior to disposal. Non-personnel and non-proprietary records generated under the RBSAP can be reviewed by the COGCC, CDPHE, or DOE upon written request.

#### 4.7 Data Management

Operational and environmental monitoring field and analytical data will be stored and managed using a Microsoft Access<sup>®</sup>-based relational data management system (DMS). The DMS will be customized to the specific data management needs of this project.

## 4.8 Reporting

The results of the radiological monitoring will be reported to the primary stakeholder agencies on a one-time, quarterly, or annual basis depending of the type of monitoring conducted. The following provides a list of reports that are anticipated and their respective reporting schedules:

- Baseline produced water and natural gas monitoring report for existing gas wells (one time report)
- Quarterly drilling, completion, and production monitoring report for producing gas wells (as necessary)
- The annual environmental groundwater and surface water monitoring and dose assessment report will be included in the fourth quarter report.

The above reports will be submitted to the primary stakeholder agencies within approximately 120 days after the receipt of laboratory analytical results. Once received and reviewed, the COGCC will post the quarterly reports on its website for public access.

**Table 8. Radionuclide Screening and Action Levels**

Radionuclide	Natural Gas <sup>1</sup>		Produced Water <sup>2</sup>		Drill Cuttings or Soil <sup>3</sup>		Groundwater <sup>4</sup>		Surface Water <sup>4</sup>	
	Screening Level (pCi/L)	Action Level (pCi/L)	Screening Level (pCi/L)	Action Level (pCi/L)	Screening Level (pCi/g)	Action Level (pCi/g)	Screening Level (pCi/L)	Action Level (pCi/L)	Screening Level (pCi/L)	Action Level (pCi/L)
Gross Alpha	-----	-----	See Note 5	See Note 5	See Note 5	See Note 5	7.5	15	7.5	15
Gross Beta	-----	-----	See Note 5	See Note 5	See Note 5	See Note 5	25	50	25	50
Gamma-Emitting Radionuclides	-----	-----	See Note 6	See Note 6	See Note 6	See Note 6	See Note 6	See Note 6	See Note 6	See Note 6
Tritium ( <sup>3</sup> H)	7.5	75	400	15,000	3,435	34,350	400	15,000	400	15,000
Cesium-137 ( <sup>137</sup> Cs)	-----	-----	15	150	16	158	15	150	15	150
Strontium-90 ( <sup>90</sup> Sr)	-----	-----	3	6	8	77	3	6	3	6
Krypton-85 ( <sup>85</sup> Kr)	-----	-----	-----	-----	13	128	-----	-----	-----	-----
Technetium-99 ( <sup>99</sup> Tc)	-----	-----	63	630	88	878	63	630	63	630
Carbon-14 ( <sup>14</sup> C)	See Note 7	See Note 7	150	1,500	252	2,520	150	1,500	150	1,500

**NOTES:**

<sup>1</sup>Natural gas screening and action levels are for <sup>3</sup>H in the methane gas phase at standard temperature and pressure (STP; 20°C and 1 atmosphere pressure). Reporting units are pCi/L of methane gas. Screening values are from 6 CCR 1007-1 Part 4 Appendix 4B, Table 4B2 (air effluent concentrations); Action level value is set at 75% of the air effluent activity; screening level value is 10% of the action level. Screening and action levels apply to laboratory analyses of <sup>3</sup>H in the methane fraction of natural gas.

<sup>2</sup>Produced Water - Action levels for <sup>3</sup>H and <sup>90</sup>Sr are 75% of the Colorado basic standards for groundwater (5 CCR 1002-41) or the water effluent concentration (6 CCR 1007-1 Part 4 Appendix 4B, Table 4B2); for specific beta and photon emitters, the action level is 75% of the derived radionuclide activity in drinking water that yields a dose of 4 mrem/yr to the total body or to any critical organ (EPA 2002); screening level is 10 percent of the action level, except for <sup>3</sup>H where the screening level is set at 10 times the minimum detectable activity (MDA) and <sup>90</sup>Sr which is set at 50% of the action level.

<sup>3</sup>Drill Cuttings/Soils - Drill cutting and soil action levels were calculated using preliminary remediation goal (PRG) guidance for radionuclides on the Risk Assessment Information System (RAIS) at [http://rais.ornl.gov/cgi-bin/prg/PRG\\_search](http://rais.ornl.gov/cgi-bin/prg/PRG_search). Action levels are calculated for a residential soil scenario for the combined effects of ingestion, inhalation, and external exposure to contaminated cuttings or soil for an exposure frequency of 350 days and an exposure duration of 1 year. The action levels are set at 75% of a carcinogenic risk of 1 in 1,000,000 (1E-6). The screening level is 10 percent of the action level.

<sup>4</sup>Groundwater/Surface Water - Action level for gross alpha is the drinking water MCL; action level for gross beta is based on EPA guidance; for specific beta and photon emitters, the action level is 75% of the derived radionuclide activity in drinking water that yields a dose of 4 mrem/yr to the total body or to any critical organ (EPA 2002); screening level is 10 percent of the action level, except for <sup>3</sup>H where the screening level is set at 10 times the MDA and gross alpha, gross beta, and <sup>90</sup>Sr where the screening level is set at 50% of the action level.

<sup>5</sup>Gross alpha and beta activity screening levels are determined as background ± 2 standard deviations; gross alpha and beta action levels are determined as background ± 3 standard deviations. Note that gross alpha activity excludes the alpha activities contributed by radon and uranium and the gross beta activity excludes the beta activity contributed by <sup>40</sup>K.

<sup>6</sup>Gamma-emitting radionuclide screening and action levels are not specified; the screening and action level is based on the specific gamma-emitting radionuclide detected (e.g., <sup>85</sup>Kr or <sup>137</sup>Cs).

<sup>7</sup>The natural gas <sup>14</sup>C screening level is determined as 2 percent modern carbon (pMC); the action level is determined as 5 pMC. Screening and action levels apply to laboratory analyses of <sup>14</sup>C in the methane fraction of natural gas.

## **5 FIELD METHODS AND SAMPLING PROCEDURES**

### **5.1 Site Access and Field Mobilization**

#### **5.1.1 Site Access**

Prior to conducting any sampling activities, the Companies or their designated representative will contact the Company, other affected working interest owners, or other parties (i.e., landowners, local, state, or federal agencies) by phone, e-mail, or letter to obtain permission to sample their gas wells or water supplies (i.e., groundwater or surface water) and schedule sampling activities. Sampling locations on private property will not be sampled without the owners' permission and/or a written access agreement. If permission is refused, sampling will not be performed. The Companies will provide escorted access and support, as necessary, for crews that will sample produced water and natural gas at the well sites. For privately or municipally owned wells, springs, or streams, the Companies or their designated representative will schedule in advance a convenient time for the landowners or municipalities where sampling is proposed. If warranted, the Companies will obtain verbal or written access agreements with the landowners or municipalities for annual access to their wells or springs.

#### **5.1.2 Field Mobilization**

Once site access permissions and the sampling events are scheduled, the field crews will contact the analytical laboratories to notify them of the pending sampling event and to obtain the appropriate sampling bottles and containers. The field crews will also contact, as necessary, equipment vendors to rent or purchase the necessary field sampling equipment and supplies. All field equipment will be tested to make sure it is in working order and calibrated before proceeding to the field. A list of the field equipment and supplies is provided in Section 5.2. All field personnel performing sampling will be qualified and trained on sampling procedures and the use of all field instruments prior to going in the field. A URS Safe Work Plan (Appendix B) discusses the safety and health requirements for working around the drilling, completion, and production sites and performing field sampling. The attached Safe Work Plan, or an equivalent, can be used if a company other than URS is implementing the RBSAP.

## 5.2 Field Equipment and Supplies

A list of the field equipment and supplies is provided below. The list is organized by field activity.

### 5.2.1 Personnel Protective Equipment

Personnel protective equipment (PPE) and supplies include:

- Hardhat
- Safety glasses
- Hearing protection
- Fluorescent safety vest
- Steel-toed boots
- Disposable, powderless, nitrile gloves
- Fire-retardant clothing (FRC)

### 5.2.2 Sample Location Documentation

Sample location documentation equipment and supplies include:

- Field logbook
- Indelible pens
- Maps or aerial photographs showing the sample locations
- Global-positioning system (GPS) coordinates of previously sampled locations
- Differential hand-held GPS unit with sub-meter accuracy
- Flagging and/or wooden survey stakes to mark sample locations

- Digital camera to photograph sampling site

### 5.2.3 Radiation Screening and Monitoring

Radiation screening equipment and supplies include:

- Thermo Scientific RadEye B-20ER multipurpose survey meter with filters, or equivalent
- Quantum Products Instadose™ dosimeters or Mirion Technologies DMC 2000XB electronic dosimeters, or equivalent, weatherproof holders, and nylon zip ties
- ICX Technologies Stride 200 real-time gamma spectrometer system, or equivalent
- Check source (e.g., <sup>137</sup>Cs) for performance testing of alpha, beta, and gamma radiation monitoring equipment

This equipment is only required for Tier I drilling sites.

### 5.2.4 Water Sampling

Surface water, groundwater, and produced water sampling equipment and supplies include:

- Field sampling data sheets (example forms provided in Appendix C)
- Multiparameter water quality probe and meter (e.g., Horiba, YSI, Hanna) and calibration and standard solutions (e.g., pH buffers, conductivity standards, etc.)
- Long-handled, disposable polyethylene dipper (for streams)
- Sample bottles (with preservative) from the analytical laboratory. Several extra sample bottles will be obtained in case of breakage and for QA/QC samples
- Graduated 1- to 5-gallon bucket (for measuring spring flow rates)
- Stopwatch (for measuring stream or spring flow rates)

- Current velocity meter – optional (for measuring stream or spring flow rates)
- Electronic water level indicator (for measuring water levels in wells)
- Garden hose (for plumbed well sampling)
- Disposable bailers and rope – optional (for sampling wells without pump)
- Submersible pump, portable generator (or battery) for submersible pump, and polyethylene and/or silicon discharge tubing – optional (for sampling wells without pump)
- 0.45-micron filter and filtering system for dissolved analytes (as needed)
- Decontamination equipment and supplies (e.g., wash/rinse tubs, brushes, Alconox<sup>®</sup>, plastic sheeting, paper towels, brushes, sponges, potable water, and deionized water)
- Large (30-gallon) trash bags
- Assorted tools (knife, screwdriver, pliers, wrenches)

### **5.2.5 Drill Cuttings and Fluids Sampling**

Drill cuttings and fluids sampling equipment and supplies include:

- Clean 1- to 5-gallon bucket with tight-fitting lid
- Sampling scoop

### **5.2.6 Natural Gas Sampling**

Natural gas sampling equipment and supplies include:

- Laboratory-supplied evacuated 20-pound steel gas cylinders (gas cylinders supplied under vacuum from laboratory)

- Braided steel connector tubing
- Non-sparking (non-ferrous) adjustable wrench

### 5.2.7 Sample Shipping and Documentation

Sample shipping and documentation equipment and supplies include:

- Indelible pens and markers (e.g., Sharpie)
- Sample labels (pre-printed and/or blank)
- Chain-of-custody (COC) forms
- Clear plastic tape
- Fiber tape
- Custody seals
- 1-gallon Ziploc<sup>®</sup> freezer bags
- Coolers
- Ice or ice substitute
- Shipping documentation (e.g., laboratory address, FedEx number, etc.)

## 5.3 Field Documentation and Measurements

### 5.3.1 Sample Location

Each well or sample location will be documented, identifying its coordinates using a differential hand-held GPS unit with sub-meter accuracy that meets COGCC requirements, so that sampling crews can locate the same site during future sampling events. The sample site coordinates will be recorded in the field logbook or on the field sample sheet to the nearest meter using the Universal Transverse Mercator (UTM) coordinate system. Photographs will be taken at

each sample site to document its location and site conditions during sampling. An overall view of the sampling area or property should be taken so that future samplers can locate the sampling site.

### **5.3.2 Background Radiation Screening**

Background radiation screening will be performed at each well pad and environmental sampling location as discussed in the following subsections.

#### **5.3.2.1 Sample Site**

Each environmental sample site (e.g., ranch or livestock wells, springs, or streams) will be screened with hand-held radiation survey instruments prior to sampling to measure background radiation activities. Alpha, beta, and gamma radiation screening will be performed using a Thermo Scientific B-20ER multipurpose survey meter (Appendix D) by placing the detector probe within about 1 inch of the ground surface and recording the radiation response. A radiation measurement will also be collected by holding the detector probe about 3 feet (“waist high”) above the ground surface and recording the reading. Gamma radiation will be measured using the appropriate filter to screen alpha and beta radiation and repeating the above measurements. The radiation measurements will be recorded in the field logbook or on sample forms as microR/hr ( $\mu\text{R/hr}$ ). Radiation survey equipment will be operated and performance tested using a check source in accordance with the manufacturer’s instructions. Radiation survey instruments must be calibrated by the manufacturer or a certified service center annually.

#### **5.3.2.2 Tier I Well Pad**

A background radiation survey will be performed using hand-held radiation survey instruments at each new Tier I well after it is constructed. Existing Tier I well pads that have not been previously surveyed for background radiation will also be surveyed for background radiation prior to drilling a new well. Background radiation screening will be performed after the well pad is constructed. For well pads, background radiation screening will be performed on a “9-point” grid over the area of the well pad. The 9 points will include measurements at each corner of the pad (4), at the midpoints of the sides of the pad (4), and at the center of the pad (1) as shown in Figure A-2 (Appendix A).

Alpha, beta, and gamma radiation screening will be performed using a Thermo Scientific B-20ER multipurpose survey meter (Appendix D) by placing the detector probe within about 1 inch of the ground surface at each grid point and recording the radiation response. A radiation measurement will also be collected by holding the detector probe about 3 feet (“waist high”) above the ground surface at each grid point and recording the reading. Gamma radiation will be measured using the appropriate filter to screen alpha and beta radiation and repeating the above measurements. The radiation measurements will be recorded in the field logbook or on sample forms as  $\mu\text{R/hr}$ . Radiation survey equipment will be operated and performance tested using a check source in accordance with the manufacturer’s instructions. Radiation survey instruments must be calibrated by the manufacturer or a certified service center annually.

### 5.3.3 Field Parameters

Field parameter measurements (i.e., pH, conductivity, temperature, dissolved oxygen, redox potential, and turbidity) will be collected at each water (e.g., produced water, fracing fluid, flowback fluid, groundwater, or surface water) sampling site using a multiparameter probe and meter. The instrument will be operated and calibrated in accordance with the manufacturer’s instructions. The instrument shall be calibrated each morning prior to sampling using certified buffers or standards. Solutions used for calibration will be checked prior to field mobilization to determine if the expiration dates have been exceeded. Any expired solution will be discarded appropriately and replaced with new solution.

For water wells, field parameter measurements will be made and recorded in the field logbook or sample form periodically during purging until the water quality field parameters have stabilized. Once stabilized, the final field parameter measurements will be made and recorded in the field logbook. Stability is demonstrated when there is no significant change in pH, temperature, and conductivity over a 10-minute period. The stability criteria are  $\pm 0.1$  units for pH,  $\pm 0.1$  degrees Celsius ( $^{\circ}\text{C}$ ) for temperature, and  $\pm 5$  percent for conductivity.

Field parameter measurements at produced water, fracing fluid, flowback fluid, groundwater, stream, seep, or spring sites can either be made in-situ or on a separate aliquot of water specifically collected for field parameter measurements. Field parameter measurements

may be taken before or after collection of the water sample. After the measurements have been recorded, the water will be discarded; this sample aliquot will not be used for laboratory analysis.

One duplicate field parameter measurement will be collected for every ten sampling locations (10 percent frequency). Field parameter measurements are considered satisfactory if the duplicate measurements fall within the acceptable range in the table below.

Field Parameter	Acceptable Range
pH	$\pm 0.1$ pH unit
Temperature	$\pm 10\%$
Oxidation-Reduction Potential	$\pm 10\%$
Conductivity	$\pm 10\%$
Dissolved Oxygen	$\pm 0.1$ mg/L
Turbidity	$\pm 10\%$ NTU

Notes: % - percent; mg/L = milligrams per liter; mV = millivolt; NTU = nephelometric turbidity unit

If duplicate acceptance criteria are not met, the instrument must be re-calibrated and new parameter measurements obtained at the sample location where the original duplicate sample did not meet the acceptance criterion.

## 5.4 Dosimeters

Ambient external radiation will be monitored as specified in Section 4. The dosimeters will be deployed at the **closest** Tier I or II well pad within each monitoring sector prior to drilling and on the drill rig during drilling and well completion. The dosimeters will be placed in personnel work areas and near drilling fluid and cuttings discharge locations on each well pad to measure cumulative radiation intensities. One dosimeter will be placed in a background area of the well pad. The dosimeters will be placed in locations where they are not likely to be disturbed or damaged, at a height of approximately 3 to 10 feet above the ground or working surface. The dosimeters will be deployed in the holders provided by the manufacturer or

enclosed in a weatherproof container. A duplicate dosimeter will be deployed for every 10 dosimeters used.

A control dosimeter, if required, will be transported with and handled the same as those deployed in the field. The control dosimeter will be used to monitor radiation exposure during shipment and handling. The control dosimeter will be kept away from all sources of radiation and retained for shipment back to the manufacturer when the field dosimeters are retrieved and returned for processing and reporting. Control dosimeters are not required if the Instadose™ or electronic dosimeters are used as they are not shipped to the manufacturer for processing. Additional dosimeters may also be placed at locations other than the well pads to measure the areal background radiation over the Tier I and II regions at the Companies discretion.

## 5.5 Surface Water Sampling

### 5.5.1 Stream Sampling

Stream water samples will be sampled and analyzed as specified in Section 4. Streams will be sampled at locations where the surface water is freely flowing. Sampling of stagnant water should be avoided. For health and safety reasons, sampling personnel should avoid wading into the stream to obtain a sample. The sample should be obtained with a pre-cleaned, long-handled, polyethylene dipper or decontaminated sampling container. Field personnel performing the sampling will wear disposable, powderless, nitrile gloves to minimize the potential for contamination of the samples during collection and subsequent handling. New gloves will be worn at each sampling site to minimize the potential for contamination of the samples. Any equipment introduced into the stream should either be pre-cleaned, dedicated equipment or decontaminated (Section 5.11) prior to use to avoid introducing contaminants into the stream during sampling.

For shallow streams, sampling will be performed by immersing the dipper directly in the stream. The dipper should be rinsed in stream water three (3) times prior to taking a sample. To collect a sample, the sampler should face upstream and immerse the dipper beneath the water surface without disturbing the bottom sediment. The sample collected in the dipper is then

poured gently into the laboratory-supplied, pre-preserved, if required, sample bottle to minimize contact with the atmosphere and avoid agitation and aeration of volatile or redox sensitive constituents.

Samples collected for volatile analytes (e.g., dissolved methane) should be placed in laboratory-supplied, pre-preserved sample containers with zero headspace. Samples collected for non-volatile analytes should be placed into the appropriate preserved or non-preserved sample containers designated by the laboratory. For pre-preserved sample bottles, special care should be taken to avoid overfilling the bottle and diluting or rinsing out the preservative. Additional preservative may be added at the laboratory during sample receipt if it is needed to adjust the sample to the proper pH. Water samples will not be filtered in the field or laboratory prior to analysis for analytes that may be sorbed to suspended particulates. Water samples may be filtered for  $^3\text{H}$  if the sample contains suspended particulates to facilitate laboratory analysis.

Once filled, the sample bottle should be capped, wiped dry and labeled, documented, stored, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Surface water samples will be analyzed for the radiological analytes listed in Table 7.

Field parameters, including pH, temperature, conductivity, turbidity, dissolved oxygen (as mg/L  $\text{O}_2$ ), and redox potential will be measured and recorded in accordance with the procedures outlined in Section 5.3.3 prior to or after the collection of each stream water sample.

Any unusual sample characteristics observed during sampling will be documented in the field logbook or on the field sample forms. Unusual sample characteristics might include noticeable discoloration of the water, excessive turbidity, precipitates (e.g., orange iron oxyhydroxides), a sheen on the surface of the water, condensate layer, odor, or sample effervescence.

### **5.5.2 Spring and Seep Sampling**

Spring and seep samples will be sampled and analyzed as specified in Section 4. Spring and seep samples will be collected at locations where the water is freely flowing. Sampling of stagnant water should be avoided. In some cases, it may be necessary to collect

samples at a point downgradient of a spring or seep to have the required flow needed to fill the sample containers. Any equipment introduced into the stream should either be pre-cleaned, disposable equipment or decontaminated (Section 5.11) prior to use to avoid introducing contaminants into the spring during sampling.

Where possible, a spring or seep flow rate measurement will be made at the time of sampling. The flow will be measured by clocking (using a stopwatch) the amount of time needed to fill a decontaminated, graduated container (e.g., a 5-gallon bucket). A minimum of 10 seconds to fill the container is recommended. Several fill-ups should be timed and the results averaged to improve the quality of this measurement. This flow measurement approach is generally valid for flows between about one gallon per minute (gpm) and 100 gpm.

The spring or seep will be sampled using a pre-cleaned, disposable, polyethylene dipper or decontaminated sampling container to avoid introducing contaminants to the spring or seep. Field personnel performing the sampling will wear disposable, powderless, nitrile gloves to prevent contamination of the samples during collection and subsequent handling. New gloves will be worn at each sampling site to minimize the potential for contamination of the samples. To collect a sample, the sampler should gently immerse the dipper beneath the water surface without disturbing the bottom sediment. The sample collected in the dipper is then poured gently into the laboratory-supplied sample bottle to avoid agitation and aeration of volatile or redox sensitive constituents.

Spring or seep samples collected for volatile analytes (e.g., dissolved methane) should be placed in laboratory-supplied, pre-preserved sample containers with zero headspace. Samples collected for non-volatile analytes should be placed into the laboratory-supplied pre-preserved or non-preserved sample containers. For pre-preserved sample bottles, special care should be taken to avoid overfilling the bottle and diluting or rinsing out the preservative. Additional preservative may be added at the laboratory during sample receipt if it is needed to adjust the sample to the proper pH. Water samples will not be filtered in the field or laboratory prior to analysis for analytes that may be sorbed to suspended particulates. Water samples may be filtered for  $^3\text{H}$  if the sample contains suspended particulates to facilitate laboratory analysis.

Once filled, the sample bottle should be capped, wiped dry and labeled, documented, stored, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Spring or seep samples will be analyzed for the radiological analytes listed in Table 7.

Field parameters including pH, temperature, conductivity, turbidity, dissolved oxygen (as mg/L O<sub>2</sub>), and redox potential will be measured and recorded in accordance with the procedures outlined in Section 5.3.3 prior to or after collection of each spring or seep sample.

Any unusual sample characteristics observed during sampling will be documented in the field logbook or on the field sample forms. Unusual sample characteristics might include noticeable discoloration of the water, excessive turbidity, precipitates (e.g., orange iron oxyhydroxides), sheen on the surface of the water, condensate layer, odor, or sample effervescence.

## 5.6 Groundwater Sampling

Groundwater samples will be sampled and analyzed from residential or livestock wells as specified in Section 4. It is anticipated that these wells are equipped with a pump and piping that is suitable for sampling. The wells may also be equipped with water treatment systems or storage tanks. The sample crew should discuss with the well owner the well construction, pump type, typical well yield, and whether the water is treated or stored to use. If possible, the sample crew should determine with the well owner where a water sample can be collected before it enters the treatment system or storage tank. In instances where access to the water before treatment or storage is not available, the water sample will be collected, but the type of treatment should be determined and documented in the field logbook or on the field sample form. A photograph should be taken at each well to document the actual groundwater sampling location. The name, mailing address, and the resident's home and work telephone numbers should be entered into the field logbook. This information will be used to transmit the well sampling results to the landowners if requested.

For wells equipped with pumps, the well will be purged using the existing pumping system to remove stagnant water standing in the well casing prior to collecting a groundwater sample. For wells without pumps, the well will either be purged manually using a bailer and rope

or a portable pumping system. Any equipment introduced into the well will either be pre-cleaned, disposable equipment or decontaminated (Section 5.11) prior to use to avoid introducing contaminants into the well during sampling. Purge rates should be slow enough to limit turbulence in the well bore and piping that may stir up sediments in the well casing. The well should be purged slowly at first, while water quality parameters are measured with a multiparameter probe and meter. Flow rates should then be gradually increased to a maximum flow rate of 3 to 5 gpm as long as no increase in entrained sediment is observed.

The well discharge should be directed into a clean, white 5-gallon bucket to measure flow and to allow the sampler to monitor water color, odor, effervescence, and entrained sediment as the well is purged. A white bucket is recommended to facilitate visual screening of the groundwater sample. Unless the well owner objects, the well should be purged for at least 15 minutes or until the water quality parameters have stabilized. The water quality parameters should be recorded in the field logbook or on the field sample forms for every five minutes of purging. After the field parameters stabilize, the last values of the field parameters should be recorded in the field logbook or on the field sample forms. In some cases, well yields may be too low to allow field measurements to stabilize without drawing down a well to the level of the pump intake. In such situations, the well should be sampled using low flow rates at the outlet.

For sampling, the well discharge rate should be reduced to 0.1 to 1 gpm to facilitate sample collection at low flow rates. Low-flow sampling reduces the agitation and aeration of dissolved gases and other volatile constituents, if present. Field personnel performing the sampling will wear disposable, powderless, nitrile gloves to prevent contamination of the samples during collection and subsequent handling. New gloves will be worn at each sampling site to minimize the potential for contamination of the samples.

Groundwater will be dispensed directly from the well discharge line or bailer into the laboratory-supplied sample containers so that agitation and aeration of volatile or redox sensitive constituents is minimized. Samples collected for volatile analyses (e.g., dissolved methane) should be placed in laboratory-supplied, pre-preserved sample containers with zero headspace to minimize volatile losses. Samples collected for non-volatile analytes should be placed into the appropriate laboratory-supplied, pre-preserved or non-preserved sample containers designated by

the laboratory. For pre-preserved sample bottles, special care should be taken to avoid overfilling the bottle and diluting the preservative. Additional preservative may be added at the laboratory during sample receipt if it is needed to adjust the sample to the proper pH. Water samples will not be filtered in the field or laboratory prior to analysis for analytes that may be sorbed to suspended particulates. Water samples may be filtered for  $^3\text{H}$  if the sample contains suspended particulates to facilitate laboratory analysis.

Once filled, the sample bottle should be capped, wiped dry and labeled, documented, stored, and shipped to the laboratory in accordance with the procedures outlined in Section 7. The groundwater samples will be analyzed for the radiological analytes listed in Table 7.

Any unusual sample characteristics observed during sampling will be documented in the field logbook or on the field sample forms. Unusual sample characteristics might include noticeable discoloration of the water, excessive turbidity, precipitates (e.g., orange iron oxyhydroxides), surface sheen, condensate layer, odor, or sample effervescence.

## 5.7 Drill Cuttings Sampling

Two composite samples of drill cuttings will be collected and analyzed as specified in Section 4. The drill cuttings will be collected from selected Fort Union and Williams Fork Formation intervals approximately equivalent to the Project Rio Blanco test horizon. The composite samples will be collected by the Companies designated field representative from two intervals that are approximately equivalent (corrected for dip and distance) to the Project Rio Blanco test interval. The drill cutting samples will be analyzed for the radiological analytes listed in Table 7. The two intervals sampled will include:

- An approximate 500-foot interval extending from approximately 750 feet to 250 feet above the approximate top of the Project Rio Blanco test interval; and
- An approximate 1,500-foot interval extending from approximately 250 feet above to 250 feet below the Project Rio Blanco test interval.

Each composite sample will be created by collecting approximately 0.5 to 1 liter grab samples of drill cuttings at approximately 50-foot frequencies over each interval. The grab samples will be placed in a clean 5-gallon plastic bucket for compositing. Once the drill cuttings aliquots have been placed in the bucket, the composite sample will be thoroughly mixed with a clean stirring device to create a reasonably homogenous composite. After the sample is thoroughly mixed, aliquots of the drill cuttings will be placed in the laboratory-supplied sample bottles.

Once filled, the sample bottle should be capped, wiped dry, labeled, documented, stored in an iced cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Drill cuttings samples will be analyzed for the radiological analytes listed in Table 7.

Any unusual sample characteristics observed during sampling will be documented in the field logbook or on the field sample forms. Unusual sample characteristics might include grain size, precipitates (e.g., orange iron oxyhydroxides), surface sheen, condensate layer, odor, etc.

## 5.8 Fracing and Flowback Fluid Sampling

Composite samples of fracing and flowback fluids will be collected and analyzed as specified in Section 4. Fracing fluid will be sampled and analyzed prior to introduction into the gas well. Flowback fluid will be sampled and analyzed once it is returned from the well. Fracing and flowback fluids will only be analyzed for  $^3\text{H}$ .

Composite fracing and flowback fluid sampling will be accomplished by extracting approximately 0.25 liter or more aliquots of fluid from each frac tank using a pre-cleaned, disposable bailer. The number of sample aliquots collected from each frac tank will vary and depends on the number of frac tanks sampled. A sufficient number of sample aliquots from each tank should be collected to create an approximate 1-gallon composite sample. For example, if there are 10 frac tanks, approximately 0.4 liters of fluid will be collected from each frac tank to create the composite sample.

The composite sample will be created by gently discharging each sample aliquot into a clean 2- to 5-gallon bucket. Once the appropriate number of aliquots have been collected from the various frac tanks to fill the bucket, any condensate that accumulates on the surface will be skimmed off and disposed in the frac tanks. Composite sample aliquots will then be taken from the bucket and placed in the unpreserved, laboratory-supplied 125 milliliter sample bottle. Preservative is not required for  $^3\text{H}$  analysis. Water samples may be filtered for  $^3\text{H}$  if the sample contains suspended particulates to facilitate laboratory analysis.

Once filled, the sample bottle should be capped, wiped dry, labeled, documented, stored in an iced cooler, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Fracing and flowback fluid samples will only be analyzed for  $^3\text{H}$  as shown in Table 7.

Field parameters, temperature, pH, specific conductance, dissolved oxygen, oxidation-reduction potential, and turbidity, will be measured on a separate sample aliquot at the well site. The field parameters will be measured in accordance with the procedures outlined in Section 5.3.3.

Any unusual sample characteristics observed during sampling will be documented in the field logbook or on the field sample forms. Unusual sample characteristics might include noticeable discoloration of the water or fluid, precipitates (e.g., iron oxyhydroxides), surface sheen, condensate layer, petroleum hydrocarbon or other odor, or sample effervescence.

## 5.9 Produced Water Sampling

Produced water samples will be collected and analyzed as specified in Section 4. Produced water sampling will be accomplished with the assistance of the Companies' representative who will be responsible for manipulating the separator valves to obtain a well-specific produced water sample. Sampling crews will not attempt to sample produced water without the presence of a Company representative. The produced water samples will be collected from either the influent line or the effluent line at the separator. If more than one gas well is plumbed to the separator, valves will be closed by the Company representative to isolate the gas well of interest. The residual fluids in the produced water and natural gas lines will be

discharged so that a well-specific sample is obtained. Once sampling is completed the Company representative will return any manipulated valves to their original position.

Samples will be collected by discharging produced water from the separator line into a decontaminated 5-gallon bucket until full. Care should be taken when discharging from the separator line as it is usually under high pressure. Sample aliquots will then be taken from the 5-gallon bucket and placed in the laboratory-supplied, pre-preserved or non-preserved sample bottles. Care should be taken to avoid overfilling the pre-preserved sample bottles so that the preservative is not diluted or rinsed out of the bottle. Additional preservative may be added at the laboratory during sample receipt if it is needed to adjust the sample to the proper pH. Water samples will not be filtered in the field or laboratory prior to analysis for analytes that may be sorbed to suspended particulates. Water samples may be filtered for  $^3\text{H}$  if the sample contains suspended particulates to facilitate laboratory analysis.

Once filled, the sample bottles should be capped, wiped dry, labeled, documented on the COC, and placed in an iced cooler. The samples will be shipped to the laboratory in accordance with the procedures outlined in Section 7. Produced water samples will be analyzed for the radiological analytes listed in Table 7.

Field parameters, temperature, pH, specific conductance, dissolved oxygen, oxidation-reduction potential, and turbidity, will be measured on a separate sample aliquot at the well site. The field parameters will be measured in accordance with the procedures outlined in Section 5.3.3.

Any unusual sample characteristics observed during sampling will be documented in the field logbook or on the field sample forms. Unusual sample characteristics might include noticeable discoloration of the water or fluid, precipitates (e.g., iron oxyhydroxides), surface sheen, condensate layer, petroleum hydrocarbon or other odor, or sample effervescence.

## 5.10 Natural Gas Sampling

Natural gas samples will be collected and analyzed as specified in Section 4. Natural gas sampling will be accomplished with the assistance of the Companies' field representative. The Company representative will be responsible for manipulating the valves on the gas well,

effluent line, and separator. Sampling crews will not attempt to sample natural gas without the presence of a Company representative. The natural gas samples will be collected from either the line to the separator or at the separator. The samples will be collected in 20-pound (19-liter) steel gas canisters provided by Isotech Laboratories. The gas canisters are shipped under vacuum, so flushing of the gas canister prior to sampling is not necessary.

Natural gas will be sampled by connecting a braided steel sampling hose outfitted with a pressure regulator and flushing valve between the sampling port on the separator line and a laboratory-supplied, evacuated 20-pound gas tank. Once the connector tubing is connected to the natural gas sampling port and the sampling canister, the connector tubing will be flushed with the flushing valve open to remove atmospheric gases from the line. Once flushing is complete and the flushing valve is closed, sampling can occur. **The gas canister valve should not be opened until it is connected to the gas sampling port to avoid losing the vacuum in the canister and introducing atmospheric gases into the sample or while flushing the braided connector with natural gas.**

To collect a gas sample, open the gas sampling canister valve. Gas will flow into the sample canister until it is full. Once the gas canister is full, tightly close its valve, then close the valve on the sampling port, open the flushing valve, and disconnect the braided connector tubing. The Company representative will return any open or closed valves at the separator to their initial configuration. Non-sparking (non-ferrous) tools should be used to connect the connector tubing to the gas sampling port.

Once filled, the gas tank should be labeled, documented, stored in its shipping carton, and shipped to the laboratory in accordance with the procedures outlined in Section 7. Natural gas samples will be analyzed for the radiological analytes listed in Table 7.

## 5.11 Decontamination Procedures

All sampling equipment introduced into any well, spring, or stream will either be pre-cleaned, disposable equipment or decontaminated using the procedures in this section. Pre-cleaned, disposable sampling equipment will be used to perform most of the sampling activities described in this RBSAP. Pre-cleaned, disposable sampling equipment does not need to be

decontaminated prior to use. However, it should remain in its sealed plastic bag until it is used to prevent cross-contamination.

Non-dedicated sampling equipment will be thoroughly cleaned prior to initiation of sampling activities and between each use at the site, to avoid cross contamination between samples. Decontamination of field instruments and sample containers will include an Alconox<sup>®</sup>, or equivalent, wash and scrubbing with a brush or sponge as appropriate to remove potential contaminants, followed by a deionized water rinse. Once cleaned, the decontaminated equipment will be stored in a manner to avoid subsequent contamination prior to its use at the next site. One rinsate sample will be collected and analyzed for every ten samples collected. The rinsate samples, if required, will be analyzed for the same radiological analytes as the groundwater samples (Table 7).

## 6 DATA QUALITY ASSURANCE OBJECTIVES

### 6.1 Data Quality Objectives

The operational and environmental monitoring program described in this RBSAP is designed to detect an unanticipated migration of identified Project Rio Blanco-related radionuclides from the subsurface nuclear cavity to producing gas wells or the environment within a 2-mile radius of Project Rio Blanco. This RBSAP specifies selected identified radionuclides to monitor that are derived from nuclear fission devices like those used at Project Rio Blanco and that are likely to be transported in either the natural gas or formation water. Likely mobile gas phase radionuclides (e.g.,  $^3\text{H}$ ,  $^{14}\text{C}$ , and  $^{85}\text{Kr}$ ) and less mobile liquid phase radionuclides (e.g.,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ , and  $^{137}\text{Cs}$ ) are considered in response to COGCC concerns regarding the migration and release of radionuclides to the environment. Operational monitoring data obtained to date have demonstrated that radionuclides have not migrated from the cavity to the currently producing gas wells within a 2-mile radius of Project Rio Blanco. Environmental monitoring data collected since 1973 have also demonstrated that Rio Blanco-related radionuclides have not migrated from the cavity to the surrounding environment.

Monitoring described in this RBSAP will provide the necessary field and laboratory data to track any changes in identified Project Rio Blanco-related radionuclide activities over time in produced water and natural gas at existing and future gas wells or within local water supplies within the region. These monitoring data will provide an early warning of the potential migration of Rio Blanco-related radionuclides to producing gas wells or the environment. Early detection of identified Rio Blanco-related radionuclides will allow appropriate actions to be taken to avoid a radiological incident or introducing radioactively-contaminated gas into the gathering system at activity levels dangerous to human health or to minimize their potential for an uncontrolled release to the environment.

Data collected under this operational and environmental monitoring program will be used to satisfy the following DQOs:

- Screen for a subset of identified Project Rio Blanco-related radionuclides in produced water and natural gas at producing gas wells within a 2-mile radius of

Project Rio Blanco that are most likely to be transported in natural gas or formation water.

- Develop background activities for selected identified Project Rio Blanco-related radionuclides in produced water, natural gas, or environmental media introduced into the borehole that can be used to compare with future monitoring results.
- Determine whether the identified Project Rio Blanco-related radionuclides detected are at or above activities that would cause the 100 millirem per year public exposure standard (6 CCR 1007-1 Part 4 Section 4.14.1.1) to be exceeded or would cause a release to the environment that would exceed air, groundwater, or surface water quality standards.
- Facilitate management of a radiological incident and determine a course of action if identified Project Rio Blanco-radionuclides are detected above their action levels during drilling, completion, or production at a natural gas well.
- Manage worker and public health and safety in the unlikely event of a radionuclide release during drilling, completion, or production of natural gas.

Monitoring data collected under this RBSAP will be of sufficient quality and analytical sensitivity to satisfy the above DQOs. To accomplish these objectives, data collected under this RBSAP will be collected, handled, shipped, and analyzed using industry standard procedures and methods to ensure that the data are of known quality, consistent, comparable, usable, and defensible. QA objectives and approaches that will be implemented to support the above DQOs are discussed in Section 6.2 and Sections 7, 8, and 9.

## 6.2 Quality Assurance Objectives

The QA objectives established for this RBSAP are listed below. The methods and procedures used to implement and accomplish these objectives are described in this RBSAP and include:

- Implement standard procedures for field sampling, sample custody, equipment operation and calibration, laboratory sample analysis, data reduction, and data reporting that will assure the consistency and thoroughness of data generation;
- Assess the quality of data generated to assure that all data are scientifically valid, of known and documented quality, and legally defensible, where appropriate. This is largely accomplished by establishing acceptance limits for parameters such as precision, accuracy, completeness, representativeness, comparability and sensitivity, and by testing generated data against acceptance criteria established for these parameters; and
- Achieve an acceptable level of confidence in the decisions that are made from data by using QC checks to control the degree of total error permitted in the data. Data that fail the QC checks or do not fall within the acceptance criteria established will be evaluated for usability in meeting project objectives during data validation.

### 6.3 Data Quality Assessment

To support the DQOs of this monitoring program, data generated must be of known and acceptable quality. To define acceptable quality for these data, data quality indicators (DQIs) were identified for each analytical parameter, and decisions were made regarding how each DQI would be assessed. The DQIs included precision, accuracy, completeness, representativeness, comparability, and sensitivity. These DQIs are briefly defined below; the approach to assessing each DQI is specifically discussed in Section 9.

#### 6.3.1 Precision

Precision is a measure of mutual agreement among replicate (or between duplicate) or collocated sample measurements of the same analyte. The closer the numerical values of the measurements are to each other, the more precise the measurement. Precision for a single analyte will be expressed as a relative percent difference (RPD) between results of field replicate or laboratory duplicate samples, or matrix spike duplicates for cases where both results are

sufficiently large (i.e., equal to or more than five times the reporting limit [RL]). Otherwise, the absolute difference between the results is compared to a factor of the RL (the RL is used for nondetect results). However, to avoid this issue, the analytical laboratories will be instructed to provide a value for nondetects to minimize the need for using the RL in the RPD calculation. Precision will be determined for no fewer than 1 sample in 20 for field replicates and laboratory duplicates or 1 in 20 for laboratory matrix spike duplicates. In addition, precision will be maintained by conducting routine instrument checks to demonstrate that operating characteristics are within predetermined limits.

### **6.3.2 Accuracy**

Accuracy is a measure of bias in a measurement system. The closer the value of the measurement agrees with the true value, the more accurate the measurement. This will be expressed as the percent recovery of a surrogate, laboratory control sample (LCS) matrix spike analyte, or of a standard reference sample. The samples having known constituent concentrations will be analyzed as unknowns in the analytical laboratory for comparison to true values. Accuracy of spiked sample analyses will be determined for no fewer than 1 sample in 20.

### **6.3.3 Completeness**

Completeness is a measure of the number of valid measurements obtained in relation to the total number of measurements planned. The closer the numbers are, the more complete the measurement process. Completeness will be expressed as the percentage of valid or usable measurements to planned measurements. A high level of completeness will be achieved by obtaining samples for the analyses required at each individual location, a sufficient volume of sample material to complete the analyses, samples that represent possible contaminant situations under investigation, and background or control samples. The completeness goal for investigative activities is 80 percent for each sampling event. The completeness goal is intended to represent the percentage of planned measurements that are judged usable, including those qualified as estimated, during validation. Data that are qualified as estimated are usable as long as the uncertainty in the measurement is considered in the interpretation. Rejected values are not considered usable.

#### **6.3.4 Representativeness**

Representativeness is a qualitative parameter that expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. The design of and rationale for the sampling program (in terms of the purpose for sampling, selecting the sampling locations, the number of samples to be collected, the ambient conditions for sample collection, the frequencies and timing for sampling, and the sampling techniques) assure that the environmental condition has been sufficiently represented.

#### **6.3.5 Comparability**

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. Data sets will be considered comparable only when precision and accuracy are considered acceptable during data validation. Sampling, analysis, and reporting will be conducted using procedures and protocols that are designed to produce data comparable to other measurement data for similar samples and analyses. This goal will be achieved by following standard procedures to collect and then analyze representative samples and by reporting analytical results in appropriate and consistent units. Each analytical procedure selected from among the acceptable options will be used for all monitoring analyses, unless rationale is provided for choosing an alternative method. In essence, comparability will be maintained by consistency in sampling conditions, selection of sampling procedures, sample preservation methods, analytical methods, and data reporting units.

#### **6.3.6 Sensitivity**

Sensitivity is the ability of an analytical method to detect and quantify an analytical parameter at the concentration or activity of interest. Sensitivity is achieved by having the laboratory provide quantitation limits and detection limits that are lower than the respective action levels or standards identified for monitoring. For field measurements, the sensitivity is defined by the instrument manufacturer.

## 7 SAMPLE DOCUMENTATION AND HANDLING

The quality of data collected during any sampling effort is dependent upon the quality and thoroughness of field sampling activities. General field operations and practices and specific sample collection and inventory will be well planned and carefully implemented per the sampling procedures presented in Section 5. In addition, the following procedures will be used to document sample collection and maintain sample integrity and custody during the process of submitting the samples to the analytical laboratories for analysis.

### 7.1 Field Notes

Detailed field notes will be kept either in a bound notebook or on project-specific data forms (Appendix C) to document all aspects of sample collection. Any additions, modifications, variances, or deviations from the sampling procedures described in Section 5 will be documented in the field logbook or on project-specific field data forms. Field notes should be sufficiently complete to re-create a sampling event. At a minimum, field notes should include the following basic information:

- Identification of RBSAP.
- Location of sampling and field personnel present.
- Date and time of activity.
- Description of activity (e.g., groundwater, produced water, natural gas sampling).
- Physical and meteorological conditions at time of sample collection.
- Standard used to conduct activity (e.g., reference to standard operating procedures [SOPs] followed).
- Any additions, modifications, or deviations from the standard method for implementation of the activity.

- Results of any field radiation measurements, including surveys of sample containers.
- Field parameter measurements, as applicable.
- Sample preparation used (e.g., filtered [list filter size], not filtered).
- Description of sample appearance (e.g., odor, smell, color, clarity, texture, etc.).
- Sample preservation used.
- Special handling or safety precautions.
- Collection of field and quality control samples.
- Type of sample collected (e.g., composite vs. grab, type of composite, homogenization activities, etc.).
- Sample volumes collected, container types, and sample analyses (e.g., gross alpha/beta, gamma-emitting radionuclides by spectroscopy, etc.).
- Decontamination procedures, as applicable.
- Any pertinent information to assist in reconstructing the sampling event (e.g., drilling terminated due to refusal, insufficient sample volume due to low yield; therefore, no QC samples collected, analyses prioritized because of low sample volume, etc.).
- Signatures or initials of appropriate field personnel. When using initials, ensure that they can be uniquely identified with a particular individual.

All entries will be recorded with indelible ink. Should corrections be necessary, field personnel should place a single strike-out line through the erroneous information, add the correct information, and initial and date the correction.

At the conclusion of field activities, all field notes will be reviewed for completeness and correctness, after which the field notes will be copied. The original logbooks and field forms will be sent to the project files. Data users will use working copies of logbooks and field notes rather than the originals.

## **7.2 Sample Containers, Preservation, and Holding Time Requirements**

To maintain sample integrity, requirements for sample containers, preservation, and holding times have been established. Table 9 presents the sample container, preservation, and holding time requirements for radiological analytes.

## **7.3 Field Quality Control Samples**

Field quality control samples consist of field duplicates and additional sample volume for the laboratory to prepare matrix spike and duplicate or matrix spike duplicate samples as appropriate for the analytical methods. Table 9 presents the field QC requirements for radiological analytes.

## **7.4 Sample Labeling**

A sample label will be placed on each sample container. The sample label will include a unique sample identification number, the date and time of sample collection, the sampler's initials, the analyses requested, filtration status, and any preservatives present.

The sample identification number will consist of the site identifier, the sample matrix, sample type (grab [G], composite [C]), field type (primary [P], duplicate [D]), and the sample fraction (total [TF] or dissolved [DF]). Components of the sample identification number will be separated by dashes. An example sample identification is FED-RG-12-4-398-PW-GPTF which indicates a primary (P) produced water (PW) grab (G) sample collected from gas well Federal RG 12-4-398 for total fraction (TF) analysis. Sample matrix identifiers include natural gas (NG), produced water (PW), groundwater (GW), spring (SP), surface water (SW), drill cuttings (DC), drilling mud (DM), fracturing fluids (FW), flowback fluids (FB), trip blank [TB]), or rinsate (RS).

Table 9. Sample Handling and Field QC Requirements for Radiological Analytes

Analysis Parameter	Analytical Laboratory	Analytical Method	Sample Container	Minimum Sample Volume	Preservation Requirements	Holding Time	Frequency of Field Quality Control		
							Field Duplicate	MS	MSD or DUP
<b>Natural Gas</b>									
Carbon-14 ( <sup>14</sup> C)	Isotech	Internal Lab SOP	LP Tank	5 L Methane <sup>1</sup>	None	None	1 per 20 field samples	NA	NA
Tritium ( <sup>3</sup> H)	Isotech	Internal Lab SOP	LP Tank	5 L Methane <sup>1</sup>	None	None	1 per 20 field samples	NA	NA
<b>Water</b>									
Gross Alpha Particle Activity	GEL	EPA 900.0 modified	1 Liter P or G	500 ml	pH<2 HNO <sub>3</sub> , ≤ 6°C	6 months	1 per 20 field samples	NA	1 per 20
Gross Beta Particle Activity	GEL	EPA 900.0 modified					1 per 20 field samples	NA	1 per 20
Gamma Spectroscopy	GEL	EPA 901.1 modified	1 Liter P or G	500 ml	pH<2 HNO <sub>3</sub> , ≤ 6°C	6 months	1 per 20 field samples	NA	1 per 20
Krypton-85 ( <sup>85</sup> Kr)	GEL	EPA 901.1 modified	2 x 1 Liter P	2000 ml	≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Cesium-137 ( <sup>137</sup> Cs)	GEL	EPA 901.1 modified	2 x 1 Liter P	2000 ml	≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Strontium-90 ( <sup>90</sup> Sr)	GEL	GL-RAD-A004 GFPC	1 Liter P or G	500 ml	pH<2 HNO <sub>3</sub> , ≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Technetium-99 ( <sup>99</sup> Tc)	GEL	HASL 300 Tc-01-RC modified	1 Liter P or G	500 ml	pH<2 HNO <sub>3</sub> , ≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
Tritium ( <sup>3</sup> H)	Isotech	EPA 906.0 modified	1 Liter G	250 ml	None	6 months	1 per 20 field samples	1 per 20	1 per 20
Total Uranium	GEL	GL-RAD-A023	250 mL P	100 mL	pH<2 HNO <sub>3</sub> , ≤ 6°C	6 months	1 per 20 field samples	1 per 20	1 per 20
<b>Drill Cuttings or Soil</b>									
Gross Alpha Particle Activity	GEL	EPA 900.0 modified	16 oz P or G wide mouth jar	20 g	None	6 months	1 per 20 field samples	NA	1 per 20
Gross Beta Particle Activity	GEL	EPA 900.0 modified		20 g	None	6 months	1 per 20 field samples	NA	1 per 20
Gamma Spectroscopy	GEL	EPA 901.1 modified		200 g	None	6 months	1 per 20 field samples	NA	1 per 20
Total Uranium	GEL	ASTM D-5174		20 g	None	6 months	1 per 20 field samples	NA	1 per 20

Notes:

<sup>1</sup> Sample volume depends on methane concentration. 5 liters of pure methane needed for analysis. Generally 19L samples are collected.

LP = Liquid propane  
ml = Milliliter

L = Liter  
P = Plastic

MS = Matrix spike  
MSD = Matrix spike duplicate

NA = Not applicable  
G = Glass

DUP = Duplicate

Sample labels may be pre-printed prior to a sample event or hand-written at the time of sample collection. If pre-printed samples labels are used, the sampler will complete the portions for the date and time collected and the sampler's initials at the time of sample collection.

Sample labels will be completed with indelible ink. After the label is placed on the sample container, it will be affixed to the sample container by means of covering the label with clear packing tape (i.e., wrap clear tape around the container) or fastening the label to the container handle (i.e., liquid propane [LP] tanks) to maintain the integrity of the label through sample shipment.

## **7.5 Sample Chain-of-Custody**

Written documentation of sample custody from the time of sample collection through the generation of data by analysis of that sample and until disposal is recognized as a vital aspect of any QA effort. The chain of custody (COC) of the physical sample and its corresponding documentation will be maintained throughout the handling of the sample. All samples will be identified, labeled, and logged onto a COC form as a part of the procedure designed to assure the integrity of the resulting data. When transferring the possession of samples, the individuals relinquishing and the individuals receiving the samples should sign, date, and note the time on the form. The original COC form will be included in the analytical data package.

The record of the physical sample (location and time of sampling) will be joined with the analytical results through accurate accounting of the sample custody. Sample custody applies to both field and laboratory operations. All laboratories completing chemical analyses will be required to maintain samples in a secure location with limited access from the time of sample receipt through sample disposal.

## **7.6 Sample Packing and Shipping**

Samples collected during this investigation will be shipped to the laboratory via an overnight carrier. If the samples are shipped via an overnight carrier, the following procedure

will be used for packaging non-gas samples (e.g., produced water, fracing fluid, flowback fluid, drill cuttings, groundwater, or surface water):

- Inert cushioning material will be placed in the bottom of the cooler;
- The cooler will be lined with a large plastic bag;
- Each sample container will be sealed in a re-sealable plastic bag and placed upright in the cooler;
- For all coolers containing samples that require  $\leq 6^{\circ}\text{C}$  preservation, blue ice or wet ice and additional packaging materials will be placed around the containers. Wet ice shall be double-bagged;
- A temperature blank will be included in each cooler containing samples that require  $\leq 6^{\circ}\text{C}$  preservation;
- Pertinent paperwork such as the COC form will be placed in a re-sealable plastic bag and taped to the inside lid of the cooler;
- A signed custody seal will be attached to the cooler in two places and covered with clear tape in such a way that the custody seal must be broken to open the cooler;
- The cooler will be sealed with packaging tape; and
- A shipping label will be affixed to the outside of the cooler.

For shipments by overnight carriers, the overnight carrier will not sign the sample COC records because the shipping containers will remain sealed until receipt at the laboratory. The laboratory will document the condition of the custody seals upon receipt of the coolers, noting the condition of the custody seals upon receipt. If the custody seals remained intact, it will be assumed that integrity of the samples was maintained throughout the shipping process.

Natural gas samples collected in LP tanks will prepared for shipment by a qualified person who has the appropriate U.S. Department of Transportation (DOT) or International Air

Transportation Association (IATA) training for shipping dangerous materials. After ensuring that the tank valve is tightly closed and the sample container is properly labeled, the LP tanks will be placed in their individual shipping cartons supplied by the laboratory. The outer package will be properly marked and labeled (Figure 12) in accordance with the dangerous goods shipping regulations. The dangerous goods shipping paperwork (Figure 13) will be completed by a person with the appropriate DOT/IATA training. The follows hazardous material information will be included on the shipping paperwork and/or package as appropriate:

Ship to: Isotech Laboratories, Inc.  
1308 Parkland Court  
Champaign, Illinois 61821  
Telephone: (217) 398-3490  
Fax: (217) 398-3494

Transportation Details: Cargo Aircraft Only  
Airport of Destination: CMI (Willard Airport, Champaign, Illinois)  
Shipment Type: Non-radioactive

UN or ID No: UN1971  
Proper Shipping Name: Methane, Compressed Gas  
Class or Division: 2.1, Flammable Gas  
Quantity and Type of Packaging: fiberboard box x 1 kg  
Packing Instructions: 200

Type of Packaging: U. S. DOT approved LP gas cylinders  
Maximum Allowed Quantity per Package: 150 kg  
Description of Contents: Gas cylinders containing methane gas samples

The laboratory will be notified of all shipments.



Figure 12. Example Labeling for Natural Gas Shipping Carton.

SHIPPER'S DECLARATION FOR DANGEROUS GOODS				(Provide at least three copies to the airline.)		
<b>Shipper</b> URS Corporation 713 Cooper Avenue, Suite 100 Glenwood Springs, CO 81601 (970) 384-4731				<b>Air Waybill No.</b> 8646 7433 4659  <b>Page 1 of 1 Pages</b>  <b>Shipper's Reference Number</b> <i>(optional)</i> 22239457.54210.00002		
<b>Consignee</b> Isotech Laboratories 1308 Parkland Court Champaign, IL 61821 (217) 398-3490						
<i>Two completed and signed copies of this Declaration must be handed to the operator</i>				<b>WARNING</b>  <b>Failure to comply with all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties.</b>		
<b>TRANSPORT DETAILS</b> This shipment is within the limitations prescribed for: <i>(delete non applicable)</i>				<b>WARNING</b> (continued)		
Airport of Departure		<input type="checkbox"/> PASSENGER AND CARGO AIRCRAFT <input checked="" type="checkbox"/> CARGO AIRCRAFT ONLY		Airport of Destination: CMI		
Airport of Destination: CMI				Shipment type: <i>(delete non-applicable)</i> <input type="checkbox"/> NON-RADIOACTIVE <input checked="" type="checkbox"/> RADIOACTIVE		
NATURE AND QUANTITY OF DANGEROUS GOODS						
Dangerous Goods Identification				Quantity and type of packaging	Packing Inst.	Authorization
UN or ID No.	Proper Shipping Name	Class or Division (Subsidiary Risk)	Packing Group			
UN 1971	Methane, Compressed Gas	2.1		1 fiberboard box x 1 kg	200	
<b>Additional Handling Information</b>						
<b>I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable International and National Governmental Regulations. I declare that all of the applicable air transport requirements have been met.</b>				<b>Name/Title of Signatory</b> Tim Joseph, H&S Manager  <b>Place and Date</b> Glenwood Springs, CO  <b>Signature</b> <small>[A typed signature may be used if the origin and destination are in the United States or its territories.]</small> <i>(see warning above)</i>		
(303) 740-2721/(800) 424-9300				Emergency Telephone Number		
FOR RADIOACTIVE MATERIAL SHIPMENT ACCEPTABLE FOR PASSENGER AIRCRAFT, THE SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN OR INCIDENT TO RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT. ADR EUROPEAN TRANSPORT STATEMENT: CARRIAGE IN ACCORDANCE WITH 1.1.4.2.1						

Figure 13. Example FedEx Shippers Declaration for Dangerous Goods.

## 8 SAMPLE ANALYSIS AND QUALITY CONTROL

To obtain data of known quality for meeting project DQOs, samples will be analyzed using approved, prescribed methods. Section 8.1 specifies the analytical methods that will be used and the RL objectives. Section 8.2 describes the laboratory QC sample requirements for each method. Section 8.3 discusses the data reduction methods. Section 8.4 specifies the laboratory data reporting requirements.

### 8.1 Analytical Methods and Reporting Limits

Table 10 presents the analytical parameters, methods, and reporting limits for each sample matrix, including the laboratory that will perform the analysis, the method that will be used, and the associated detection level for radiological analytes. The 900 series methods are described in *Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980. The HASL 300 methods are described in the DOE *Environmental Measurements Laboratory Procedures Manual, 28th Edition*, revised February 1997. In addition, Isotech Laboratories will conduct the  $^3\text{H}$  and  $^{14}\text{C}$  analyses in accordance with laboratory SOPs that are consistent with the methodologies presented in these two sources. The laboratory QA manuals can be obtained, where available, for review upon request.

The proposed lower limits of detection (e.g., minimum detectable activities [MDAs]) proposed in Table 10 are for "typical" soil and water matrices. These MDAs will be achieved where possible. However, URS experience with analysis of these radiological constituents at Projects Rio Blanco and Rulison has shown that the produced waters, flowback fluids, and drilling muds typically have higher MDAs because of the high total dissolved solids (TDS) contents of these media. Because of method-specified limits on the residue mass after evaporation for gross alpha and beta analyses, the high TDS content of the produced waters results in the evaporation of a smaller sample volume during analysis, and, thus, generally results in higher MDAs for the produced waters, flowback fluids, and drilling muds.

Table 10. Analytical Parameters, Methods, and Reporting Limits for Radiological Analytes.

Parameter	Analytical Laboratory	Analytical Method <sup>1</sup>	Analytical Technique	Definitive or Screening Analysis	Lower Limit of Detection	Analytical Turnaround Time
<b>Natural Gas</b>						
Carbon-14 ( <sup>14</sup> C)	Isotech	Laboratory SOP <sup>2</sup>	liquid scintillation counting	definitive	0.5 pMC	28 days
Tritium ( <sup>3</sup> H)	Isotech	Laboratory SOP <sup>2</sup>	liquid scintillation counting	definitive	10-15 TU <sup>3</sup>	28 days
<b>Water</b>						
Gross Alpha Activity	GEL	EPA 900.0 Modified	gas flow proportional counting	definitive	5 pCi/L	28 days
Gross Beta Activity	GEL	EPA 900.0 Modified	gas flow proportional counting	definitive	5 pCi/L	28 days
Gamma Spectroscopy	GEL	EPA 901.1 Modified	gamma spectroscopy	definitive	5 pCi/L	28 days
Krypton-85 ( <sup>85</sup> Kr)	GEL	EPA 901.1 Modified	gamma spectroscopy	definitive	5 pCi/L <sup>4</sup>	28 days
Cesium-137 ( <sup>137</sup> Cs)	GEL	EPA 901.1 Modified	gamma spectroscopy	definitive	5 pCi/L	28 days
Strontium-90 ( <sup>90</sup> Sr)	GEL	GL-RAD-A004 GFPC	gas flow proportional counting	definitive	5 pCi/L	28 days
Technetium-99 ( <sup>99</sup> Tc)	GEL	HASL 300 Tc-01-RC Modified	liquid scintillation counting	screening	50 pCi/L	28 days
Tritium ( <sup>3</sup> H)	Isotech	EPA 906.0 Modified	liquid scintillation counting	definitive	10-15 TU	28 days
Total Uranium	GEL	GEL-RAD-A023	laser kinetic phosphorimetry	definitive	1 µg/L	28 days

Table 10. Analytical Methods and Reporting Limits for Radiological Analytes (continued).

Parameter	Analytical Laboratory	Analytical Method <sup>1</sup>	Analytical Technique	Definitive or Screening Analysis	Lower Limit of Detection	Analytical Turnaround Time
<b>Drill Cuttings or Soil</b>						
Gross Alpha Activity	GEL	EPA 900.0 Modified	gas flow proportional counting	definitive	4 pCi/g	28 days
Gross Beta Activity	GEL	EPA 900.0 Modified	gas flow proportional counting	definitive	10 pCi/g	28 days
Gamma Spectroscopy	GEL	EPA 901.1 Modified	gamma spectroscopy	definitive	0.1 pCi/g	28 days
Total Uranium	GEL	ASTM D-5174	laser kinetic phosphorimetry	definitive	1 µg/g	28 days
<p>pMC = percent Modern Carbon  TU = Tritium units  pCi/L = picoCuries per Liter</p> <p><sup>1</sup> Analytical method specified or equivalent approved method.  <sup>2</sup> Gas Sample Preparation for <sup>14</sup>C and <sup>3</sup>H Analysis by internal standard operating procedure; analysis is subcontracted.  <sup>3</sup> One (1) tritium unit (TU) = approximately 3.2 pCi/L.  <sup>4</sup> Accurate quantitation can not be guaranteed due to the volatility of the analyte.</p> <p>Method Sources: EPA 900 series methods found in "<i>Prescribed Procedures for Measurement of Radioactivity in Drinking Water</i>," EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980. HASL 300 methods found in USDOE Environmental Measurements Laboratory Procedures Manual, 28th Edition, Revised February 1997.</p>						

## 8.2 Laboratory Quality Control Samples

QC practices used for radiochemical analyses are intended to assure that the radionuclide determinations are under control. QC involves continuous testing of those processes that influence the extent to which the results of the analyses remain within the required limits of precision and accuracy. QC samples that are analyzed for radiological methods consist of five types: instrument calibration standards, blank samples, control samples, "spiked" samples, and replicate samples. Each type of QC sample and the overall QC frequency is described below.

### 8.2.1 Instrument Calibration

Instrumentation calibration assures that accurate and reliable measurements are obtained. Instrument calibration standards are certified reference materials used primarily to calibrate the measurement apparatus. A key requirement of such materials is that they be traceable to the National Institute of Standards and Technology or to other recognized organizations.

All instruments will be calibrated in accordance with the analytical method requirements. All analytes reported will be present in the initial and continuing calibrations, and these calibrations will meet the acceptance criteria specified in the method, at a minimum. All results reported will be within the calibrated range. Multipoint calibrations will contain the minimum number of calibration points specified in the method. The standards used in the calibration will include all contiguous standards analyzed within the calibration range. It is permissible to drop the highest and lowest concentration standards from the calibration as long as the calibration range is adjusted appropriately. Records of standards preparation and instrument calibration will be maintained and submitted with the final data package.

### 8.2.2 Blank Samples

Blank samples, commonly called "method blanks," are prepared using deionized water that is analyzed like the samples. A blank is prepared to represent the sample matrix as closely as possible and analyzed exactly like the calibration standards, samples, and QC samples. All appropriate reagents are added to the sample, in the proper sequence, and the normal steps

involved in the analysis are followed. Ideally, the blank samples would be the same matrix as the routine sample but without the analyte of interest. Results of method blanks provide an estimate of the within-batch variability of the blank response and an indication of bias introduced by the analytical procedure.

For radiological analyses, the activity of each routine sample is typically corrected by subtracting the instrument background count rate from it to obtain net activity. All the uncertainties of the measurements obtained throughout the analytical procedure should be propagated when calculating the uncertainty of the final result. However, very often, only the Poisson errors of the counts of the background count and of the sample are propagated when they are the most significant contributors to the total uncertainty.

### **8.2.3 Control, Spiked, and Replicate Samples**

Control samples contain known concentrations of the analyte. If possible, they should be the same matrix as the routine samples, and they should have concentrations in the same range as the routine samples. Control samples are usually included by the analyst in the sample batches to be analyzed, and their values should be known with an uncertainty better than that which will be required of measurements of the routine samples.

“Spiked” samples are prepared by adding a known amount of the radionuclide of interest to blank samples (i.e., LCS) or to samples that have already been analyzed (i.e., matrix spike samples) to provide a matrix with a known activity.

Replicate samples usually consist of two or more aliquots of homogenized solid, liquid, or gas samples. Individual samples that are measured by nondestructive techniques, such as gamma-ray spectroscopy, may be measured more than once to obtain replication of the data. If a single replicate measurement is made, it is called a matrix duplicate.

### **8.2.4 QC Sample Frequency**

For most radiochemical procedures, QC samples are added to make up between 10 and 20 percent of the sample batch. Table 11 presents the laboratory QC sample frequency for the various radiological analytes. It is good analytical practice to process high-level and low-

Table 11. Laboratory Quality Control Criteria for Radiological Analytes.

Parameter	Analytical Method	Frequency of Lab QC Samples				
		Instrument Calibration	Method Blank	Laboratory Control Sample (LCS)	Matrix Spike	Matrix Duplicate
<b>Natural Gas</b>						
Carbon-14 ( <sup>14</sup> C)	Laboratory SOP	per method requirements	1 per batch	1 per batch	NA	NA
Tritium ( <sup>3</sup> H)	Laboratory SOP	per method requirements	1 per batch	1 per batch	NA	1 per 10
<b>Water</b>						
Gross Alpha Particle Activity	EPA 900.0 modified	per method requirements	1 per batch	NA	NA	1 per 20
Gross Beta Particle Activity	EPA 900.0 modified	per method requirements	1 per batch	NA	NA	1 per 20
Gamma Spectroscopy	EPA 901.1 modified	per method requirements	1 per batch	NA	NA	1 per 20
Krypton-85 ( <sup>85</sup> Kr)	EPA 901.1 modified	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Cesium-137 ( <sup>137</sup> Cs)	EPA 901.1 modified	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Strontium-90 ( <sup>90</sup> Sr)	GL-RAD-A004 GFPC	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Technetium-99 ( <sup>99</sup> Tc)	HASL 300 Tc-01-RC modified	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Tritium ( <sup>3</sup> H)	EPA 906.0 modified	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20
Total Uranium	GEL-RAD-A023	per method requirements	1 per batch	1 per batch	1 per 20	1 per 20

Table 11. Laboratory Quality Control Criteria for Radiological Analytes (continued).

Parameter	Analytical Method	Frequency of Lab QC Samples				
		Instrument Calibration	Method Blank	Laboratory Control Sample (LCS)	Matrix Spike	Matrix Duplicate
<b>Drill Cuttings or Soil</b>						
Gross Alpha Particle Activity	EPA 900.0 modified	per method requirements	1 per batch	NA	NA	1 per 20
Gross Beta Particle Activity	EPA 900.0 modified	per method requirements	1 per batch	NA	NA	1 per 20
Gamma Spectroscopy	EPA 901.1 modified	per method requirements	1 per batch	NA	NA	1 per 20
Total Uranium	ASTM D-5174	per method requirements	1 per batch	NA	NA	1 per 20

**Notes:** An analytical batch consist of a set of up to 20 samples of the same matrix prepared and analyzed in the same time frame.

level samples in independent batches whenever possible to minimize the possibility of cross-contamination. When radiological samples of very low activity are to be analyzed, blank sample analyses and instrument background measurements should be increased.

The best estimates of a reagent blank or blank sample activity, instrument background count rate, and detection efficiency are obtained from the mean value of replicate determinations. Whenever possible, the mean and standard error of the replicate determinations should be used in calculating a final value for radiological analyses.

### 8.3 Data Reduction

The quality of the data reported by the laboratory depends not only upon the care with which sampling and analysis are performed, but also upon the care with which calculations of the resulting data are performed, and upon the manner in which the data are presented in reports. A key aspect of a QA program is maintaining records that document each step of the process that leads to the data that ultimately are reported. This section outlines the methodology for assuring the correctness of the data reduction process.

The specific data reduction, verification, and reporting procedures and assigned personnel vary between laboratories; however, equivalent procedures must be performed by each laboratory to assure that accurate and consistent data handling, review, and reporting are achieved.

The laboratory analyst performing analyses is responsible for the reduction of raw data generated at the laboratory bench to calculate sample concentrations. The data reduction procedures are described in the laboratory's method SOPs. For many methods, data reduction software is included with the instrument or the Laboratory Information Management System (LIMS). In those cases, the analyst must verify that the data reduction was correct. The system may require manual manipulation to correctly calculate sample concentrations.

The analytical process includes verification of a QA review of the data. Specific requirements, acceptance criteria, and corrective actions for each analysis are included in the analytical methods. The QC checks are reviewed at several levels by laboratory analysts,

supervisors, designated QC specialists, document control staff, or by a combination of these staff. After the data have been reviewed and verified, the laboratory reports are signed and released for distribution.

Most laboratories use a LIMS to electronically track and report sample and QC data. The data are reported electronically from the LIMS to the project staff using pre-established formats. The LIMS files must undergo a QC check to verify that the results are complete and correct, and that the files are properly formatted.

## 8.4 Laboratory Data Reporting

The laboratory will report the results in both hardcopy data packages and EDDs. Hardcopy reports will include the following:

- Cover sheet listing the field samples and corresponding laboratory identification number (ID) for the samples reported in the data package
- Detailed case narrative describing any problems encountered with analysis and any deviations from laboratory SOPs or prescribed methods
- Tabulated sample results for all field samples, including associated uncertainties
- Tabulated results for all blank samples
- Tabulated results for all QC samples
- Initial calibration and continuing calibration summary data
- Raw data to support all information reported on summary forms
- Standards traceability data
- Sample tracking and receiving information, including the original COC form

The specifications for EDDs will be agreed upon prior to sample collection.

## 9 DATA VERIFICATION AND VALIDATION FOR RADIOCHEMISTRY PARAMETERS

To evaluate if the analytical data are sufficient for their intended use, all data will be validated. Validation will consist of two levels. The first level of analytical data review and validation occurs at the analytical laboratory and is discussed in Section 9.1. The second level of validation is independent of the laboratory and is discussed in Section 9.2. The results of the independent data validation process will be documented in a data validation report (Section 9.3) that includes an overall assessment addressing the DQIs of sensitivity, accuracy, precision, completeness, comparability, and representativeness.

### 9.1 Laboratory Validation

Data reduction is the process of converting measurement system outputs to an expression of the parameter that is consistent with the comparable objective identified in this plan. As discussed in Section 8.3, reduction of analytical data will be completed in accordance with the laboratory's QA Plan and SOPs.

The first level of data review, which may contain multiple sublevels, will be conducted by the analytical laboratory. The laboratory has the initial responsibility for the correctness and completeness of the analytical data. The laboratory data reviewer will evaluate the quality of the analytical data based on an established set of laboratory guidelines (laboratory QA Plan and SOPs) and this RBSAP. The laboratory reviewer will review the data packages to confirm the following:

- Sample preparation information is correct and complete.
- Analysis information is correct and complete.
- The appropriate laboratory SOPs have been followed.
- Analytical results are correct and complete.
- QC sample results are within established control limits.

- Blank results are within appropriate QC limits.
- Analytical results for QC sample spikes, sample duplicates, initial and continuous calibration verifications of standards and blanks, standard procedural blanks, laboratory control samples, and other method-specific QC analyses are correct and complete.
- Tabulation of reporting limits related to the sample is correct and complete.
- Documentation is complete (all anomalies in the preparation and analysis have been documented; holding times are documented).

The laboratory will perform the in-house analytical data reduction and QA review under the direction of the laboratory manager or designee. The laboratory is responsible for assessing data quality and advising of any data that were rated "preliminary" or "unacceptable," or other notations that would caution the data user of possible unreliability. Data reduction, QA review, and reporting by the laboratory will include the following:

- Raw data produced by the analyst are processed and reviewed for attainment of quality control criteria as outlined in this RBSAP, the laboratory QA Plan and SOPs, and/or established EPA methods and for overall reasonableness.
- The laboratory data reviewer will check all manually entered sample data for entry errors, will check for transfer errors for all data electronically uploaded from the instrument output into the software packages used for calculations and generation of report forms, and will decide whether any sample re-analysis is required.
- The laboratory data reviewer will review initial and continuing calibration data , matrix spike/matrix spike duplicate recoveries, internal standard recoveries, LCS recoveries, sample results, and other relevant QC measures.
- Upon acceptance of the preliminary reports by the laboratory data reviewer, the Laboratory QA Officer or designee will review and approve the data packages, prior to the final reports being generated.

The data reduction and the QC review steps will be documented, signed, and dated by the analyst and the laboratory project manager or designee.

## 9.2 Independent Data Validation

The second level of analytical data review and validation will be performed by data validation personnel independent of the laboratory generating the data. The purpose of this second level of review is to provide an independent review of the data package; it will include a review of laboratory performance criteria and sample-specific criteria. The following subsections discuss the process for independent review of laboratory performance criteria and sample-specific criteria. The amount and level of data validation will be based on the end use of the data and nature of the decisions that will be based on the data.

The first level of independent data review by the analytical laboratory includes a thorough review of laboratory performance parameters (which are independent of the field samples being analyzed). The independent validation will include a verification of the laboratory review of the performance criteria for the following:

- A minimum of one data package per method per matrix per site per year
- Ten percent of the data for each matrix (i.e., soil or water), whichever is greater

Regardless of the number of samples, a minimum of one data package will be reviewed for all combinations of samples, analyses, and laboratory operations to verify that the laboratory analysis is in compliance with method specifications. The review of laboratory performance criteria is discussed in Section 9.2.1.

The second level of independent data review will also include a review of sample-specific parameters for 100 percent of the data packages from each laboratory, for each analysis type for those parameters that are sample-related such as: holding times, blank results, sample-specific chemical recovery, matrix spike recoveries, duplicate analysis precision, and field duplicate agreement. Because transcription and calculation are reviewed and verified by the laboratory and are in the laboratory's control, these parameters will be evaluated from the results reported by the laboratory. Any significant problems identified during the review of the

laboratory performance criteria that indicate a systematic problem will also be included during the review of the sample-specific criteria. The review of sample-specific criteria is described in Section 9.2.2.

Validation acceptance criteria will be method-specified acceptance criteria. The sample-specific and laboratory performance evaluation procedures discussed for radiological parameters are based on guidance in SAIC (2000).

During the process of data validation, the reviewer will assign data qualifiers to results to indicate limitation on data usability. A list of independent reviewer assigned data qualifier and their definitions is provided as Table 12.

**Table 12. Independent Reviewer Data Qualifier Definitions.**

The following definitions provide brief explanations of the data qualifiers assigned to results during the independent data review process. If the data reviewer chooses to use additional qualifiers, a complete explanation of those qualifiers will accompany the data review.	
U	The analyte was analyzed, but was not detected at a level greater than or equal to the level of the adjusted reporting limit for sample and method.
J	The analyte was positively identified and the result is an approximate concentration of the analyte in the sample (due either to the quality of the data because certain QC criteria were not met, or the concentration of the analyte was below the reporting limit).
NJ	The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.
N (Rads)	Analyte was identified as present, but a quantitative value was not reported.
UJ	The analyte was not detected at a level greater than or equal to the adjusted reporting limit. However, the reported adjusted reporting limit is approximate and may be inaccurate or imprecise.
R	The sample results are unusable because certain data quality criteria were not met. The analyte may or may not be present in the sample.

### 9.2.1 Laboratory Performance Parameters

The subsections below provide a general overview of the data validation procedure for each of the following laboratory performance review parameters.

- Calibration
- Laboratory Control Sample

- Radionuclide Quantitation and Implied Detection Limits
- Chemical Separation Specificity
- Target Radionuclide List Identification (gamma spectroscopy)
- Tentatively Identified Radionuclides (gamma spectroscopy)
- Vérification
- System Performance

For packages designated for review of laboratory performance parameters, the following evaluation parameters will be reviewed as applicable to the individual analytical methods.

### **Calibration**

Compliance requirements for satisfactory instrument calibration are established to ensure that the instrument is capable of producing acceptable quantitative data. Initial and continuing calibration demonstrates that the instrument is capable of acceptable performance at the beginning of the calibration period, and routine calibration verification and system verification checks document that the initial calibration is still valid.

The reviewer will verify that the instrument was calibrated each time the instrument was set up and at the required frequency in the analytical method. The reviewer will evaluate the quality of the raw calibration data (e.g., shape and smoothness of high voltage plateaus, efficiency versus energy curves, and quench curves). The data reviewer will observe the QC charts and verify that the proper limits have been established and that recalibration was performed whenever the limits were exceeded. Additionally, the reviewer will verify calibration calculations.

For radiological parameters, if the specified calibration and/or verification frequency is not followed, the efficiency or quench curves are not smooth, or the QC results fall outside appropriate tolerance limits, the results for affected analytes will be qualified as estimated (J or UJ). If errors are found to occur at a significant rate, if less than 100 percent of the results are recalculated, and the estimated magnitude of potential bias associated with such errors would be between 10 and 20 percent in typical sample results, all associated results will be qualified as

estimated (J or UJ). Analogously, results will be qualified as unusable (R) if the estimated potential bias in unchecked sample results is greater than 20 percent.

If the initial or continuing calibration evaluation criteria for any analyte are not satisfied, then all results for that analyte associated with the initial calibration will be qualified as estimated (J or UJ). If the data reviewer can discern a probable magnitude and/or direction of bias to the associated sample results based on the information provided, it will be documented in the data validation report.

**Laboratory Control Sample (as applicable to the method)**

The LCS serves as a monitor of the overall accuracy and performance of all steps in the analysis, including the sample preparation. LCS should be analyzed for every matrix, every batch, or for every 20 samples (5 percent of samples), whichever is more frequent.

For radiological analyses, the following evaluation criteria apply when the activity in the LCS is greater than 10 times the detection limit (also referred to as the “minimum detectable activity” [MDA]). The reviewer will compare recoveries for aqueous LCSs to the acceptance range of 80 to 120 percent and recoveries for solid media to the acceptance range of 70 to 130 percent. The reviewer will verify that the LCS recoveries for at least one of the analytes was calculated properly.

- For aqueous samples, if the LCS recovery is within 50 to 80 percent or 120 to 150 percent, results for the associated analytes will be qualified as estimated (J). If the LCS recovery is less than 50 percent or greater than 150 percent, the associated results will be qualified as unusable (R).
- For solid samples, if the LCS recovery is within 40 to 70 percent or 130 to 160 percent, results for the associated analytes will be qualified as estimated (J). If the LCS recovery is less than 40 percent or greater than 160 percent, the associated results will be qualified as unusable (R).

In the case of unacceptably low LCS recoveries, the reviewer will verify that the laboratory re-prepared and re-analyzed all associated samples, including the LCS and that acceptable results were obtained for the new LCS.

### **Radionuclide Quantitation and Implied Detection Limits**

The raw data will be reviewed to ensure that the reported quantitation results are accurate and that the required detection limits are met.

Radionuclide activities must be calculated according to the appropriate procedures specified in the analytical methods. Detection limits specified in Table 10 must be met unless other detection limits are approved or the nature of the sample matrix precludes attaining the detection limit in Table 10. For example, the high solids content of the formation waters that will be analyzed may not allow the detection level for gross alpha to be achieved. Analytical uncertainties must be reported with all results, regardless of the sign or size of the result. The reported uncertainty must include all uncertainties associated with the analysis. If the reported uncertainty only includes counting uncertainty, this fact must be documented in the case narrative.

For solid samples, a minimum of 100 grams must be homogenized prior to subsampling an aliquot for analysis. Homogenization of the entire sample is recommended for all samples and is required for liquid samples with more than one phase. The minimum homogenized sample aliquot size used for analysis must be 1 gram for dry solids or 1 milliliter for liquid samples, although further dilution may be performed after chemical dissolution or extraction.

The reviewer will review the raw data to verify the correct calculation of sample results reported by the laboratory. The reviewer will recalculate a minimum of one sample result for each matrix. The reviewer will verify that there are no transcription or reduction errors (e.g., dilutions, percent solids, sample weights) on one or more samples. The reviewer will verify that all analytical uncertainties have been propagated and reported or otherwise documented. The reviewer will verify that appropriate aliquot sizes have been used for sample preparation and mounting.

The reviewer will check the detection limits by verifying that, for blanks and other samples with uncertainties greater than the result, the 2 standard deviation uncertainty multiplied by 1.65 is less than or equal to the specified detection limit.

If errors are found in the calculations, the laboratory will be contacted to resolve the problem. Professional judgment will be used to assign data qualification.

If inappropriate sample sizes are used, all associated results will be qualified as estimated values (J).

Net negative results at a frequency more than that expected from a 2 standard deviation uncertainty that have combined uncertainties smaller than the absolute values of the negative results may be an indication of improper blank subtraction or measurement error. In such cases, the data reviewer will contact the laboratory to determine the root cause of the error and whether the raw data can be re-processed to correct the problem. If contact with the laboratory is unable to resolve the problem, data associated with this condition may be qualified as unusable (R) or estimated (J) depending on the magnitude of the potential error taking into consideration project objectives.

If detection limit requirements were not met, the cause will be investigated. The effect on data usability will be evaluated and documented in the data validation report.

If analytical uncertainties are not reported for radionuclides and they cannot be obtained from the laboratory, the associated results will be qualified as unusable (R).

If any discrepancies are found, the reviewer may contact the laboratory to obtain additional information. If a discrepancy cannot be resolved, the data reviewer will use professional judgment to determine if data qualification is warranted. All uses of professional judgment will be documented in the data validation report.

### **Chemical Separation Specificity**

For analytes that are chemically separated prior to analysis (e.g., alpha speciation by spectroscopy), the chemical separation specificity will be evaluated. Chemical separation specificity evaluates the laboratory's ability to chemically separate various isotopes with similar chemical properties. There should be no radionuclides that interfere with the quantitation of the radionuclide of interest once the chemical separation process has been completed.

For example, the chemical separation specificity can be verified for alpha spectroscopy measurements by observation of the alpha energy spectrum. Thus, for alpha spectroscopy, the reviewer will check that the energy of the observed peak of interest is within 40 kilo electron volts (keV) of the energy for the radionuclide of interest. The reviewer will also check the energy spectra for any peaks that overlap or that have associated peaks that may interfere with the peak radionuclide of interest. Lastly, if interfering radionuclides are present and can be corrected from associated peaks in the spectrum, the reviewer will check to see if the peak area for the radionuclide of interest has been properly corrected.

Data will be qualified as nondetect (U) if the energy of the peak of interest is more than 40 keV from the energy of the radionuclide of interest and no other peaks are found within 40 keV. Results will be qualified as unusable (R) or estimated (J) if the energy spectrum contains any peaks that overlap with or have associated peaks that may interfere with the peak of the radionuclide of interest and it is impossible to correct for the interference, or if the results have not been properly corrected for the interfering radionuclide. The reviewer will use professional judgment in choosing the proper qualifier dependent on the magnitude of the potential interference relative to project objectives.

#### **Target Radionuclide List Identification (gamma spectroscopy)**

The target radionuclide list (TRL) contains those radionuclides for which a quantitative analysis may be required by some programs. If data are provided for TRL analytes, net quantitation with uncertainties will be provided for all TRL analytes, regardless of whether the radionuclide is present or absent.

The reviewer will check that the energy of the identified peaks is within 2 keV of the standard library energy for the identified radionuclide. The reviewer will verify that the net peak areas and associated uncertainties have been obtained for all TRL radionuclides not meeting the above criterion. The reviewer will check the energy spectra for any peaks that overlap or that have associated peaks that may interfere with the peak of the radionuclide of interest. When interfering radionuclides are present and can be corrected from associated peaks in the spectrum, the reviewer will check to see if the peak for the radionuclide of interest has been properly corrected.

For TRL radionuclides that are not detected in the computerized peak search, the net peak area results will be qualified as estimated (J) or unusable (R), depending on the conditions encountered.

Results for TRL radionuclide peaks will be qualified as unusable (R), nondetect (U), or estimated (J) if they are detected but fail to meet the positive identification criteria; the gamma energy spectrum contains interfering peaks that cannot be corrected; or the result includes interferences that could have been corrected but were not. The reviewer will use professional judgment in choosing the proper qualifier dependent on the magnitude of the potential interference relative to project objectives and, in the case of an improper choice of peaks, whether a peak meeting positive identification criteria is present.

Results for TRL radionuclide peaks will be qualified as estimated (J) or unusable (R) if improper quantitation methods were used and the results were not recalculated.

If any discrepancies are found, the reviewer will contact the laboratory to obtain additional information. If a discrepancy remains unresolved, the reviewer will use professional judgment to decide which value is the best value and whether data qualification is warranted.

#### **Tentatively Identified Radionuclides (gamma spectroscopy)**

Gamma spectra peaks in radionuclide analyses that are not TRL isotopes are potentially attributable to tentatively identified radionuclides (TIRs). If required by the end use of the data, TIRs must be qualitatively identified by a radionuclide spectrum library computer search and the identification assessed by the data reviewer. If TIR data are present, the results will be evaluated.

For all samples and blanks, the reviewer will verify that the laboratory has generated a computer library search for all significant peaks (greater than 3 standard deviations of the background activity) in the spectrum not attributable to TRLs.

To be identified as a TIR, the following criteria must be met:

- Fifty percent of total abundance of all gamma peaks listed in the library spectrum must be present in the sample spectrum.

- The sampling to counting (analysis) time must not be greater than ten half-lives of the identified radionuclide.

The reviewer will examine all gamma peaks in every sample and blank spectra and verify that the TIR peaks present in samples are not found in the blank. The reviewer will check that expected radionuclides are present. Professional judgment will be used in evaluating TIR results and evaluating the need for qualification, however, some qualification guidelines follow:

- All TIR results without supporting data will be qualified as tentatively identified with an estimated concentration (NJ).
- All TIR results without quantitation will be qualified as tentatively identified (N).
- A TIR result will be qualified as unusable (R) if the identification is determined to be unacceptable, a common laboratory artifact, or attributable to the laboratory blank (comparable concentration to blank).

### **Verification**

The reviewer will verify that information reported on the summary forms was calculated properly and that the results are traceable back to the raw data for 10% of the reported sample results in the data packages undergoing an evaluation of laboratory performance parameters. In addition, the reviewer may also verify that all spike solutions and standards were used within their recommended shelf lives.

If errors are found in the reported sample results, the laboratory will be contacted and corrected results will be requested. The data review narrative will detail any such instances and the resultant resolution. The reviewer will collate the revised data into the data package and mark all revised and all superseded data accordingly.

### **System Performance**

A thorough review of ongoing data acquisition may yield indicators of instrument performance and changes in the system that may degrade the quality of the data being generated. Some examples of changes in instrument performance include abrupt, discreet shifts in background; change in detector response as noted by contamination and/or gain or threshold

changes; and poor spectroscopy, denoted by high background or shifts in energy calibration, extraneous peaks, loss of resolution, peak tailing, or peak splitting. The reviewer will evaluate the raw data for each sample to evaluate if unexpected activity, extraneous peaks, loss of resolution, or loss of expected background peaks has occurred.

If the raw data indicate that the system performance had degraded, the reviewer will use professional judgment to decide if the system has degraded to the point of affecting data quality or validity and assign appropriate qualification.

### 9.2.2 Sample-Specific Criteria

The subsections below provide a general overview of the data validation procedure for each of the following sample-specific review parameters:

- Case narrative comments
- COC and Sample Receipt
- Holding times
- Blanks
- Matrix-specific QC samples
  - Sample-specific chemical recovery (radionuclides)
  - Matrix spike recovery
  - Duplicate analysis
- Standard uncertainty
- Field QC samples
  - Field duplicate agreement
  - Rinsate blanks
- Data package completeness

For all data packages, the following evaluation parameters will be reviewed as applicable to the individual analytical methods.

### Case Narrative Comments

The case narrative will be reviewed. The case narrative should include comments related to any problems encountered during the preparation and analysis of the samples. Any problems noted in the case narrative will be investigated by the data reviewer and evaluated against method requirements. If the analytical method does not specify requirements related to the criterion under evaluation, the data reviewer should utilize professional judgment to evaluate the effect of the reported item or condition on the associated analytical data. The affect on data quality and usability of any such problems will be noted in the data validation report. All uses of professional judgment will be described in the report of the data validation process.

### Chain of Custody and Sample Receipt

The COC document will be reviewed to verify that all requested analyses were performed on the sample submitted. Additionally, the sample receiving information will be reviewed to evaluate the integrity of the samples upon receipt at the laboratory.

If criteria for sample preservation are not met, associated sample results may be qualified as estimated (J). If sample integrity was compromised during shipment (e.g., breakage) the effect on data quality and usability will be noted in the data validation report. All uses of professional judgment shall be described in the report of the data validation process.

### Holding Times

Holding times will be evaluated by comparing the sample collection date on the COC form to the analysis date found on the laboratory analysis reports (i.e., data sheets). Holding time will be compared to the holding time requirements listed in Table 9.

If criteria for holding times are not met, associated sample results will be qualified as estimated (J). However, the reviewer will also use professional judgment to determine the reliability of the data and the effects of additional storage on the sample results based on the half-lives of the compound of interest and its parent isotopes. Consideration will be given to whether the result can be corrected back to the time of sample collection to provide more accurate and reliable data. The expected bias may be high or low, depending on the rates of decay and in-growth, and the reviewer may determine that results less than the critical level (CL) are unusable (R).

### **Blanks**

Blank analysis results are used to assess the existence and magnitude of contamination problems. If a problem exists with any blank, the reviewer will evaluate whether there is an inherent variability in the data for the entire data set or if the problem is an isolated occurrence not affecting other data.

Blanks should be analyzed for every matrix and every batch, or at a frequency of 5 percent, whichever is more frequent. The results for all blanks should be plotted to determine that each blank result falls within the recommended tolerance limits of  $\pm 3$  standard deviations.

For radiological parameters, the net blank result (e.g., the blank result after subtraction of background) must be less than the associated uncertainty if the average blank or instrument background counts are subtracted to determine net counts. If the net blank result is larger than the associated uncertainty, contamination will be suspected. If the blank QC results fall outside the appropriate tolerance limits or if the net blank result is greater than the associated uncertainty, and the sample concentration is less than five times the blank concentration or within the combined uncertainty, the sample results will be qualified as nondetect (U) for the associated analyte. Results for associated samples that are greater than five times and less than ten times the blank amount will be qualified as estimated (J).

### **Sample Specific Chemical Recovery (Radiological Methods)**

Laboratory performance on individual sample radiological analyses subject to chemical process and separation is established by means of spiking with tracer quantities of other radioisotopes of the same element or carrier quantities of the inactive isotope of the same or a chemically similar element. All samples are spiked prior to preparation. The evaluation of these spikes is not necessarily straightforward, because the sample matrix may produce interferences which are outside the control of the laboratory.

While professional judgment will be used to evaluate the results obtained for sample-specific chemical recovery, the following qualification strategy may be used for results whose quantitation does not include correction for the low recoveries:

- For recoveries between 50 and 120 percent, the data are acceptable for use without qualification.
- For recoveries between 20 and 50 percent and 120 and 150 percent, associated results may be qualified as estimated (J).
- For recoveries greater than 150 percent or less than 20 percent, associated results may be qualified based on professional judgment as estimated (J) or unusable (R).
- If the calculation includes correction for low recoveries, the following strategy may be used:
  - For recoveries between 10 and 120 percent, the data are acceptable for use without qualification.
  - For recoveries between 5 and 10 percent and 120 and 150 percent, associated results may be qualified as estimated (J).
  - For recoveries greater than 200 percent or less than 5 percent, associated results may be qualified as unusable (R).

Any use of professional judgment will be explained in the data validation report.

**Matrix Spike (as applicable to the method)**

The matrix spike sample analysis provides information about the effect of each sample matrix on the digestion and measurement methodology. A matrix spike sample should be analyzed for every matrix and every batch, or for every 20 samples (5 percent of samples), whichever is more frequent, when sample-specific chemical recovery mechanisms are not available and the sample undergoes a chemical process. Samples identified as field blanks must not be used for spiked sample analysis.

For radiological parameters, the reviewer will compare recoveries for aqueous matrix spike samples to the acceptance range of 80 to 120 percent and recoveries for solid media to the acceptance range of 70 to 130 percent. However, the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of 4 or more. The reviewer will verify that the matrix spike recoveries were calculated properly for at least one of the analytes.

- For aqueous samples, if the MS recovery is within 50 to 80 percent or 120 to 150 percent, results for the associated analytes will be qualified as estimate (J). If the LCS recovery is less than 50 percent or greater than 150 percent, the associated results will be qualified as unusable (R).

For aqueous samples, if the MS recovery is within 40 to 70 percent or 130 to 160 percent, results for the associated analytes will be qualified as estimate (J). If the LCS recovery is less than 40 percent or greater than 160 percent, the associated results will be qualified as unusable (R).

**Duplicate Analysis (matrix duplicate or spiked duplicate)**

Duplicate analyses are indicators of laboratory precision based on each sample matrix. Samples identified as field blanks should not be used for duplicate analyses. At least one duplicate should be analyzed for every matrix, every batch, or for every 20 samples (5 percent of samples), whichever is more frequent.

For radiological parameters, the duplicate analyses results must be in agreement when the 2 standard deviation (95 percent confidence limit) uncertainties are considered. For this to be true, the duplicate error ratio (DER) should be less than 1. The DER is calculated as follows:

$$DER = \frac{|S - D|}{\sqrt{(2\sigma_S)^2 + (2\sigma_D)^2}}$$

where,

S = First Sample Value (original)

D = Second Sample Value (duplicate)

$2\sigma_S$  = First Sample Uncertainty at the  $2\sigma$  level

$2\sigma_D$  = Second Sample Uncertainty at the  $2\sigma$  level

The reviewer will compare reported DERs to the evaluation criterion of less than one. The reviewer will recalculate at least one DER value. If the DER value is greater than 1, the results for affected analyte will be qualified as estimated (J) in all associated samples of the same matrix. Other equations used by laboratories to express duplicate agreement will be considered using professional judgment with the concept that the criterion should be consistent with agreement within the 95-percent confidence limits.

**Standard Uncertainty (radionuclides)**

In addition to criteria for individual measures of accuracy and precision, the data will be evaluated against a criterion for “total” or standard uncertainty. To evaluate the standard uncertainty, one must first choose the measure of accuracy and precision for a given set of samples that will be used in the calculation. If an MS measurement has been made on a site sample of similar matrix, then the MS result will be used as the contributing accuracy QC measure. If such a matrix-specific number is not available, then the Laboratory Control Sample (LCS) results will be used. If no LCS is available, then the calibration verification or calibration check analyses will be used. For precision, the duplicate measurements on the sample performed by the laboratory will be used.

A standard uncertainty (SU) value will be calculated for each batch of samples analyzed. The standard uncertainty will be calculated using the equation shown below. This equation is modified after Equation 19.4 of the MARLAP manual (USEPA et al. 2004).

$$SU(\%) = \sqrt{\left(\frac{1}{n(n-1)}\right) \left[ (A - Ec_{ms})^2 + (P - Ec_p)^2 \right]} * 100$$

where:

$Ec_{ms}$  = counting error (square root of the number of counts or half the 2 sigma error)

$Ec_p$  = square root of the sum of squares of the duplicate counting errors

A = measured accuracy

P = measured precision

n = 2

For example, if the MS recovery is 80 percent ( $A=0.2$ ), the duplicate RPD is 22 percent ( $P=0.22$ ), and the 1 sigma counting error for the MS sample is 0.8 mg/kg for a reported concentration of 4 mg/kg ( $Ec_{ms} = 0.2$ ). Additionally, the counting error for the first sample used for the duplicates analysis is 1.1 for a reported concentration of 5 mg/kg and the counting error for the second sample used for the MS was 1.3 mg/kg for a reported concentration of 4 mg/kg, then

$$Ec_p = \frac{\sqrt{(1.1)^2 + (1.3)^2}}{\frac{(5+4)}{2}} = 0.38$$

Thus, calculated standard uncertainty is:

$$SU(\%) = \sqrt{\left(\frac{1}{2(2-1)}\right) \left[ (0.2 - 0.2)^2 + (0.22 - 0.38)^2 \right]} * 100 = 11\%$$

Thus, for standard uncertainty, if A and P are small compared to  $E_c$ , then the standard uncertainty value calculated will be close to  $E_c$ . Conversely, if A and P are large compared to  $E_c$ , then a typical error value is calculated.

For sample batches whose calculated standard uncertainty is greater than 50 percent, each sample within the batch will be qualified as estimated (J).

### **Field Quality Control Samples**

The types of field quality control samples that will be collected under this RBSAP include field duplicates and rinsate blanks. The evaluation for each type of field quality control sample is described below.

### **Field Duplicate Agreement**

Field duplicate sample results will be used as an indication of overall precision (i.e., field and laboratory precision) and/or the representativeness of the samples to the medium sampled.

Results for radiochemical activity in field duplicate samples will be reviewed by evaluating differences in results relative to the two sigma counting error (uncertainty) for each result, as reported by the laboratory. The difference between the field duplicate result and the field original result is compared against a laboratory reported uncertainty (2 sigma counting error) for each sample result. If one of the field duplicate pair is nondetect (with no uncertainty reported), the uncertainty is calculated as if equal to that of the positive result. Field duplicate sample results differing from the field original results by a magnitude more than the combined

uncertainty for both the field original and field duplicate results (i.e., DER greater than 1) will be discussed in the data validation report.

### **Rinsate Blank Results**

The results for rinsate blanks reported in the data package will be reviewed. Sample results for analytes detected in an associated rinsate blank at concentrations <5x the equivalent blank concentration (<10x for common laboratory contaminants) will be qualified as nondetect (U). The result will be qualified as nondetect at the reported concentration if the reported concentration is greater than the RL or as nondetect (U) at the RL if the reported concentration is less than the RL.

For aqueous blanks applied to soil/sediment samples, qualification is assigned based on comparison of the sample result to the equivalent concentration in the blank. The equivalent concentration is determined by assuming that all of the analyte present in the blank aliquot analyzed is present in the soil sample aliquot analyzed. The reviewer should note that the blank analyses may not involve the same weights, volumes, or dilution factors as the associated samples. These factors must be taken into consideration when applying the 5x or 10x criterion, such that a comparison of the total contamination is actually made.

### **Data package completeness**

All analytical data received from the laboratory shall meet the data package requirements specified in Section 8.4. Fully validatable data packages will be submitted as appropriate. The laboratory will be contacted with regard to any missing or incorrect deliverables in the data packages, as noted during the validation process. The data reviewer will document all subsequent submittals and re-submittals from the laboratory, recalculations, and data reviewer corrections. The full deliverable data package will be reviewed for evaluation and compliance with method specifications.

A summary of the laboratory performance and sample-specific validation criteria is provided in Table 13 for radiological analytes.

### 9.3 Data Validation Reports

The results of the independent data validation process will be documented in a data validation report, which will include an overall assessment addressing the DQIs of sensitivity, accuracy, precision, completeness, comparability, and representativeness. The data validation report will include definitions of all data qualifiers assigned, discuss all instances in which evaluation criteria were not satisfied and data qualification assigned, and state whether the data are considered usable for the intended purpose. Additionally, any method non-compliances identified during the review, professional judgments used, and conclusions reached concerning usability of non-compliant data will be described in data validation reports.

**Table 13. Laboratory Performance and Sample-Specific Validation Criteria  
for Radiological Analytes.**

Laboratory Performance Criteria	Criterion	Qualification
Laboratory Control Sample	80-120% (aqueous)	50-80% or 120-150% - Qualify results as estimated (J/UJ) <50 or >150 – Qualify associated results as unusable (R)
	70-130% (solid)	40-70% or 130-160% - Qualify results as estimated (J/UJ) <40 or >160 – Qualify associated results as unusable (R)
Detection Limit	If the uncertainty is greater than the result, than $2\delta \times 1.65 \leq$ Detection Limit	Qualify the result as estimated (J)
Net Negative Results	Criteria specified in Section 9.2.1	Data associated with this condition may be qualified as unusable (R) or estimated (J) depending on the magnitude of the potential error taking into consideration project objectives.
Chemical Separation Specificity (alpha spectrometry only)	Criteria specified in Section 9.2.1	Data will be qualified as nondetect (U) if the energy of the peak of interest is more than 40 keV from the energy of the radionuclide of interest and no other peaks are found within 40 keV.
		Results will be qualified as unusable (R) or estimated (J) if the alpha energy spectrum contains any peaks that overlap with or have associated peaks that may interfere with the peak of the radionuclide of interest and it is impossible to correct for the interference, or if the results have not been properly corrected for the interfering radionuclide.
Target Radionuclide List Identification (gamma spectrometry)	Criteria specified in Section 9.2.1	Professional judgment, however, Section 9.2.1 of the RBSAP provides guidance.
Tentatively Identified Radionuclide (gamma spectroscopy)	Criteria specified in Section 9.2.1	Professional judgment, however, Section 9.2.1 of the RBSAP provides guidance.
Sample Specific Criteria	Criterion	Qualification
Holding Time	Holding times are presented in Table 9	Sample results will be qualified as estimated (J/UJ).
Method Blank (MB)	MB < the appropriate tolerance limits or The net blank result < the associated uncertainty	If the sample concentration is < 5x the blank concentration or within the combined uncertainty, the sample result is qualified as nondetect (U).
		If the sample concentration is greater than five times and less than ten times the blank amount, the sample result is qualified as estimated (J).
Sample Specific Chemical Recovery (as applicable)	50-120%	20-50% and 120-150% - Qualify results as estimated (J). <20% or >150% - Qualify results as unusable (R)
Matrix Spike Samples (as applicable to the method)	80-120% (aqueous)	50-80% or 120-150% - Qualify results as estimated (J/UJ) <50 or >150 – Qualify associated results as unusable (R)
	70-130% (solid)	40-70% or 130-160% - Qualify results as estimated (J/UJ) <40 or >160 - Qualify associated results as unusable (R)
Duplicate Analysis (method duplicate or spike duplicate)	Duplicate Error Ratio $\leq 1$	Qualify the results in all associated samples as estimated (J/UJ)
Field Duplicate	Duplicate Error Ratio $\leq 1$	Comment in the data validation report.
Balance of Total to Partial Analyses	$\pm 30\%$ (Aqueous) $\pm 50\%$ (Solid)	Qualify total and partial results as estimated (J/UJ).
Standard Error	< 50%	Qualify all associated results as estimated (J/UJ).
Standard Uncertainty	> 50%	For sample batches whose standard uncertainty is > 50%, each sample in the batch will be qualified as estimated (J)

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