APPENDIX B

ENVIRONMENTAL PROTECTION AGENCY
ANNUAL WATER SAMPLING AND ANALYSIS
CALENDAR YEARS 2005-2006

Department of Energy
Washington, DC 20585

August 13, 2007

James W. Hix
5550 Marshall Street
Arvada, CO 80002

Re: Freedom of Information Act Request #2007-000146

Dear Mr. Hix:

This is in response to the request for information that you submitted to the Department of Energy (DOE) pursuant to the Freedom of Information Act (FOIA), 5 U.S.C. 552, for copies of the Annual Water Sampling and Analysis for 2005 and 2006 for the Project Rulison Test Site in Garfield County, Colorado.

As a result of our search, the Office of Legacy Management has located two documents that are responsive to your request:

- Annual Water Sampling and Analysis, Calendar Year 2005," dated November 2005
- Annual Water Sampling and Analysis, Calendar Year 2006

These documents are being released to you in their entirety.

You may challenge the adequacy of this search for responsive documents by submitting a written appeal to the Director, Office of Hearings and Appeals, HG-1/L'Enfant Plaza Building, U.S. Department of Energy, 1000 Independence Avenue. SW, Washington, DC 20585-1615. You should submit the appeal within 30 calendar days of receipt of this determination.

The written appeal, including the envelope, must clearly indicate that a Freedom of Information Act appeal is being made. The appeal must contain all the elements required by 10 C.F.R. § 1004.8 to the extent applicable. Judicial review will thereafter be available to you (1) in the District of Columbia, (2) in the district where you reside, (3) in the district where you have your principal place of business, or (4) in the district where the DOE records are located.

I appreciate the opportunity to assist you. If you have any questions, please contact Pamela Watson, (412) 386-5410.

Sincerely,

Michael W. Owen
Director
Office of Legacy Management

Enclosures(s)

cc: Abel Lopez, Director
FOIA/Privacy Act Officer
Office of the Executive Secretariat

Enclosure List

System of Records No. DOE-55, Freedom of Information and Privacy Act Requests for Records

1. Report entitled "Annual Water Sampling and Analysis, Calendar Year 2005," dated November 2005. 32 pages. (F2007-00146)

2. Undated report entitled "Annual Water Sampling and Analysis, Calendar Year 2006." 29 pages. (F2007-00146)

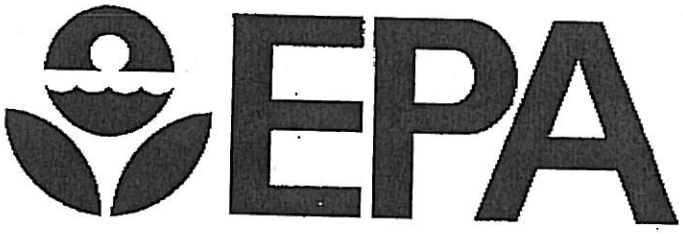
United States Environmental Protection Agency

Office of Radiation and Indoor Air
Washington, DC 20460

EPA-402-R-04-006
November 2005

Annual Water Sampling and Analysis, Calendar Year 2005

SHOAL Test Site Area
FAULTLESS Test Site Area
RULISON Test Site Area
RIO BLANCO Test Site Area
GASBUGGY Test Site Area
GNOME Test Site Area



Annual Water Sampling and Analysis, Calendar Year 2005

SHOAL Test Site Area
FAULTLESS Test Site Area
RULISON Test Site Area
RIO BLANCO Test Site Area
GASBUGGY Test Site Area
GNOME Test Site Area

by
Max G. Davis
Rose (Kitty) Houston

Prepared for the U.S. Department of Energy
under Interagency Agreement
DE-AI08-96NV11969

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NOTICE

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency (EPA) through Interagency Agreement (IAG) DE-AI08-96 NV 11969 from the United States Department of Energy (DOE). This document has been subjected to the Agency's peer and administrative reviews, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

The U. S. Environmental Protection Agency, Radiation and Indoor Environments National Laboratory in Las Vegas, Nevada (R&IE), operates the radiological surveillance program and monitors former nuclear test areas in Alaska, Colorado, Mississippi, Nevada, and New Mexico, each year under the Long Term Hydrological Monitoring Program (LTHMP). The LTHMP is designed to detect residual man-made radionuclides in surface and ground water resulting from underground nuclear test activities. This report describes the sampling and analysis of water samples collected from six former nuclear test sites in three western states during 2005: Projects Shoal and Faultless in Nevada; Projects Rulison and Rio Blanco in Colorado; and Projects Gasbuggy and Gnome in New Mexico. Monitoring results for Alaska and Mississippi are reported separately.

Radiological results for 2005 are consistent with results from previous years. No increase was seen in either tritium concentrations or gamma-ray emitting radionuclides at any site, with the exception of Well HC-3 at the SHOAL Site. A small amount of ^{137}Cs was detected in three samples collected from this well, which is well below the safe drinking water standard of 15pCi/l (See Table 1) Tritium levels at the sites are generally decreasing or stable and are well below the 20,000 pCi/L guideline specified in the National Primary Drinking Water Regulations; Radionuclides; Final Rule (40CFR9/141/142), with the exception of samples from several deep wells adjacent to the nuclear cavity at the Gnome site As in previous years, the highest tritium value recorded for any sample, 3 46 x 10^7 pCi/L, was from, Well DD-1 (Project Gnome).

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CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
Bq/L	Becquerel per liter
^{137}Cs	Cesium-137
^{60}Co	Cobalt-60
CRQA	Center for Radioanalysis and Quality Assurance
DCG	Derived Concentration Guide (20,000 pCi/L for Tritium in Drinking Water)
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
g	gram
^{3}H-	enriched tritium
^{3}H	tritium
HpGe	high purity germanium gamma detector
IAG	Interagency Agreement
ITC	International Technology Corporation
^{131}I	Iodine 131
keV	kilo electron volts (one thousand electron volts)
kg	kilogram, 1000 grams
kT	kiloton (one thousand tons TNT equivalent)
L	liter
LTHMP	Long-Term Hydrological Monitoring Program
m	meter
MCL	maximum contaminant level
MDA	minimum detectable activity
MDC	minimum detectable concentration
MeV	one million electron volts
min	minute
mL	milliliter (one thousandth of a liter)
MT	megaton (one million tons TNT equivalent)
ORIA	Office of Radiation and Indoor Air
pCi/L	picocuries per liter = 10^{-12} curies per liter = 1/1,000,000,000,000 curies per liter
PHS	U.S. Public Health Service
REECo	Reynolds Electrical & Engineering Company
R&IE	Radiation and Indoor Environments National Laboratory, Las Vegas, NV
^{90}Sr	Stronium-90
SGZ	surface ground zero
USGS	U.S. Geological Survey
^{131}Xe	Xenon-131
^{133}Xe	Xenon-133

ACKNOWLEDGMENTS

The external peer review was provided by Vernon Hodge, Ph.D., Chemistry, University of Nevada, Las Vegas. In addition, the authors would like to acknowledge David R. Musick, Director of CRQA, Richard Flotard, Ph.D., and George Dilbeck, Ph.D., as internal reviewers.

1.0 INTRODUCTION

Under an Interagency Agreement with the Department of Energy (DOE), the Radiation & Indoor Environments National Laboratory (R&IE), Office of Radiation and Indoor Air (ORIA), EPA, located in Las Vegas, NV, conducts a Long-Term Hydrological Monitoring Program (LTHMP) to measure radioactivity concentrations in water sources near the sites of former underground nuclear explosions. The results of the LTHMP provide assurance that radioactive materials from the tests have not migrated into drinking water supplies. This report presents the results for the samples collected in February, March, May, and June of 2005, around the following test site areas:

- Project SHOAL Test Site, Churchill County, Nevada
- Project FAULTLESS Test Site, Nye County, Nevada
- Project RULISON Test Site, Garfield County, Colorado
- Project RIO BLANCO Test Site, Rio Blanco County, Colorado
- Project GASBUGGY Test Site, Rio Arriba County, New Mexico
- Project GNOME Test Site, Eddy County, New Mexico

2.0 Sample Analysis

Radiochemical laboratory procedures used to analyze the samples collected for this report are summarized in R&IE's SOPs (see Appendix A and B). These include standard methods to identify natural and man-made gamma-emitting radionuclides, tritium, plutonium, strontium, and uranium in water samples. Two types of tritium analyses were performed; conventional and electrolytic enrichment. The enrichment method lowers the minimum detectable concentration (MDC) from approximately 300 pCi/L to 5 pCi/L. An upper limit of activity of 800 pCi/L has been established for the tritium enrichment method because sample cross contamination becomes a problem at higher levels.

It has been decided by EPA, that a maximum of 25 percent of all samples collected would be analyzed by the low-level enrichment method. This decision was based on the time required for analysis and an assessment of past results. Under the current sampling and analysis protocol for the site, all samples are initially screened for tritium activity by the conventional method, and selected samples are enriched. At this time, only sampling locations that are in a position to show migration are selected for enrichment.

Sufficient sample is collected from new sampling locations to perform all routine analyses, and a full-suite of other radiochemical determinations including assays for strontium, plutonium, and uranium.

Summary of Analytical Procedures

Type of Analysis	Analytical Equipment	Counting Period (Min)	Analytical Procedures	Size of Sample	Approximate Detection Limit[a]
HpGe Gamma[b]	HpGe detector calibrated at 0.5 keV/ channel (0.04 to 2 MeV range) individual detector. Efficiencies ranging from 15 to 35%.	~150	Radionuclide concentration quantified from gamma spectral data by online computer program.	3.5 L	Varies with radionuclides and detector used, if counted to a MDC of approx. 5 pCi/L for ^{137}Cs.
^{3}H	Automatic liquid scintillation counter	300	Sample prepared by distillation.	30 40 mL	300 to 700 pCi/L
^{3}H-Enrichment	Automatic liquid scintillation counter	300	Sample concentrated by electrolysis following distillation	250 mL	5 pCi/L

[a] The detection limit is defined as the smallest amount of radioactivity that can be reliably detected, i.e., probability of Type I and Type II error at 5 percent each (DOE 1981).
[b] Gamma spectrometry using a high purity intrinsic germanium (HpGe) detector.
[c] Sample distilled, then concentrated to ~5 mL by electrolysis.

2.1 Sampling at Project SHOAL, Nevada

History

Project SHOAL, a 12-kT nuclear test emplaced at 365 m (1200 ft), was conducted on October 26, 1963, in a sparsely populated area near Frenchman Station, Nevada, 28 miles southeast of Fallon, Nevada. The test, a part of the Vela Uniform Program, was designed to investigate detection of a nuclear detonation in an active earthquake zone. The working point was in granite and no surface crater was created. The effluent released during drillback was detected onsite only and consisted of 110 curies of ^{131}Xe and ^{133}Xe, and less than 1.0 curie of ^{131}I.

2.1.1 Sample Collection

Samples were collected on February 14-17, 2005. The sampling locations are shown in Figure 1. All of the locations were sampled with the exception of Well H-3. The pump was inoperable. The routine sampling locations included one spring, two windmills, and eleven wells of varying depths. At least one location, Well HS-1, should intercept radioactivity migrating from the test cavity, if it should occur (Chapman and Hokett 1991). Well HC-3 was sampled in February 2005. A small amount of ^{137}Cs was detected. It was suspected that cross contamination might have occurred. In July 2005, the well was sampled a second time, all sampling equipment to be used was decontaminated in accordance with the SOP CER-804. After analysis was completed, detectable amount of ^{137}Cs still existed. Once again the sampling cable, tools, and all equipment was decontaminated in accordance with the outlined procedure. It was then decided that a third sampling would take place. New sampling equipment, barrels, and collection containers were cleaned prior to use. Analysis determined once again small amounts of ^{137}Cs still existed. These results are below the safe drinking water standards of 15pCi/L of ^{137}Cs. In February 2006, this well will be investigated further and re-sampled. A full set of chemistry will be performed.

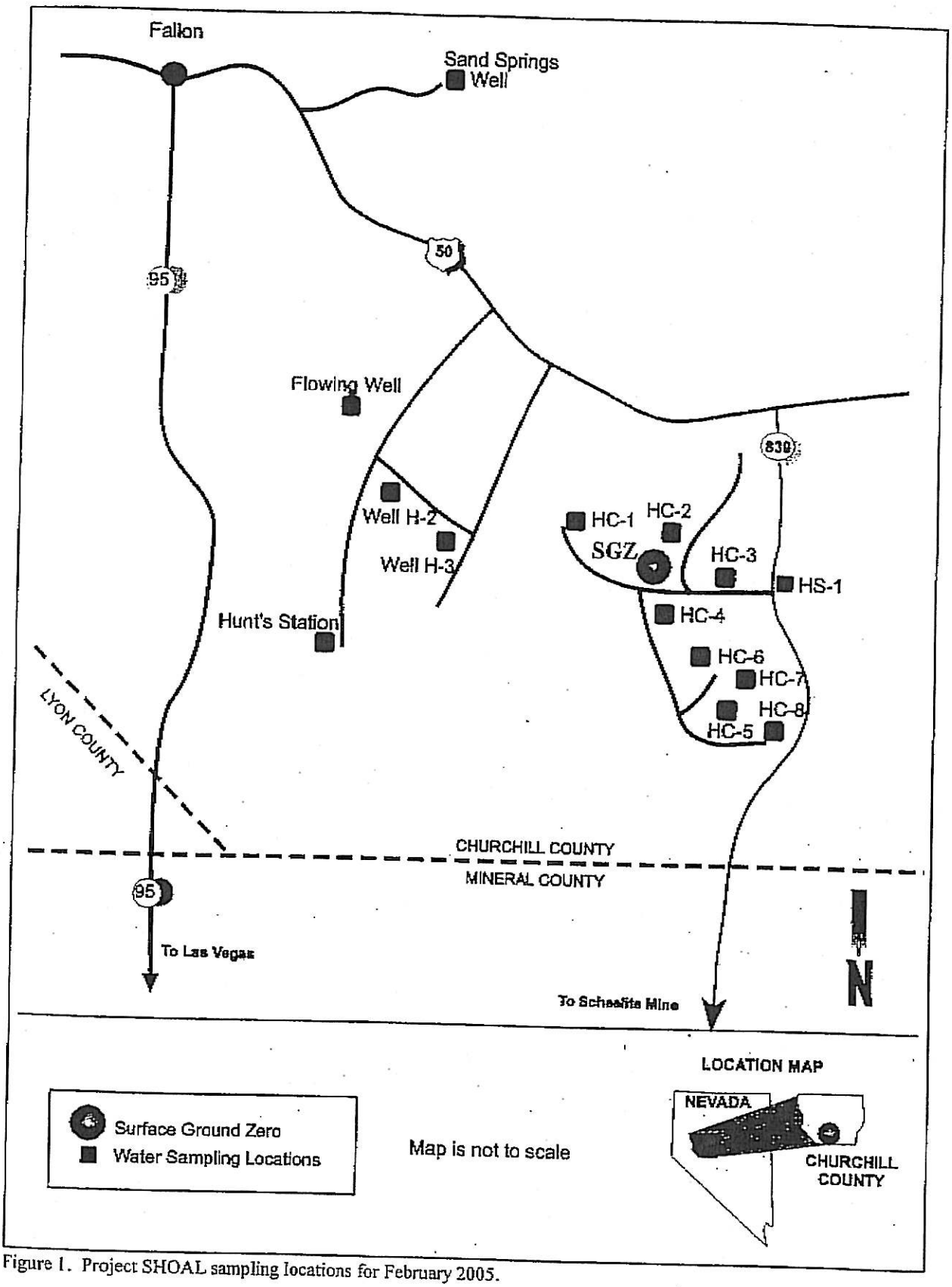

Figure 1. Project SHOAL sampling locations for February 2005.

2.1.2 Water Analysis Results

Gamma-ray spectral analysis results indicated that ^{137}Cs was detected in Well HC-3. Tritium concentrations at all locations except for two were below the MDC. The only sampling locations that had a tritium concentration above the MDC was Well HC-4 of 26 ± 7 pCi/L and Well HC-3 of 11 ± 5.6 (see Table 1, below).

2.1.3 Conclusions

No radioactive materials attributable to the SHOAL nuclear test were detected in samples collected in the offsite area during 2005.

Analysis Results for Water Samples Collected at the SHOAL Site - February 2005

TABLE 1

Sample Location	Collection Date	Enriched Tritium pCi/L ± 2 SD	(MDC)	Tritium[b] pCi/L ± 2 SD	(MDC)	Gamma Spectrometry[c] pCi/L	(MDC)
Hunts Station	2/15/05			80 ± 160[a]	(261)	ND	(4.9)
Flowing Spring	2/15/05			63 ± 160[a]	(261)	ND	(5.0)
Spring Windmill	2/14/05	4.0 ± 6.0[a]	(9.8)			ND	(5.0)
Well H-2	2/15/05			74 ± 160[a]	(261)	ND	(5.0)
Well H-3	2/15/05					Pump inoperable	
Well HS-1	2/14/05	-.55± 6.0[a]	(9.7)			ND	(4.9)
Well HC-1	2/15/05			34 ± 159[a]	(261)	ND	(4.9)
Well HC-2	2/15/05	-4.6± 7.0[a]	(11)			ND	(4.9)
Well HC-4	2/17/05	26 ± 7	(10)			ND	(3.8)
Well HC-5	2/17/05			-17.0±158[a]	(261)	ND	(4.9)
Well HC-6	2/17/05			131±161[a]	(261)	ND	(5.0)
Well HC-7	2/17/05			131 ± 161[a]	(261)	ND	(4.8)
Well HC-8	2/15/05			-11 ± 158[a]	(261)	ND	(5.0)
HC-3 Filter	2/16/05					Cs-137	(8.6)
Well HC-3	2/16/05			-11.0±158[a]	(261)	4.7±2.3	(1.9)
Well HC-3	7/20/05	11±5.6	(8.8)			7.5±2.1	(1.9)
Well HC-3	8/17/05					5.0±2.0	(2.0)

(a) Indicate results are less than MDC (enriched or conventional method).
(b) Value in parenthesis represents ^{137}Cs MDC (pCi/L).
ND Non-detected.
MDC Minimum detectable concentration.

2.2 Sampling at Project FAULTLESS, Nevada

History

Project FAULTLESS was a "calibration test" conducted on January 19, 1968, in a sparsely populated area near Blue Jay Maintenance Station, Nevada. The test had a yield of less than 1 MT and was designed to test the behavior of seismic waves and to determine the usefulness of the site for high-yield tests. The emplacement depth was 975 m (3,200 ft). A surface crater was formed, but as an irregular block along local faults rather than as a saucer-shaped depression. The area is characterized by basin and range topography, with alluvium overlying tuffaceous sediments. The working point of the test was in tuff. The groundwater flow is generally from the highlands to the valley and through the valley to Twin Springs Ranch and Railroad Valley (Chapman and Hokett, 1991).

2.2.1 Sample Collection

Sampling was conducted on March 14-16, 2005. Sampling locations are shown in Figure 2. They include two springs and seven wells of varying depths. All sampling locations were collected.

At least two wells (HTH-1 and HTH-2) are positioned to intercept migration from the test cavity, should it occur (Chapman and Hokett, 1991). All samples yielded negligible gamma activity. These results were all consistent with results obtained in previous years. The consistently below-MDC results for tritium indicate that, to date, migration into the sampled wells has not taken place and no event-related radioactivity has entered area drinking water supplies.

2.2.2 Water Analysis Results

All gamma-ray spectral analysis results indicated that no man-made gamma-ray emitting radionuclides were present above MDC. Tritium concentrations at all the locations were below the MDC.

2.2.3 Conclusions

Tritium concentrations in water samples collected onsite and offsite are consistent with those of past studies at the FAULTLESS site. No radioactive materials attributable to the FAULTLESS test were detected in samples collected in the offsite areas. All samples were analyzed for the presence of gamma-ray emitting radionuclides.

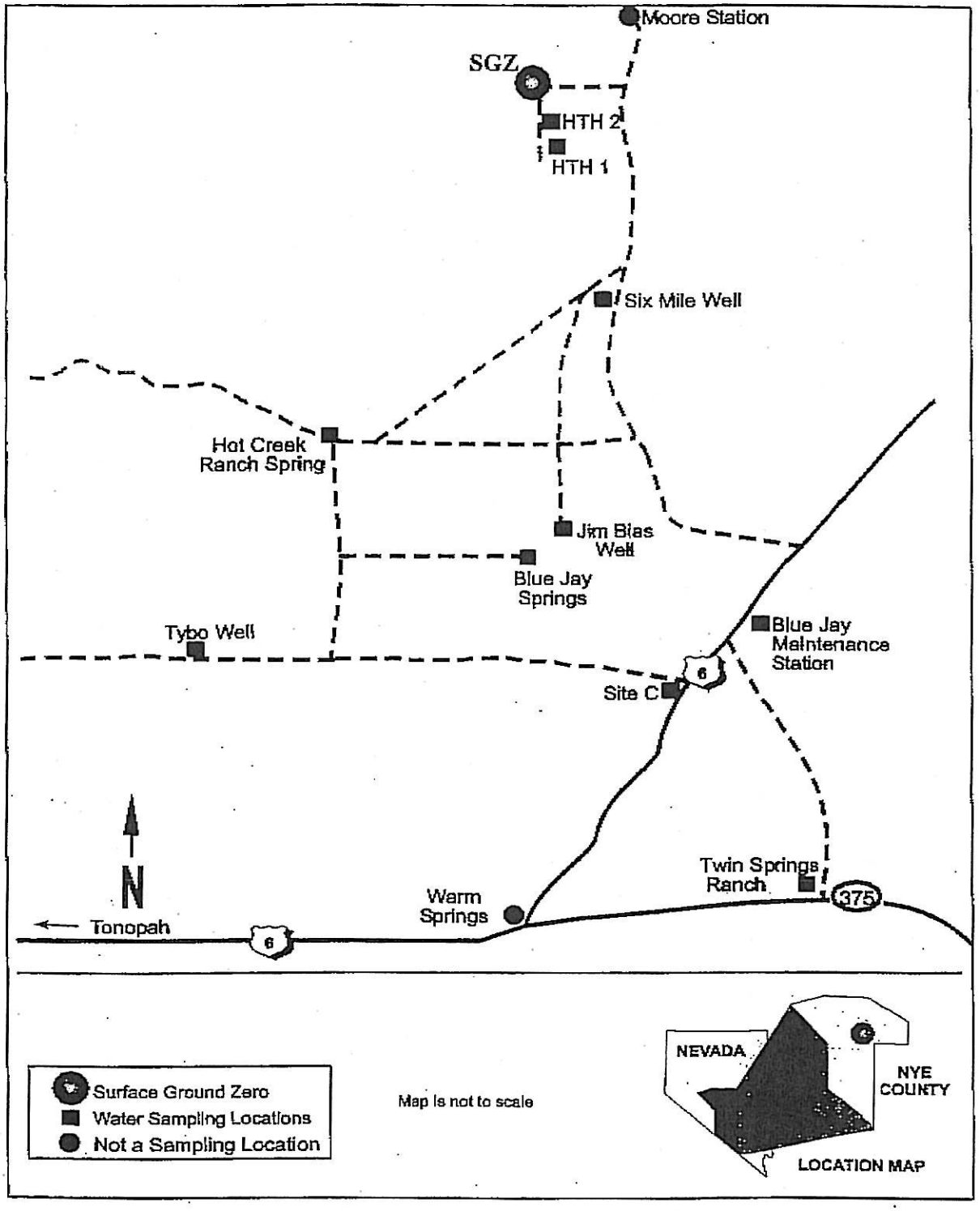

Figure 2. Project FAULTLESS sampling locations for March 2005.

Analysis Results for Water Samples Collected at the FAULTLESS Site - March 2005.

TABLE 2

Sample Location	Collection Date	Enriched Tritium[a] pCi/L ± 2 SD (MDC)	Tritium[a] pCi/L ± 2 SD (MDC)	Gamma Spectrometry[b] pCi/L (MDC)
Hot Creek Ranch	3/16/05	3.8 ± 5.4[a] (8.7)		ND (5.0)
Blue Jay Springs	3/16/05		-17.0± 165[a] (272)	ND (4.9)
Blue Jay Maint Station	3/15/05		17.0 ± 166[a] (272)	ND (4.8)
Well HTH-1	3/15/05	5.9 ± 5.4[a] (8.7)		ND (5.0)
Well HTH-2	3/23/05		96.0± 167[a] (272)	ND (1.5)
Site C Base Camp	3/15/05		-91 ± 163[a] (272)	ND (4.9)
Six Mile Well	3/16/05		-51.0±164[a] (272)	ND (5.0)
Tybo Well	3/16/05		-17.0± 165[a] (272)	ND (4.7)
Twin Springs Ranch	3/14/05	2.2± 5.8[a] (9.6)		ND (5.0)

(a) Indicate results are less than MDC (enriched or conventional method).
(b) Value in parenthesis represents ^{137}Cs MDC (pCi/L).
ND Non-detected.
MDC Minimum detectable concentration.

2.3 Sampling at Project RULISON, Colorado

History

Co-sponsored by the U.S. Atomic Energy Commission (AEC) and Australia Oil Company under the Plowshare Program, Project RULISON was designed to stimulate natural gas recovery in the Mesa Verde formation. The test, conducted near Grand Valley, Colorado, on September 10, 1969, consisted of a 40-kT nuclear explosive emplaced at a depth of 2,568 m (8,425 ft). Production testing began in 1970 and was completed in April 1971. Cleanup was initiated in 1972, and the wells were plugged in 1976. Some surface contamination resulted from decontamination of drilling equipment and fallout from gas flaring. Contaminated soil was removed during the cleanup operations.

2.3.1 Sample Collection

Sampling was conducted on May 11, 2005, from all sampling locations at Grand Valley and Rulison, Colorado. Routine sampling locations are shown in Figure 3. Sampling included the Grand Valley municipal drinking water supply springs, water supply wells for six local ranches, and two sites in the vicinity of surface ground zero (SGZ), including one test well and two surface-discharge springs.

2.3.2 Water Analysis Results

Tritium has never been observed in measurable concentrations in the Grand Valley City Springs. All of the remaining sampling sites show detectable levels of tritium, which have generally exhibited a stable or decreasing trend over the last two decades. The range of tritium activity in 2005, was from 26 ± 7 pCi/L at the spring 500ft east of GZ to 35 ± 6 pCi/L at Tim Jacobs Ranch (see Table 3). All enriched values were less than 0.25 percent of the DCG (20,000 pCi/L). The detectable tritium activities are consistent with values found in current precipitation and, perhaps, a small residual componen remaining from clean-up activities at the site. This is supported by Desert Research Institute analysis, which indicates that most of the sampling locations at the RULISON site are shallow, drawing water from the surficial aquifer, and therefore, unlikely to become contaminated by radionuclide migration from the Project RULISON cavity (Chapman and Hokett 1991).

Analysis Results for Water Samples Collected at the RULISON Site - May 2005

TABLE 3

Sample Location	Collection Date	Enriched Tritium pCi/L ± 2 SD (MDC)	Tritium[a] pCi/L ± 2 SD (MDC)	Gamma Spectrometry[b] pCi/L (MDC)
Battlement Creek	5/11/05		-64 ± 171[a] (284)	ND (4.9)
City Springs	5/11/05		47 ± 173[a] (284)	ND (4.7)
Daniel Gardner	5/11/05		-29 ± 172[a] (284)	ND (4.4)
CER Test Well	5/11/05		5.8 ± 172[a] (284)	ND (5.0)
CER Test Well R	5/11/05		88 ± 174[a] (284)	ND (5.0)
Patrick McCarty	5/11/05		53 ± 174[a] (284)	ND (4.9)
Potter Ranch	5/11/05		-99± 170[a] (284)	ND (4.9)
Morressiana Rch	5/11/05		82 ± 174[a] (284)	ND (4.5)
Tim Jacobs	5/11/05	35 ± 5.7 (8.4)		ND (1.9)
Kevin Whelan	5/11/05	26 ± 5.8 (9.0)		ND (4.9)
Spring 300 yds N. of GZ	5/11/05		53 ± 174[a] (284)	ND (4.7)
Spring 500 ft E. of GZ (Casey Weldon)	5/11/05	26 ± 7.1 (11)		ND (4.3)

(a) Indicate results are less than MDC (enriched or conventional method).
(b) Value in parenthesis represents ^{137}Cs MDC (pCi/L).
ND Non-detected.
MDC Minimum detectable concentration.
R Rinse sample

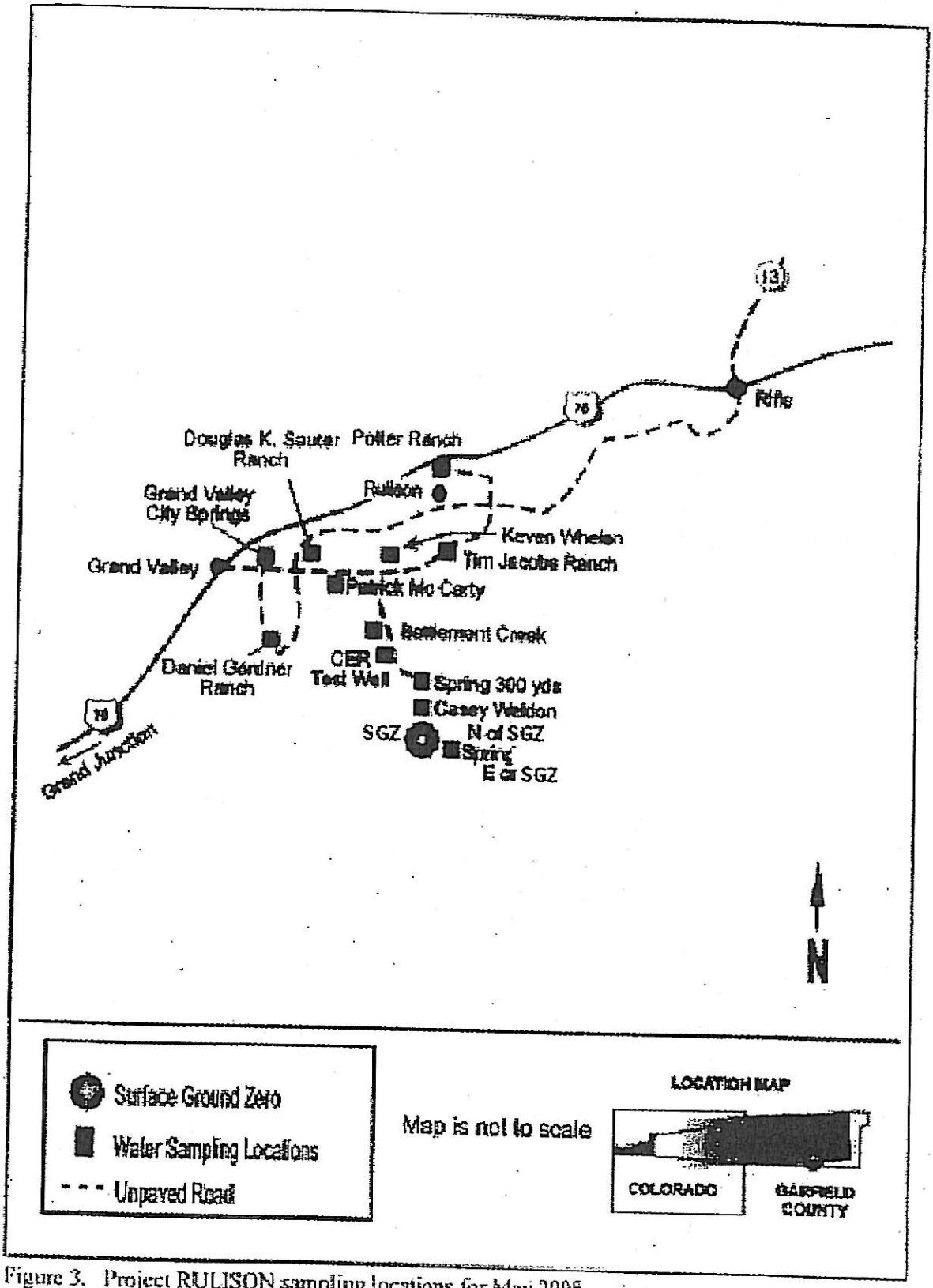

Figure 3. Project RULISON sampling locations for May 2005.

2.3.3 Conclusions

Tritium concentrations in water samples collected onsite and offsite are consistent with those of past studies at the RULISON Test Site. In general, the current level of tritium in shallow wells at the RULISON 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. All routine samples were analyzed for presence of gamma-ray emitting radionuclides.

2.4 Sampling at Project RIO BLANCO, Colorado

History

Project RIO BLANCO, a joint government-industry test designed to stimulate natural gas flow, was conducted under the Plowshare Program. The test was conducted on May 17, 1973, at a location between Rifle and Meeker, Colorado. Three explosives with a total yield of 99 kT were emplaced at 1,780, 1,920, and 2,040 m (5,840, 6,299, and 6,693 ft) depths in the Ft. Union and Mesa Verde formations. Production testing continued until 1976 when cleanup and restoration activities were completed. Tritiated water produced during testing was injected to 1,710 m (5,610 ft) in a nearby gas well.

2.4.1 Sample Collection

Sampling was conducted on May 12-13, 2005, and locations are shown in Figure 4. The routine sampling locations included four springs, four surface, and five wells, three of which are located near the cavity. At least two of the wells (Wells RB-D-01 and RB-D-03) are suitable for monitoring because they were down gradient and would indicate possible migration of radioactivity from the cavity.

2.4.2 Water Analysis Results

Gamma-ray spectral analysis results indicated that no man-made gamma-ray emitting radionuclides were present in any offsite samples. Three of the 15 samples collected were above the MDC for enriched tritium and none were above the MDC using the conventional method (see Table 4, page 12).

2.4.3 Conclusions

Tritium concentrations in water samples collected onsite and offsite are consistent with those of past studies at the RIO BLANCO Site. No radioactive materials attributable to the RIO BLANCO test were detected in samples collected in the offsite areas during May 2005. All samples were analyzed for presence of gamma-ray emitting radionuclides.

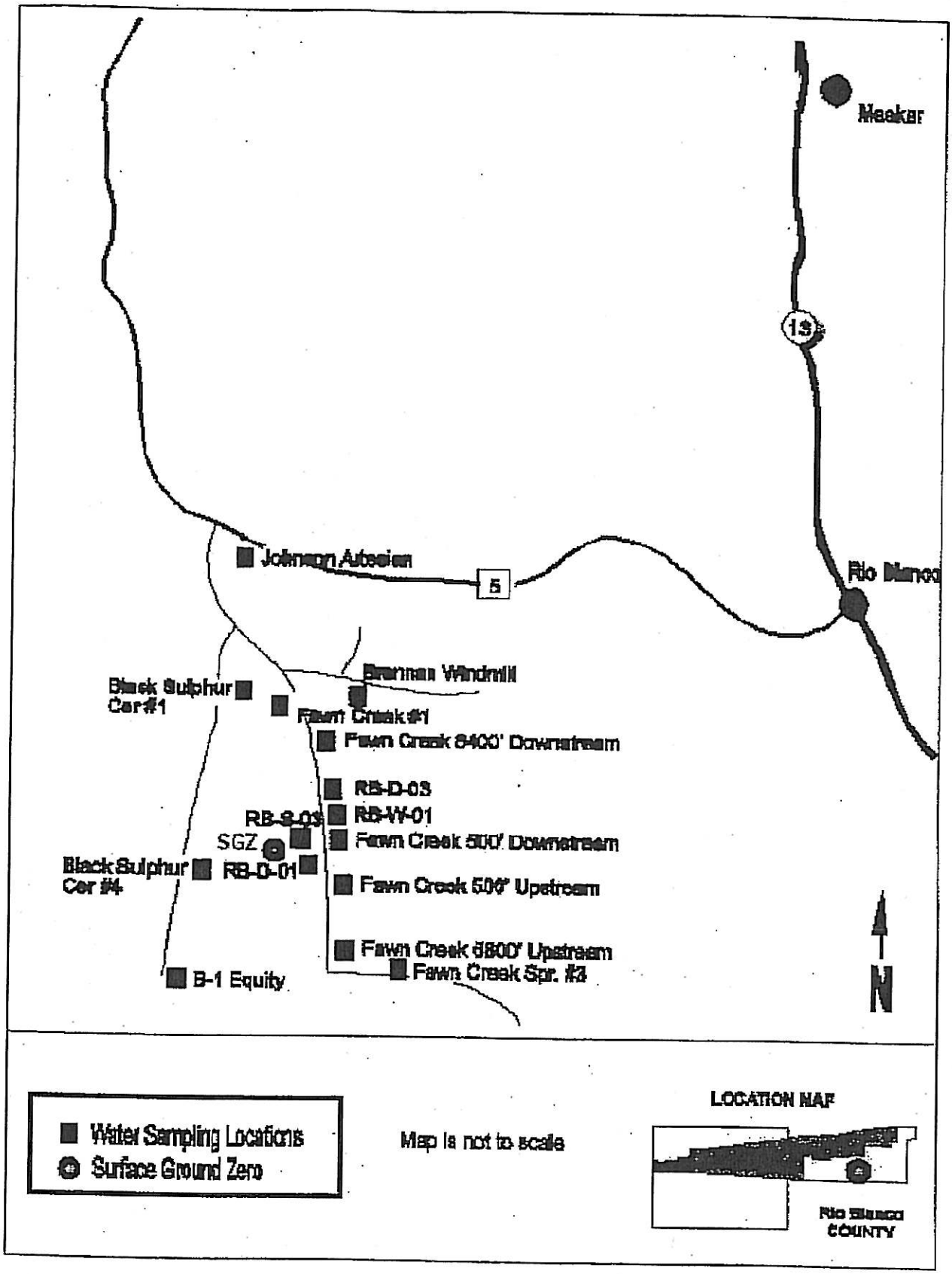

Figure 4. Project RIO BLANCO sampling locations for May 2005.

Analysis Results for Water Samples Collected at the RIO BLANCO Site - May 2005

TABLE 4

Sample Location	Collection Date	Enriched Tritium pCi/L ± 2 SD (MDC)	Tritium[a] pCi/L ± 2 SD (MDC)	Gamma Spectrometry[b] pCi/L (MDC)
B-1 Equity Camp	5/13/05	21 ± 7.1 (11)		ND (5.0)
Brennan Windmill	5/12/05		-38 ± 185[a] (305)	ND (4.7)
CER #1 Black Sulphur	5/13/05		38 ± 186[a] (305)	ND (4.6)
CER #4 Black Sulphur	5/13/05		-95 ± 184[a] (305)	ND (4.4)
Fawn Creek #1	5/12/05		105 ± 187[a] (305)	ND (4.9)
Fawn Creek #3	5/12/05		52 ± 186[a] (305)	ND (4.8)
Fawn Creek 500' Upstream	5/12/05		114 ± 187[a] (305)	ND (4.4)
Fawn Creek 6800' Upstream	5/12/05		109 ± 187[a] (305)	ND (4.2)
Fawn Creek 500' Downstream	5/12/05		66 ± 186[a] (305)	ND (4.3)
Fawn Creek 8400' Downstream	5/12/05	27 ± 6.4 (9.8)		ND (5.0)
Johnson Artesian Well	5/12/05		43 ± 186[a] (305)	ND (4.8)
Well RB-D-01	5/12/05	10 ± 6.0 (9.5)		ND (4.0)
Well RB-D-03	5/12/05	-.53 ±5.7[a] (9.5)		ND (4.7)
Well RB-S-03	5/12/05		-109 ± 183[a] (305)	ND (4.7)
Well RB-W-01	5/12/05		-81 ± 184[a] (305)	ND (5.0)
Well RB-D-01 R	5/12/05		114 ± 187[a] (305)	
Well RB-S-03 R	5/12/05		62 ± 186[a] (305)	
Well RB-D-03 R	5/12/05		-47 ± 184[a] (305)	
Well RB-W-01 R	5/12/05		100 ± 187[a] (305)	

(a) Indicate results are less than MDC (enriched or conventional method).
(b) Value in parenthesis represents ^{137}Cs MDC (pCi/L).
ND Non-detected.
MDC Minimum detectable concentration
R Rinse sample.

2.5 Sampling at Project GASBUGGY, New Mexico

History

Project GASBUGGY was a Plowshare Program test co-sponsored by the U.S. AEC and El Paso Natural Gas Co., conducted near Gobernador, New Mexico, on December 10, 1967. A nuclear explosive with a 29-kT yield was detonated at a depth of 1,290 m (4,232 ft) to stimulate a low productivity natural gas reservoir. Production testing was completed in 1976 and restoration activities were completed in July 1978.

The principal aquifers near the test site are the Ojo Alamo Sandstone, an aquifer containing non-potable water located above the test cavity, and the San Jose formation and Nacimiento formation

Both surficial aquifers contain potable water. The flow regime of the San Juan Basin is not well known, although it is likely that the Ojo Alamo Sandstone discharges to the San Juan River 50 miles northwest of the Gasbuggy site. Hydrologic gradients in the vicinity are downward, but upward gas migration is possible (Chapman and Hokett, 1991).

2.5.1 Sample Collection

Annual sampling at Project GASBUGGY was completed during June 14-16, 2005. All of the routine sampling locations were collected except for Bubbling Spring which was dry (see Figure 5) and EPNG-10-36 which was plugged in 2003.

2.5.2 Water Analysis Results

Tritium concentrations of water samples collected onsite and offsite are consistent with those of past studies at the GASBUGGY Site.

Well EPNG 10-36 has yielded tritium activities between 100 pCi/L in 2000 to 0.05 ± 4 in 2003. In 2003, Well EPNG 10-36 was plugged due to the severe deterioration of the well casing. DOE will drill several wells in the near future, placed in strategic location designed to intercept migration of radionuclides, if they should occur. The migration mechanism and route are not currently known, although an analysis by Desert Research Institute indicated two feasible routes, one through the Printed Cliffs sandstones, and the other one through the Ojo Alamo sandstone, one of the principal aquifers in the region (Chapman and Hokett, 1991).

Gamma-ray spectral analysis results indicated that no man-made gamma-ray emitting radionuclides were present in any onsite and offsite samples above the MDC. Tritium concentrations at all locations except for three were below the MDC. The sampling locations that had a tritium concentration above the MDC were Cedar Springs of 19 ± 6 pCi/L, LaJara Creek 25 ±6 pCi/L and Well 23 South 17 ±6 pCi/L (see Table 5, page 15).

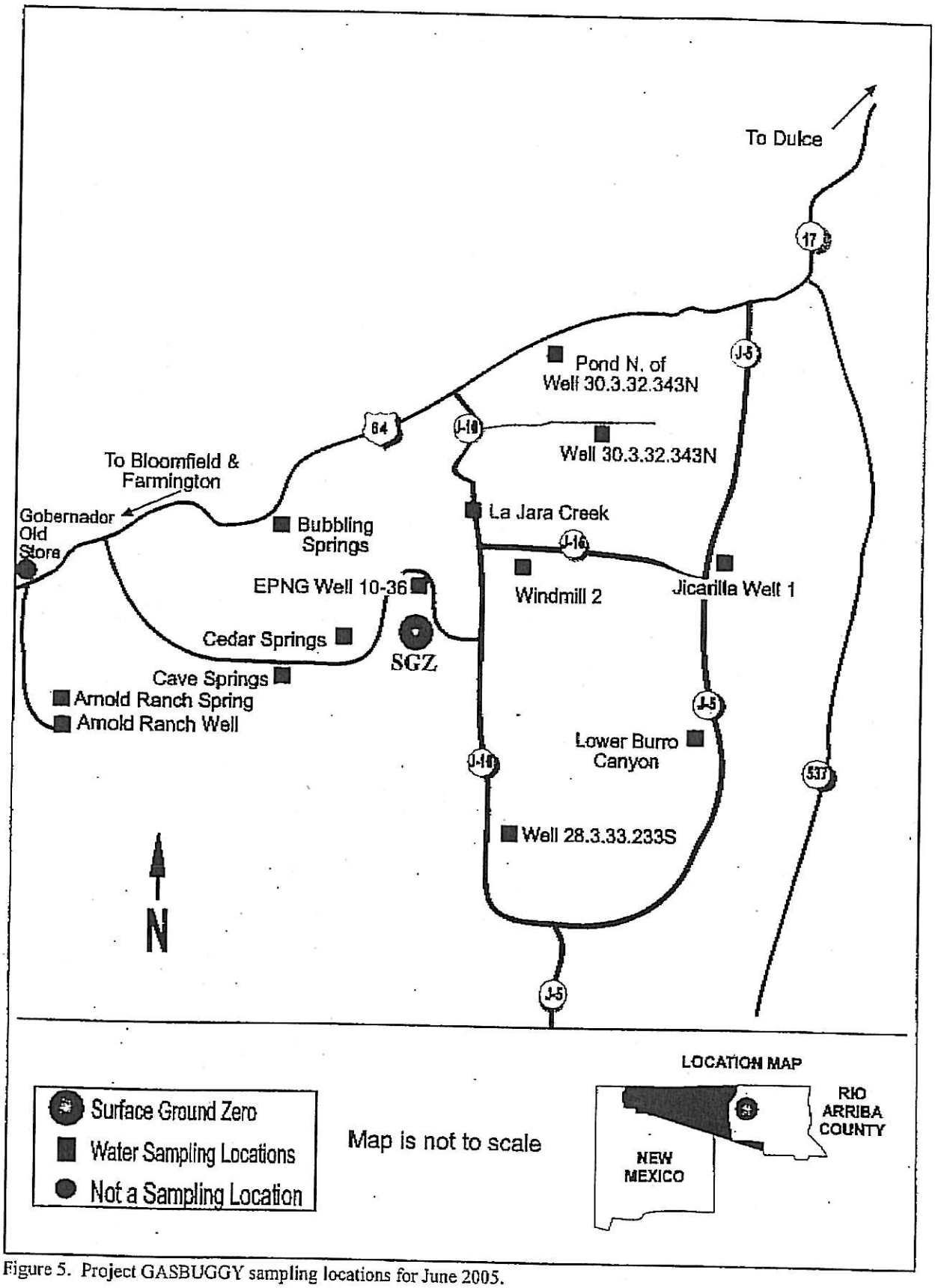

Figure 5. Project GASBUGGY sampling locations for June 2005.

2.5.3 Conclusions

Tritium concentrations of water samples collected onsite and offsite are consistent with those of past studies at the GASBUGGY Site.

Analysis Results for Water Samples Collected at the GASBUGGY Site - June 2005

TABLE 5

Sample Location	Collection Date	Enriched Tritium pCi/L ± 2 SD (MDC)	Tritium[a] pCi/L ± 2 SD (MDC)	Gamma Spectrometry[b] pCi/L (MDC)
Arnold Ranch Spring	6/15/05		38±173[a] (284)	ND (4.9)
Bubbling Springs	6/14/05			No sample, spring dry
Cave Springs	6/15/05	9.5 ±6.7[a] (11)		ND (4.9)
Cedar Springs	6/16/05	19 ±5.8 (9.0)		ND (4.9)
La Jara Creek	6/15/05	25 ±5.8 (8.9)		ND (4.9)
Lower Burro Canyon	6/15/05		-26 ± 172[a] (284)	ND (5.0)
Pond N. of Well 30.3.32.343	6/16/05		32 ± 173[a] (284)	ND (5.0)
Well EPNG-10-36	6/16/05			No Sample Well Plugged
Jicarilla Well 1	6/15/05	5.8 ±5.4[a] (9.0)	-	ND (4.9)
Well 28.3.33.233 (South)	6/15/05	17 ± 6.0 (9.3)		ND (5.0)
Well 30.3.32.343 (North)	6/16/05			No Sample Windmill disconnected
Windmill #2	6/15/05		-21 ± 172[a] (284)	ND (4.8)
Arnold Ranch Well	6/15/05		-85 ± 171[a] (284)	ND (4.7)

(a) Indicate results are less than MDC (enriched or conventional method).
(b) Value in parenthesis represents ^{137}Cs MDC (pCi/L).
ND Non-detected.
MDC Minimum detectable concentration.

2.6 Sampling at Project GNOME, New Mexico

History

Project GNOME, conducted on December 10, 1961, near Carlsbad, New Mexico, was a multipurpose test emplaced at a depth of 370m (1,216 ft) in the Salado salt formation. The explosive yield was slightly-more-than 3-kT. Oil and gas are produced from the geologic units below the working point. The overlying Rustler formation contains three water-bearing zones: brine located at the boundary of the Rustler and Salado formations, the Culebra Dolomite which is used for domestic and stock supplies, and the Magenta Dolomite which is above the zone of saturation (Chapman and Hokett, 1991) The ground water flow is generally to the west and southwest.

Radioactive gases were accidentally vented following the test. In 1963, USGS conducted a tracer study involving injection of 20 Ci tritium, 10 Ci ^{137}Cs, 10 Ci ^{90}Sr, and 4 Ci ^{131}I in the Culebra Dolomite zone; using Wells USGS 4 and 8. During remediation activities in 1968-69, contaminated material was placed in the test cavity and the shaft up to within 7 ft of the surface. More material was slurried into the cavity and drifts in 1979. A potential exists for discharge of this slurry to the Culebra Dolomite and to Rustler-Salado brine. Potentially, this may increase as the salt around the cavity compresses, forcing contamination upward and distorting and cracking the concrete stem and grout.

2.6.1 Sample Collection

Annual sampling at Project GNOME was completed during June 21-23, 2005. The routine sampling sites, depicted in Figure 6, includes ten monitoring wells in the vicinity of surface GZ; the municipal supplies at Loving and Carlsbad, New Mexico.

2.6.2 Water Analysis Results

No tritium activity was detected in the Carlsbad municipal supply or the Loving Station well. An analysis by Desert Research Institute (Chapman and Hokett, 1991) indicates that these sampling locations, which are on the opposite side of the Pecos River from the Project GNOME site, are not connected hydrologically to the site and, therefore, cannot become contaminated by Project GNOME radionuclides.

Tritium results greater than the MDC were detected in water samples from four of the 12 sampling locations in the immediate vicinity of GZ. Tritium activities in wells LRL-7, USGS-4, DD-1 and USGS-8 ranged from 761 ± 183 (LRL-7) to $3.46 \times 10^{7} \pm 1.63 \times 10^{4}$ (DD-1) pCi/L. Well DD-1 collects water from the test cavity; Well LRL-7 collects water from a side drift; and Wells USGS-4 and USGS-8 were used in the radionuclide tracer study conducted by the USGS. None of these wells are sources of potable water (See Table 6).

In addition to tritium, ^{137}Cs and ^{90}Sr concentrations were observed in samples from Wells DD-1, LRL-7, and USGS-8, while ^{90}Sr activity was detected in Well USGS-4 as in previous years (see Table 6). No tritium was detected in the remaining sampling locations, including Well USGS-1, which the DRI analysis (Chapman and Hokett, 1991) indicated is positioned to detect any migration of radioactivity from the cavity. All other tritium results were below the MDC.

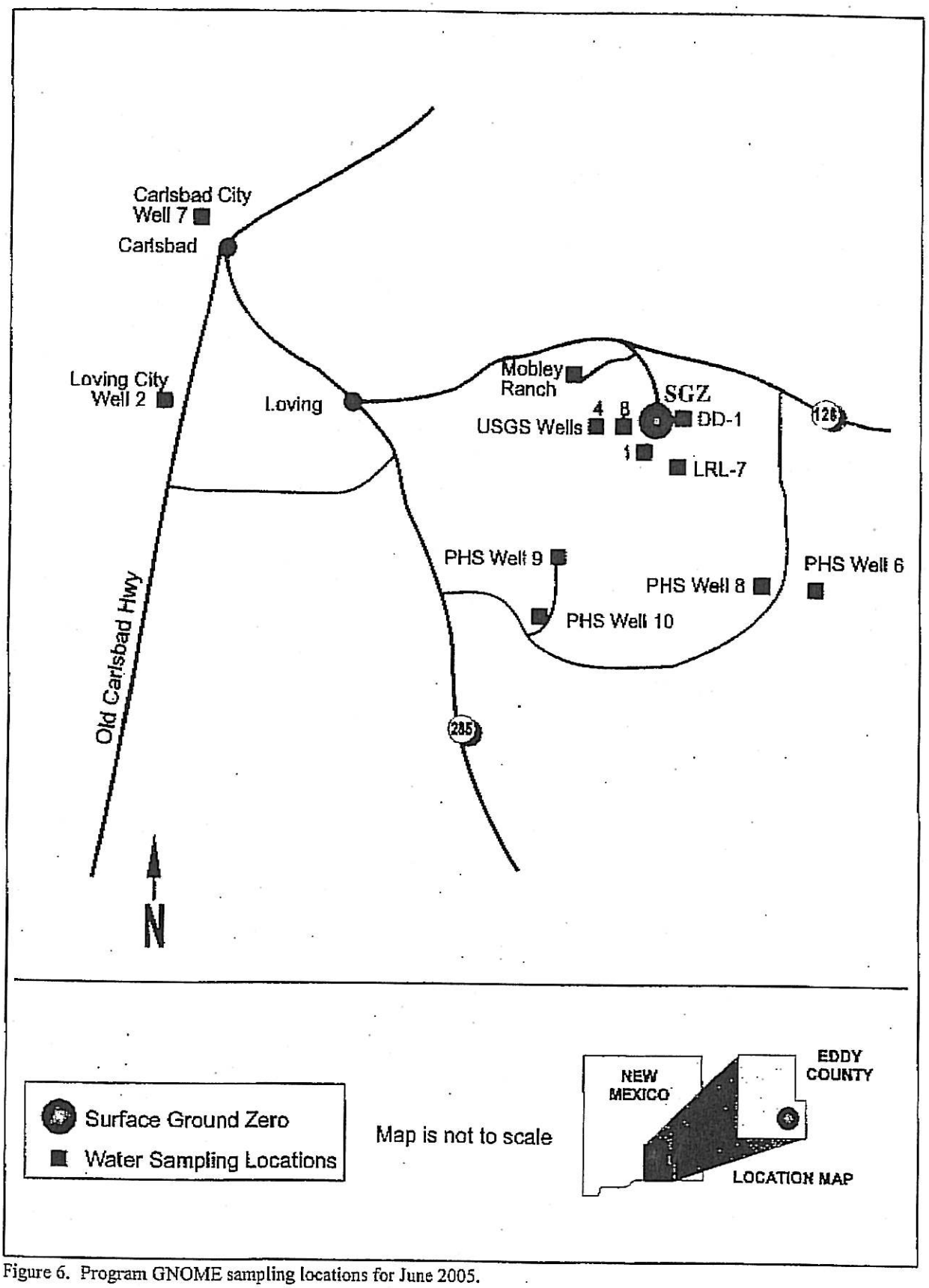

Figure 6. Program GNOME sampling locations for June 2005.

2.6.3 Conclusion

No radioactive materials attributable to the GNOME Test were detected in samples collected in the offsite areas during June of 2005.

Analysis Results for Water Samples Collected at the GNOME Site - June 2005

TABLE 6

Sample Location	Collection Date	Enriched Tritium pCi/L ± 2 SD (MDC)	Tritium pCi/L ± 2 SD (MDC)	Gamma Spectrometry[b] pCi/L (MDC)
Well 7 City	6/22/05	4.5±5.4[a] (8.8)		ND (4.9)
Well 2 City	6/22/05			No sample-well plugged
Well PHS 6	6/22/05		173±170[a] (274)	ND (4.9)
Well PHS 8	6/22/05		121±169[a] (274)	ND (5.0)
Well PHS 9	6/23/05	7.7±6.0[a] (9.7)		ND (4.6)
Well PHS 10	6/23/05		63 ± 168[a] (274)	ND (5.0)
Well USGS 1	6/21/05		5.8 ±167[a] (274)	ND (4.4)
Well USGS 4	6/21/05		$3.12x10^4$±517 (274)	ND (1.7)
Well USGS 8	6/21/05		$3.65x10^4$±555 (274)	89±14 (1.9)
J. Mobley Ranch	6/22/05	10 ± 6.5 (10)		ND (4.7)
Well DD-1	6/23/05		$3.46x10^7$±$1.63x10^6$ (274)	$6.12x10^5$ ±$9.24x10^4$ (3980)
Well LRL-7	6/21/05		761±183[a] (274)	26±4.6 (1.9)
Well DD-1 R	6/23/05		86± 169[a] (274)	
Well USGS 4 R	6/21/05		.00±167[a] (274)	
Well USGS 8 R	6/21/05		110±169[a] (274)	
Well LRL-7 R	6/21/05		-17±166[a] (274)	

(a) Indicate results are less than MDC (enriched or conventional method).
(b) Value in parenthesis represents ^{137}Cs MDC (pCi/L).
ND Non-detected.
MDC Minimum detectable concentration.
R Rinse sample.

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GLOSSARY OF TERMS

Background Radiation

The radiation in man's environment, including cosmic rays and radiation from naturally-occurring and man-made radioactive elements, both outside and inside the bodies of humans and animals. The usually quoted average individual exposure from background radiation is 125 millirem per year in mid-latitudes at sea level.

Curie (Ci)

The basic unit used to describe the rate of radioactive disintegration. The curie is equal to 37 billion disintegrations per second, which is the equivalent of 1 gram of radium. Named for Marie and Pierre Curie who discovered radium in 1898. One microcurie (μCi) is 0.000001 Ci.

Isotope

Atoms of the same element with different numbers of neutrons in the nuclei. Thus ^{12}C, ^{13}C, and ^{14}C are isotopes of the element carbon, the numbers denoting the approximate atomic weights. Isotopes have very nearly the same chemical properties, but have different physical properties (for example ^{12}C and ^{13}C are stable, ^{14}C is radioactive).

Enrichment Method

A method of electrolytic concentration that increases the sensitivity of the analysis of tritium in water. This method is used for selected samples if the tritium concentration is less than 800 pCi/L.

Minimum Detectable Concentration (MDC)

The smallest amount of radioactivity that can be reliably detected with a probability of Type I and Type II errors at 5 percent each (DOE 1981).

Offsite

Areas exclusive of the immediate Test Site Area.

Type I Error

The statistical error of accepting the presence of radioactivity when none is present. Sometimes called alpha error.

Type II Error

The statistical error of failing to recognize the presence of radioactivity when it is present. Sometimes called beta error.

Appendix A

Typical MDC Values for Gamma Spectroscopy
(100 minute count time)

Geometry*	Marinelli	Model	430G
Matrix	Water	Density	1.0 g/ml
Volume	3.5 liter	Units	pCi/L

Isotope	MDC	Isotope	MDC
		Ru-106	4.76E+01
Be-7	4.56E+01	Sn-113	8.32E+00
K-40	4.92E+01	Sb-125	1.65E+01
Cr-51	5.88E+01	I-131	8.28E+00
Mn-54	4.55E+01	Ba-133	9.16E+00
Co-57	9.65E+00	Cs-134	6.12E+00
Co-58	4.71E+00	Cs-137	6.43E+00
Fe-59	1.07E+01	Ce-144	7.59E+01
Co-60	5.38E+00	Eu-152	2.86E+01
Zn-65	1.24E+01	Ra-226	1.58E+01
Nb-95	5.64E+00	U-235	1.01E+02
Zr-95	9.06E+00	Am-241	6.60E+01

Disclaimer
The MDA's provided are for background matrix samples presumed to contain no known analytes and no decay time. All MDA's provided here are for one specific *Germanium detector and the geometry of interest. The MDA's in no way should be used as a source of reference for determining MDA's for any other type of detector. All gamma spectroscopy MDA's will vary with different types of shielding, geometries, counting times and decay time of sample.

Appendix B

Standard Operating Procedures for the Center for Radioanalysis & Quality Assurance

RQA-302	Standard Operating Procedures of Gamma-Ray Detector Systems
RQA-602	Tritium Enrichment Procedure
RQA-603	Standard Operating Procedure for ^{89}Sr and ^{90}Sr in Water, Air Filters and Milk
RQA-604	Standard Operating Procedure of Convention Tritium in Water (Rev. June 7, 2004)
RQA-606	Analysis of Plutonium, Uranium and Thorium in Environmental Samples by Alpha Spectroscopy

Standard Operating Procedures for the Center for Environmental Restoration, Monitoring & Emergency Response

CER-203	Standard Operating Procedure for the Long-Term Hydrological Monitoring Program
CER-804	Sampling Equipment Decontamination Procedures

(2)

Annual Water Sampling and Analysis, Calendar Year 2006

SHOAL Test Site Area
FAULTLESS Test Site Area
RULISON Test Site Area
RIO BLANCO Test Site Area
GASBUGGY Test Site Area
GNOME Test Site Area

by

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Prepared for the U.S. Department of Energy
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ABSTRACT

The U. S. Environmental Protection Agency, Radiation and Indoor Environments National Laboratory in Las Vegas, Nevada (R&IE), operates the radiological surveillance program and monitors former nuclear underground test areas in Alaska, Colorado, Mississippi, Nevada, and New Mexico, each year under the Long Term Hydrological Monitoring Program (LTHMP). The LTHMP is designed to detect residual man-made radionuclides in surface and ground water resulting from underground nuclear test activities. This report describes the sampling and analysis of water samples collected from six former nuclear test sites in three western states during 2006: Projects Shoal and Faultless in Nevada; Projects Rulison and Rio Blanco in Colorado; and Projects Gasbuggy and Gnome in New Mexico. Monitoring results for Alaska and Mississippi are reported separately.

Radiological results for 2006 are consistent with results from previous years. No increase was seen in either tritium concentrations or gamma-ray emitting radionuclides at any site. Tritium levels at the sites are generally decreasing or stable and are well below the 20,000 pCi/L guideline specified in the National Primary Drinking Water Regulations; Radionuclides; Final Rule (40CFR9/141/142), with the exception of samples from several deep wells adjacent to the nuclear cavity at the Gnome site. Three deepest wells at this site Well USGS-#8, Well LRL-#7, and Well DD-#1, were not sampled this year at the recommendation of DOE.

Negative values for tritium

Negative values for tritium are obtained when the counts registered on the liquid scintillation counter for a regular sample are less than the average counts obtained for the fossil water samples used as background samples. The average background counts are deducted from the sample counts to correct for background radiation affecting the detector in the scintillation counter. It is normal to get some negative values for samples with little or no tritium in them, since environmental samples are at background levels.

The incidence of negative results is slightly higher this year than in past years due to a change in the scintillation cocktail used for counting. We are no longer able to use the Beckman Ready Safe scintillation cocktail used in previous years because a change in the formulation has substantially raised the background counts from around 3.5 to 12 counts per minute. The result is an unacceptable near doubling of the detection limit and the 2-sigma error for the samples. All of the replacement scintillation cocktails show a slightly greater variability in counting resulting in more instances where the average background counts exceed the counts for the low activity samples. We are now using EcoLume liquid scintillation cocktail.

All samples were also analyzed for the presence of gamma-ray emitting radionuclides. None were detected above minimum detectable concentration (MDC) see Appendix B, page 21.

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CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
Bq/L	Becquerel per liter
CERMER	Center for Environmental Restoration Monitoring and Emergency Response
CRQA	Center for Radioanalysis and Quality Assurance
DCG	Derived Concentration Guide (20,000 pCi/L for Tritium in Drinking Water)
DOE	U.S. Department of Energy
DRI	Desert Research Institute
EPA	U.S. Environmental Protection Agency
g	gram
^{3}H	tritium
$^{3}H+$	enriched tritium
HpGe	high purity germanium gamma detector
IAG	Interagency Agreement
ITC	International Technology Corporation
^{131}I	Iodine-131
keV	kilo electron volts (one thousand electron volts)
kg	kilogram, 1000 grams
KT	kiloton (one thousand tons TNT equivalent)
L	liter
LTHMP	Long-Term Hydrological Monitoring Program
m	meter
MCL	maximum contaminant level
MDA	minimum detectable activity
MDC	minimum detectable concentration
MeV	one million electron volts
min	minute
mL	milliliter (one thousandth of a liter)
MT	megaton (one million tons TNT equivalent)
ORIA	Office of Radiation and Indoor Air
pCi/L	picocuries per liter = 10^{-12} curies per liter = 1/1,000,000,000,000 curies per liter
PHS	U.S. Public Health Service
REECo	Reynolds Electrical & Engineering Company
R&IE	Radiation and Indoor Environments National Laboratory, Las Vegas, NV.
^{90}Sr	Strontium-90
SGZ	surface ground zero
USGS	U.S. Geological Survey
^{131}Xe	Xenon-131
^{133}Xe	Xenon-133

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1.0 INTRODUCTION

Under an Interagency Agreement with the Department of Energy (DOE), the Radiation & Indoor Environments National Laboratory (R&IE), Office of Radiation and Indoor Air (ORIA), EPA, Las Vegas, NV, conducts a Long-Term Hydrological Monitoring Program (LTHMP) to measure radioactivity concentrations in water sources near the sites of former underground nuclear explosions. The results of the LTHMP provide assurance that radioactive materials from the tests have not migrated into drinking water supplies. This report presents the results for the samples collected in February, March, May, and July of 2006, around the following test site areas:

- Project SHOAL Test Site, Churchill County, Nevada.
- Project FAULTLESS Test Site, Nye County, Nevada.
- Project RULISON Test Site, Garfield County, Colorado.
- Project RIO BLANCO Test Site, Rio Blanco County, Colorado.
- Project GASBUGGY Test Site, Rio Arriba County, New Mexico.
- Project GNOME Test Site, Eddy County, New Mexico.

Summary of Analytical Procedures

Type of Analysis	Analytical Equipment	Counting Period (Min)	Analytical Procedures	Size of Sample	Approximate Detection Limit [a]
HpGe Gamma [b]	HpGe detector calibrated at 0.5 keV/ channel (0.04 to 2 MeV range) individual detector. Efficiencies ranging from 15 to 35%.	~150	Radionuclide concentration quantified from gamma spectral data by online computer program.	3.5 L	Varies with radionuclides and detector used, if counted to a MDC of approx. 5 pCi/L for ^{137}Cs.
^{3}H	Automatic liquid scintillation counter.	300	Sample prepared by distillation.	4 mL	300 pCi/L
^{3}H+ [c]	Automatic liquid Enrichment scintillation counter.	300	Sample concentrated by electrolysis following distillation.	5 mL	5pCi/L

[a] The detection limit is defined as the smallest amount of radioactivity that can be reliably detected, i.e., probability of
[b] Gamma spectrometry using a high purity intrinsic germanium (HpGe) detector.
[c] Sample distilled, and then concentrated to ~5 mL by electrolysis.

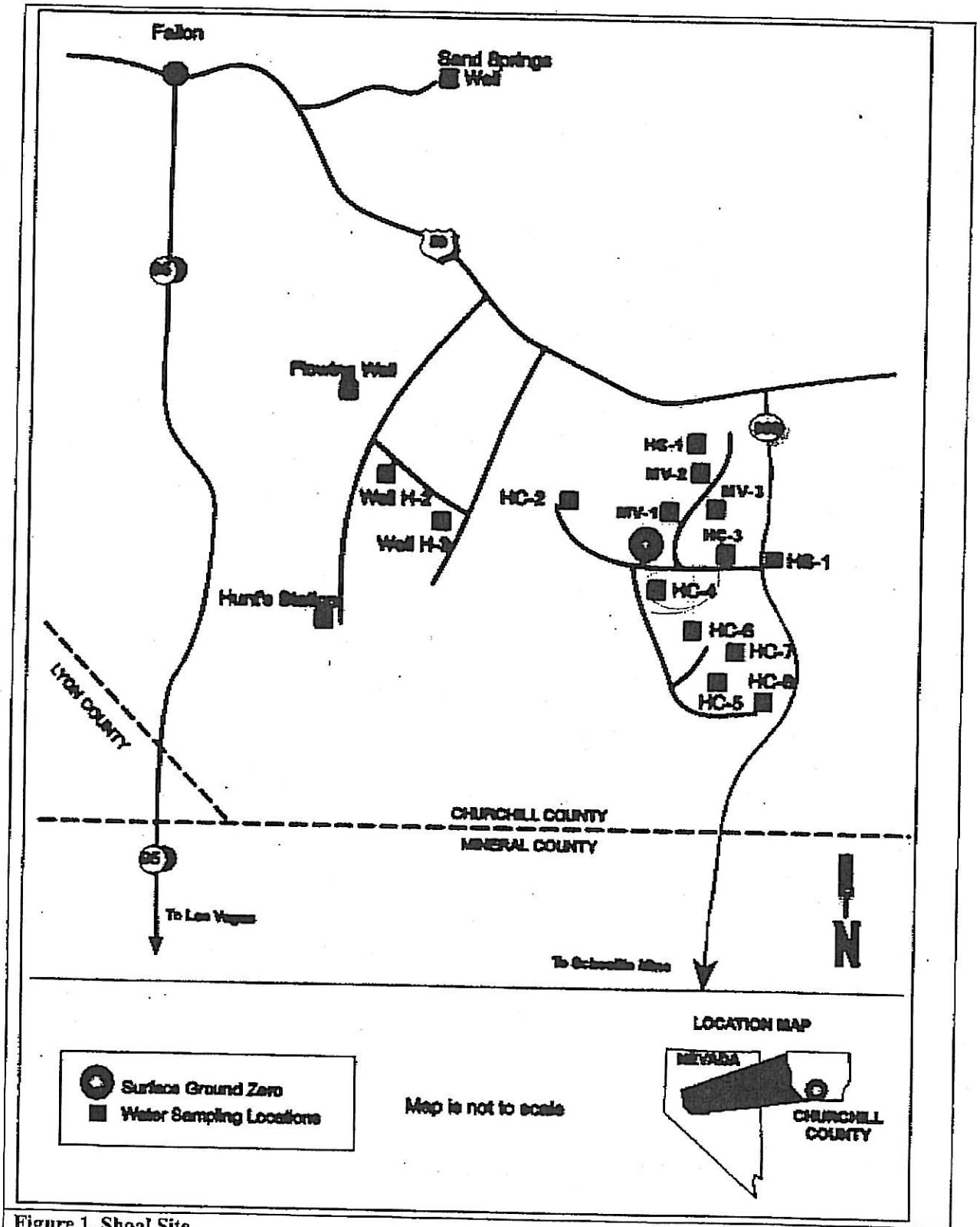

Figure 1. Shoal Site.

2.0 Sample Analysis

Radiochemical laboratory procedures used to analyze the samples collected for this report are summarized in R&IE's SOPs (see Appendix A and B). These include standard methods to identify natural and man-made gamma-emitting radionuclides, tritium, plutonium, strontium, and uranium in water samples. Two types of tritium analyses were performed: conventional and electrolytic enrichment. The enrichment method lowers the MDC from approximately 300 pCi/L to 5 pCi/L. An upper limit of activity of 800 pCi/L has been established for the tritium enrichment method because sample cross contamination in laboratory equipment becomes a problem at higher levels.

It was decided by EPA, that a maximum of 25 percent of all samples collected would be analyzed by the low-level enrichment method. This decision was based on the time required for analysis and an assessment of past results. Under the current sampling and analysis protocol for the sites, all samples are initially screened for tritium activity by the conventional method, and selected samples are enriched. At this time, only sampling locations that are in a position to show migration are selected for enrichment.

Sufficient sample is collected from new sampling locations to perform all routine analyses, and a full-suite of other radiochemical determinations including assays for strontium, plutonium, and uranium.

2.1 Sampling at Project SHOAL, Nevada

History

Project SHOAL, a 12-KT nuclear test emplaced at 365 m (1,204 ft), was conducted on October 26, 1963, in a sparsely populated area near Frenchman Station, Nevada, 28 miles southeast of Fallon, Nevada. The test, a part of the Vela Uniform Program, was designed to investigate detection of a nuclear detonation in an active earthquake zone. The working point was in granite and no surface crater was created. The effluent released during drillback was detected onsite only and consisted of 110 curies of ^{131}Xe and ^{133}Xe, and less than 1.0 curie of ^{131}I.

2.1.1 Sample Collection

Samples were collected on March 13-16, 2006. The sampling locations are shown in Figure 1. All of the locations were sampled with the exception of Well H-3, the pump remains inoperable. The routine sampling locations included one spring, two windmills, and eleven wells of varying depths. At least one location, Well HS-1, should intercept radioactivity migrating from the test cavity, if it should occur (Chapman and Hokett, 1991). Three new monitoring wells have now been completed and are to be added to the LTHMP program. These wells are to be sampled for the first time in 2007. The placement and positioning of these three wells are intended to also intercept radioactivity from the test cavity. Well HC-3 was sampled in March 2006, by the EPA, and an additional sample was collected in July 2006, by the Desert Research Institute (DRI), Reno, NV.

2.1.2 Water Analysis Results

Gamma-ray spectral analysis results indicated that ^{137}Cs was detected in Well HC-3 onsite. The reading for ^{137}Cs was 3.5 ± 1.7 pCi/L, with the MDC of 1.8 pCi/L. Tritium concentrations at all locations were below, the MDC, except for Well HC-4, which had a reading of 266 ± 8.9 pCi/L enriched tritium method. This however, is well below the safe drinking water standards of 20,000 pCi/L for tritium.

Analysis Results for Water Samples Collected at the SHOAL Site - March 2006

TABLE 1

Sample Location	Collection Date	Enriched Tritium		Tritium[a]		Gamma Spectrometry	
		pCi/L ± 2 SD	MDC	pCi/L ± 2 SD	MDC	pCi/L ± 2 SD	MDC
Hunts Station	3/14/06			32 ± 136[a]	(225)	ND	(4.8)
Flowing Spring Well	3/14/06			-18 ± 136[a]	(225)	ND	(5.0)
Spring Windmill Well	3/14/06			4.6 ± 137[a]	(225)	ND	(4.8)
Well H-2	3/14/06			1.8 ± 137[a]	(225)	ND	(4.9)
Well H-3						No sample pump inop.	
Well HS-1	3/13/06			-79 ± 135[a]	(225)	ND	(5.0)
Well HC-1	3/14/06			-69 ± 135[a]	(225)	ND	(4.7)
Well HC-2	3/14/06			42 ± 138[a]	(225)	ND	(4.7)
Well HC-3	3/15/06	21 ± 6.1	(9.5)			3.5 ± 1.7	(1.8)
Well HC-4	3/16/06	266 ± 8.9	(8.9)			ND	(5.0)
Well HC-5	3/16/06			4.2 ± 138[a]	(225)	ND	(5.0)
Well HC-6	3/16/06			147 ± 141[a]	(226)	ND	(5.0)
Well HC-7	3/16/06	5.5 ± 5.0[a]	(8.1)			ND	(4.8)
Well HC-8	3/16/06			50 ± 138[a]	(225)	ND	(4.8)
HC-3 (Filter)	3/15/06					Gamma only	(3.0)

(a) Indicate results are less than MDC (enriched or conventional method).
ND-Non-detected.
MDC-Minimum detectable concentration.

2.1.3 Conclusions

No radioactive materials attributable to the SHOAL nuclear test were detected in samples collected in the offsite areas during 2006. All samples were analyzed for the presence of gamma-ray emitting radionuclides.

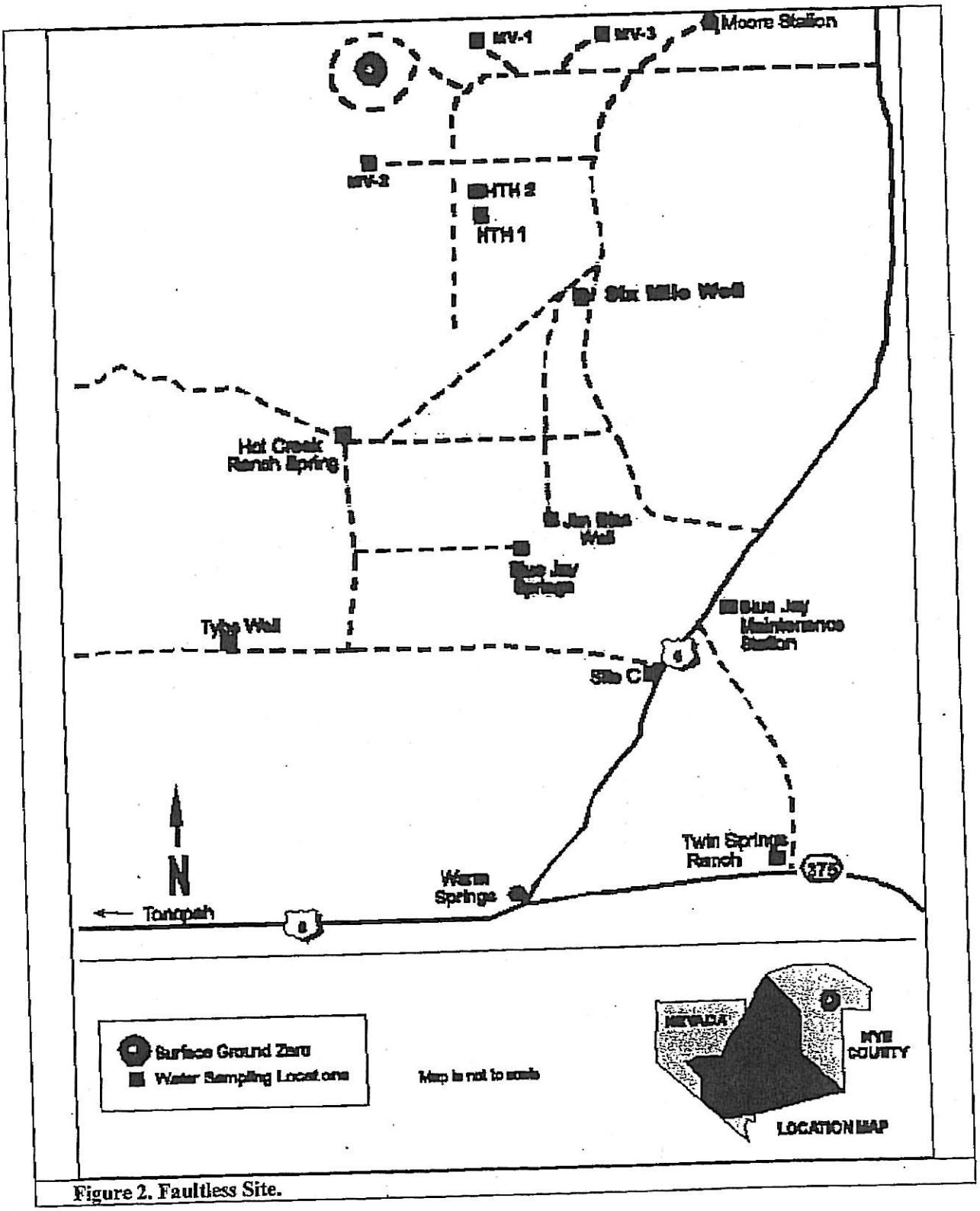

Figure 2. Faultless Site.

2.2 Sampling at Project FAULTLESS, Nevada

History

Project FAULTLESS was a "calibration test" conducted on January 19, 1968, in a sparsely populated area near Blue Jay Maintenance Station, Nevada. The test had a yield of less than 1-MT and was designed to test the behavior of seismic waves and to determine the usefulness of the site for high-yield tests. The emplacement depth was 975 m (3,200 ft). A surface crater was formed, but as an irregular block along local faults rather than as a saucer-shaped depression. The area is characterized by basin and range topography, with alluvium overlying tufaceous sediments. The working point of the test was in tuff. The groundwater flow is generally from the highlands to the valley and through the valley to Twin Springs Ranch and Railroad Valley (Chapman and Hokett, 1991).

2.2.1 Sample Collection

Sampling was conducted on February 13-15, 2006. Sampling locations are shown in Figure 2. It includes two springs and seven wells of varying depths. All sampling locations were collected. The pump in Well HTH-2 has now been replaced allowing the well to be sampled this year.

At least two wells (HTH-1 and HTH-2) are positioned to intercept migration from the test cavity, should it occur (Chapman and Hokett, 1991). Additionally, three new wells have been added to this site and were sampled for the first time during February 2006. These wells are called Monitoring Validation Wells, MV#1, MV#2, MV#3, and are also positioned to intercept any migration. All samples yielded negligible gamma activity. These results were all consistent with results obtained in previous years. The consistently below-MDC results for tritium indicate that, to date, migration into the sampled wells has not taken place and no event-related radioactivity has entered area of drinking water supplies.

2.2.2 Water Analysis Results

All gamma-ray spectral analysis results indicated that no man-made gamma-ray emitting radionuclides were present above MDC. Tritium concentrations at all the locations were below the MDC, well below 20,000 pCi/L safe drinking water standard (see Table 2, page 7).

Analysis Results for Water Samples Collected at the FAULTLESS Site - February 2006

TABLE 2

Sample Location	Collection Date	Enriched Tritium pCi/L ± 2 SD	MDC	Tritium pCi/L ± 2 SD	MDC	Gamma Spectrometry pCi/L	MDC
Hot Creek Ranch	2/15/06			69 ± 166[a]	(271)	ND	(4.9)
Blue Jay Springs	2/15/06			-21 ± 164[a]	(271)	ND	(4.2)
Blue Jay Maintenance Station	2/13/06			52 ± 166[a]	(271)	ND	(4.9)
Well HTH-1	2/14/06	-1.8 ± 5.9[a]	(9.8)			ND	(4.9)
Well HTH-2	2/14/06	-3.6 ± 4.0[a]	(6.8)			ND	(4.6)
Site C Base Camp	2/15/06			-5.5 ± 163[a]	(271)	ND	(4.9)
Six Mile Well	2/15/06			74 ± 166[a]	(271)	ND	(5.0)
Tybo Well	2/15/06			-3.9 ± 165[a]	(271)	ND	(5.0)
Twin Springs Ranch	2/13/06			24 ± 165[a]	(271)	ND	(5.0)
MV- #1 Well	2/14/06	-1.3 ± 4.1[a]	(6.9)			ND	(1.8)
MV- #2 Well	2/14/06	-3.5 ± 5.3[a]	(8.8)			ND	(1.6)
MV-#3 Well	2/14/06	3.4 ± 5.9[a]	(9.8)			ND	(1.9)

(a) Indicate results are less than MDC (enriched or conventional method).
ND-Non-detected.
MDC- Minimum detectable concentration.

2.2.3 Conclusions

Tritium concentrations in water samples collected onsite and offsite are consistent with those of past studies at the FAULTLESS site. No radioactive materials attributable to the FAULTLESS test were detected in samples collected in the offsite areas during 2006. All samples were analyzed for the presence of gamma-ray emitting radionuclides.

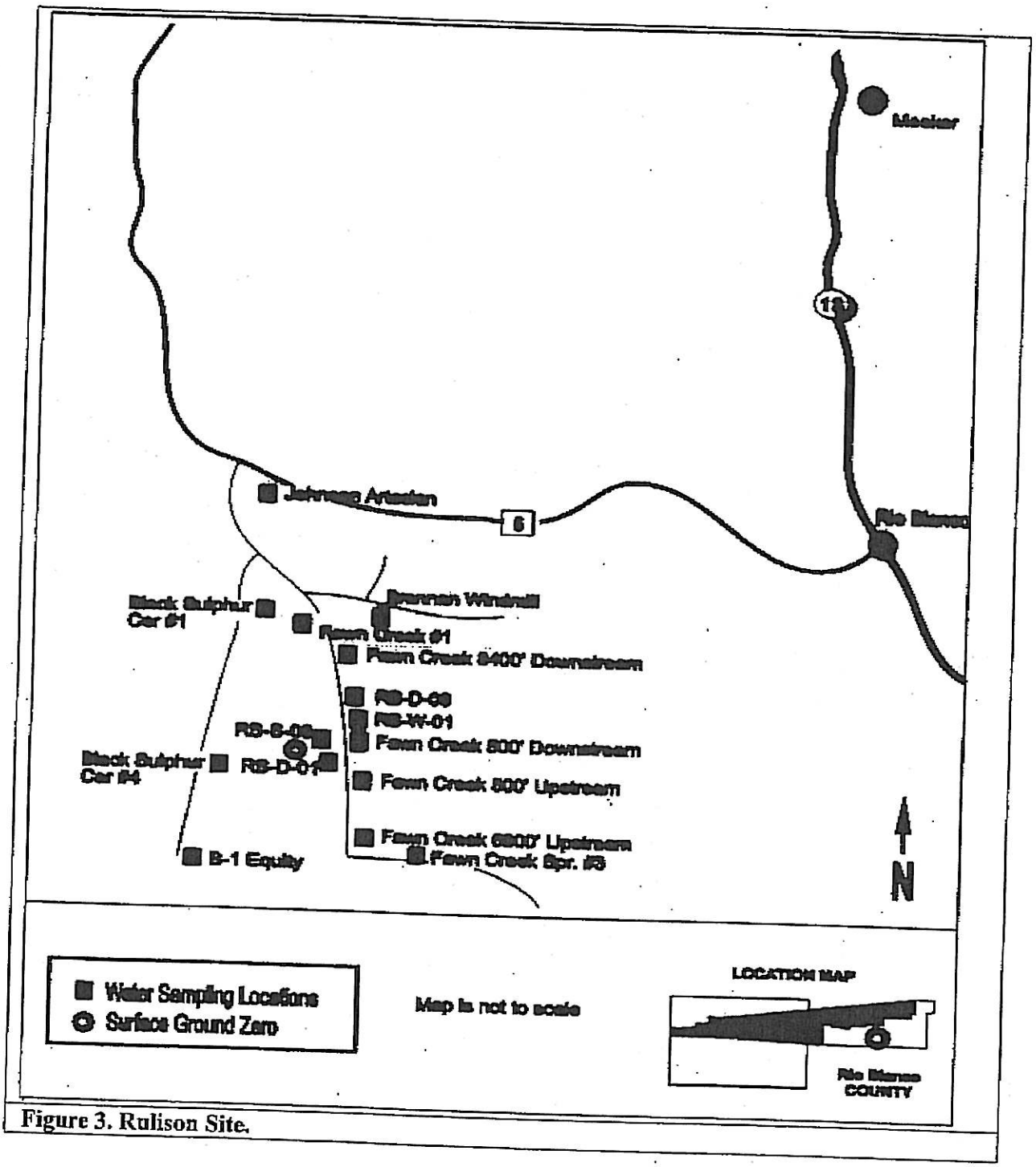

Figure 3. Rulison Site.

2.3 Sampling at Project RULISON, Colorado

History

Co-sponsored by the U.S. Atomic Energy Commission (AEC) and Australia Oil Company under the Plowshare Program, Project RULISON was designed to stimulate natural gas recovery in the Mesa Verde formation. The test, conducted near Grand Valley, Colorado, on September 10, 1969, consisted of a 40-KT nuclear explosive emplaced at a depth of 2,568 m (8,425 ft). Production testing began in 1970 and was completed in April 1971. Cleanup was initiated in 1972, and the wells were plugged in 1976. Some surface contamination resulted from decontamination of drilling equipment and fallout from gas flaring. Contaminated soil was removed during the cleanup operations including one test well and two surface-discharge springs.

2.3.1 Sample Collection

Sampling was conducted on May 10, 2006, from all sampling locations at Grand Valley and Rullson, Colorado. Routine sampling locations are shown in Figure 3. Sampling included the Grand Valley municipal drinking water supply springs, water supply wells for six local ranches, and two sites in the vicinity of surface ground zero (SGZ), including one test well and two surface-discharge springs.

2.3.2 Water Analysis Results

Tritium has never been observed in measurable concentrations in the Grand Valley City Springs. All of the remaining sampling sites show detectable levels of tritium, which have generally exhibited a stable or decreasing trend over the last two decades. The range of tritium activity in 2006, was from 13 ± 5 pCi/L at Spring 300yds North of GZ, to 27 ± 5 pCi/L, at the Potter Ranch (see Table 3). All enriched values were less than 0.14 percent of the DCG (20,000 pCi/L). The detectable tritium activities are consistent with values found in current precipitation and, perhaps, a small residual component remaining from clean-up activities at the site. This is supported by Desert Research Institute (DRI) analysis, which indicates that most of the sampling locations at the RULISON site are shallow, drawing water from the surficial aquifer, and therefore, unlikely to become contaminated by radionuclide migration from the Project RULISON cavity, (Chapman and Hokett, 1991), (see Table 3, page 10).

Analysis Results for Water Samples Collected at the RULISON Site - May 2006
TABLE 3

Sample Location	Collection Date	Enriched Tritium		Tritium		Gamma Spectrometry	
		pCi/L ± 2 SD	MDC	pCi/L ± 2 SD	MDC	pCi/L ± 2 SD	MDC
Battlement Creek	5/10/06	26 ± 5.2	(7.9)			ND	(4.9)
City Springs	5/10/06			94 ± 147 [a]	(239)	ND	(4.3)
Daniel Gardner	5/10/06			94 ± 147 [a]	(239)	ND	(5.0)
CER Test Well	5/10/06			89 ± 147 [a]	(239)	ND	(3.7)
Patrick McCarty	5/10/06			74 ± 147 [a]	(239)	ND	(4.8)
Potter Ranch	5/10/06	27 ± 4.8	(7.9)			ND	(5.0)
Morrisana Orchard	5/10/06			69 ± 147 [a]	(239)	ND	(1.5)
Tim Jacobs	5/10/06			15 ± 147 [a]	(239)	ND	(2.0)
Spring 300yds N. of Ground Zero	5/10/06	13 ± 4.8	(7.7)			ND	(4.8)
Spring 500ft. E. of Ground Zero	5/10/06			15 ± 147 [a]	(239)	ND	(4.8)
K. Whelan Ranch	5/10/06			14 ± 147 [a]	(239)	ND	(4.9)

(a) Indicate results are less than MDC (enriched or conventional method).
ND- Non-detected.
MDC- Minimum detectable concentration.

2.3.3 Conclusions

Tritium concentrations in water samples collected onsite and offsite are consistent with those of past studies at the RULISON Test Site. In general, the current level of tritium in shallow wells at the RULISON 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. No radioactive materials attributable to the Rulison test were detected in samples collected in the offsite areas during 2006. All routine samples were analyzed for presence of gamma-ray emitting radionuclides.

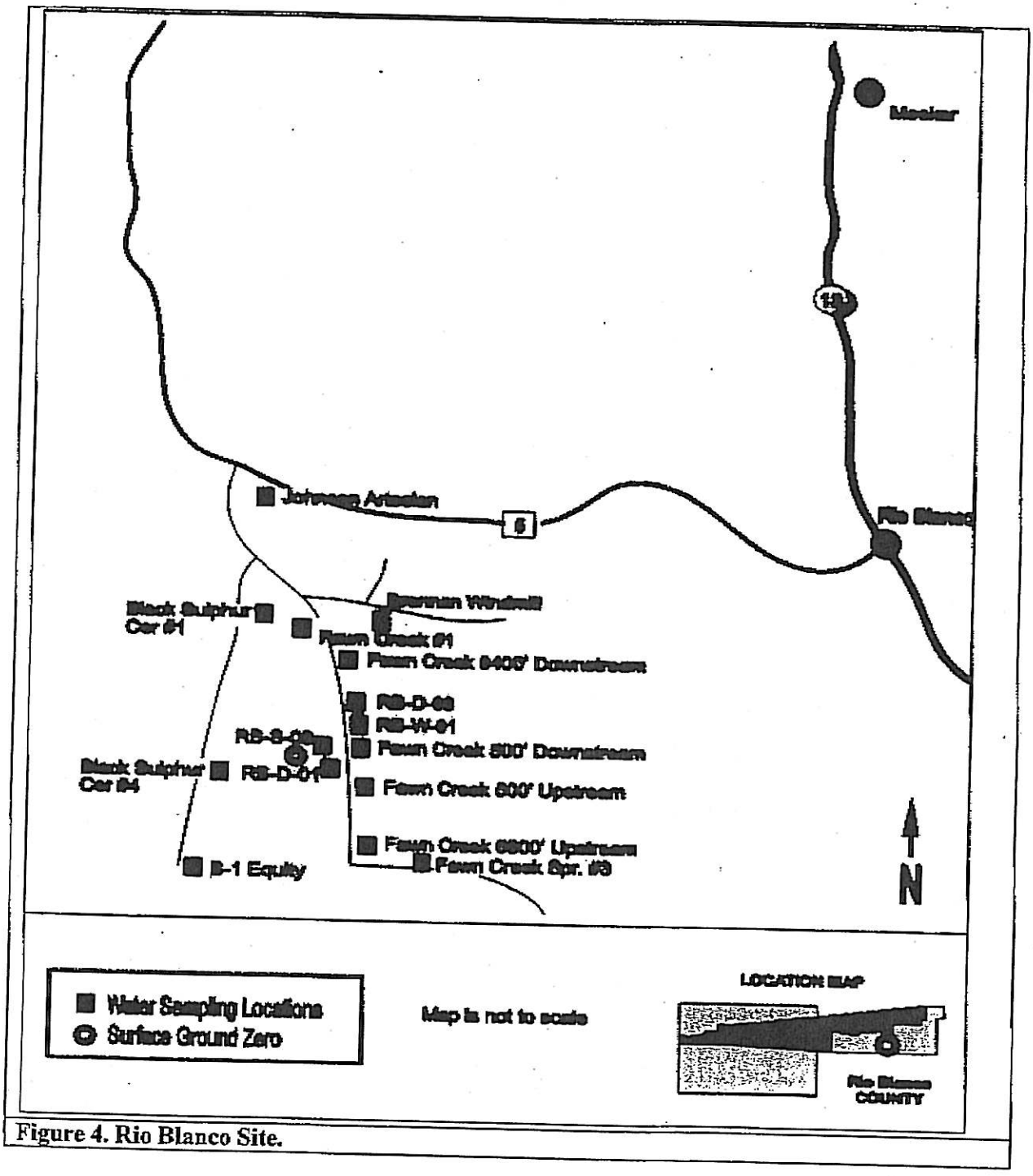

Figure 4. Rio Blanco Site.

2.4 Sampling at Project RIO BLANCO, Colorado

History

Project RIO BLANCO, a joint government-industry test designed to stimulate natural gas flow, was conducted under the Plowshare Program. The test was conducted on May 17, 1973, at a location between Rifle and Meeker, Colorado. Three explosives with a total yield of 99-KT were emplaced at 1,780, 1,920, and 2,040 m (5,840, 6,299, and 6,693 ft) depths in the Ft. Union and Mesa Verde formations. Production testing continued until 1976, when cleanup and restoration activities were completed. Tritiated water produced during testing was injected to 1,710 m (5,610 ft) in a nearby gas well.

2.4.1 Sample Collection

Sampling was conducted on May 11-12, 2006, and locations are shown in Figure 4. The routine sampling locations included four springs, four surface, and five wells, three of which are located near the cavity. At least two of the wells (Wells RB-D-01 and RB-D-03) are suitable for monitoring because they were down gradient and would indicate possible migration of radioactivity from the cavity.

2.4.2 Water Analysis Results

Gamma-ray spectral analysis results indicated that no man-made gamma-ray emitting radionuclides were present in any offsite samples. (see table 4, page 14).

Analysis Results for Water Samples Collected at the RIO BLANCO Site - May 2006

TABLE 4

Sample Location	Collection Date	Enriched Tritium		Tritium[b]		Gamma Spectrometry	
		pCi/L ± 2 SD	MDC	pCi/L ± 2 SD	MDC	pCi/L ± 2 SD	MDC
B-1 Equity Camp	5/12/06			51 ± 133 [a]	(218)	ND	(4.9)
Brennan Windmill	5/12/06			20 ± 133 [a]	(218)	ND	(4.8)
CER #1 Black Sulphur	5/12/06			51 ± 133 [a]	(218)	ND	(4.0)
CER #4 Black Sulphur	5/12/06			125 ± 134 [a]	(218)	ND	(4.8)
Fawn Creek #1	5/11/06			17 ± 132 [a]	(218)	ND	(4.9)
Fawn Creek #3	5/11/06			6.8 ± 132 [a]	(218)	ND	(5.0)
Fawn Creek 500' Upstream	5/11/06			78 ± 133 [a]	(218)	ND	(4.7)
Fawn Creek 6800' Upstream	5/11/06			34 ± 131 [a]	(218)	ND	(5.0)
Fawn Creek 500' Downstream	5/11/06			41± 133 [a]	(218)	ND	(4.7)
Fawn Creek 8400' Downstream	5/11/06			-54 ± 131 [a]	(218)	ND	(4.9)
Johnson Artesian Well	5/11/06			130 ± 133 [a]	(213)	ND	(4.7)
Well RB-D-01	5/11/06	-4.8 ± 4.6[a]	(7.7)			ND	(4.9)
Well RB-D-03	5/12/06			195 ± 133 [a]	(217)	ND	(4.8)
Well RB-S-03	5/11/06	-3.1 ± 5.5[a]	(9.2)			ND	(5.0)
Well RB-W-01	5/12/06	3.9 ± 4.3 [a]	(9.2)			ND	(4.9)

(a) Indicate results are less than MDC (enriched or conventional method).
ND-Non-detected.
MDC-Minimum detectable concentration.

2.4.3 Conclusions

Tritium concentrations in water samples collected onsite and offsite are consistent with those of past studies at the RIO BLANCO Site. No radioactive materials attributable to the RIO BLANCO test were detected in samples collected in the offsite areas during May 2006. All samples were analyzed for presence of gamma-ray emitting radionuclides.

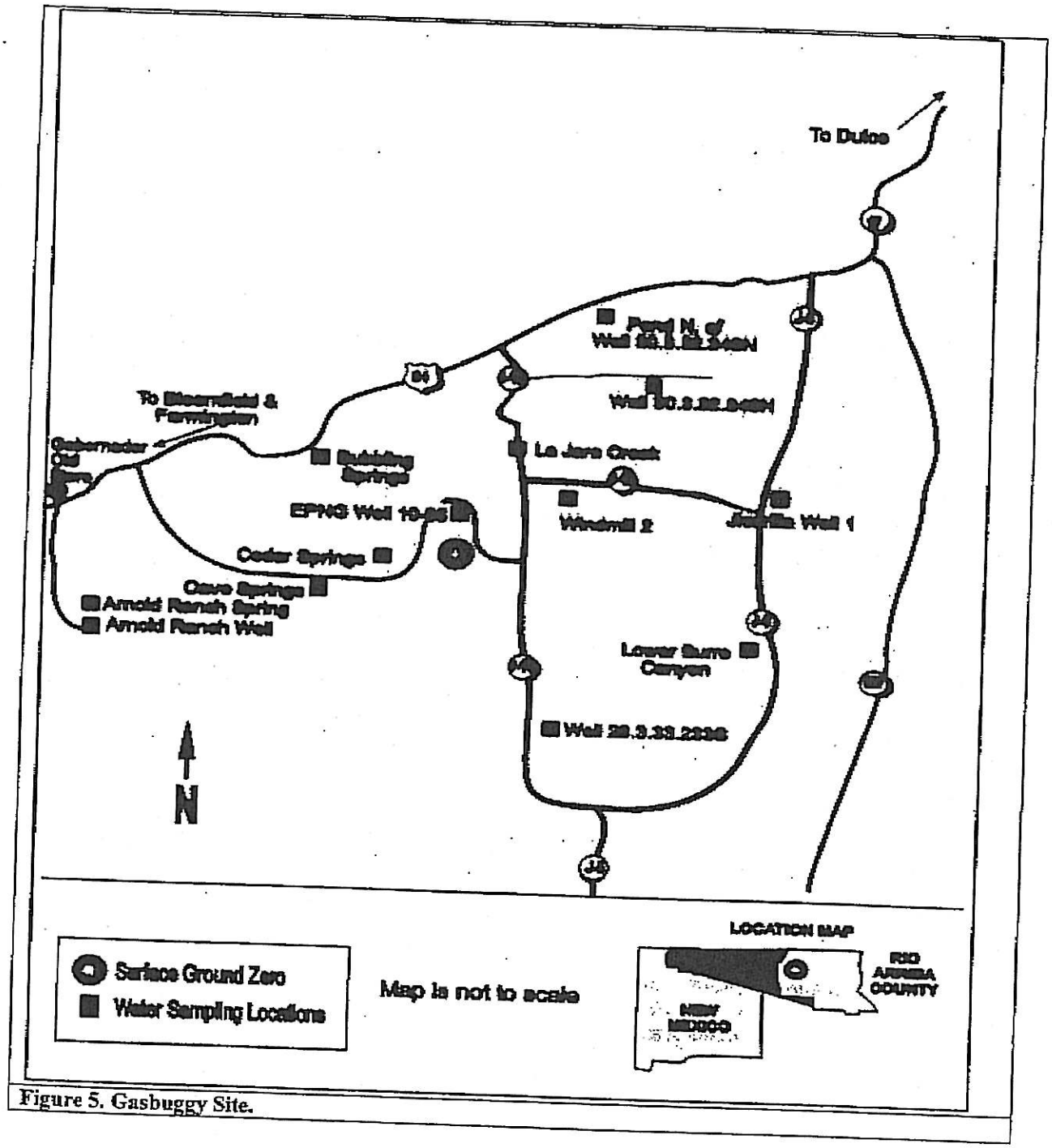

Figure 5. Gasbuggy Site.

2.5 Sampling at Project GASBUGGY, New Mexico

History

Project GASBUGGY was a Plowshare Program test co-sponsored by the U.S. AEC and El Paso Natural Gas Co., conducted near Gobernador, New Mexico, on December 10, 1967. A nuclear explosive with a 29-KT yield was detonated at a depth of 1,290 m (4,240 ft) to stimulate a low productivity natural gas reservoir. Production testing was completed in 1976 and restoration activities were completed in July 1978.

The principal aquifers near the test site are the Ojo Alamo Sandstone, an aquifer containing non-potable water located above the test cavity, and the San Jose formation and Nacimiento formation. Both surficial aquifers contain potable water. The flow regime of the San Juan Basin is not well known, although it is likely that the Ojo Alamo Sandstone discharges to the San Juan River 50 miles northwest of the Gasbuggy site. Hydrologic gradients in the vicinity are downward, but upward gas migration is possible (Chapman and Hokett, 1991).

2.5.1 Sample Collection

Annual sampling at Project GASBUGGY was completed during July 12-14, 2006. All of the routine sampling locations were collected including Bubbling Springs which yielded enough for tritium results, (see Figure 5). Well EPNG-10-36 which was plugged in 2003 has been removed from the sampling plan.

2.5.2 Water Analysis Results

Tritium concentrations of water samples collected onsite and offsite are consistent with those of past studies at the GASBUGGY Site. Prior to Well EPNG 10-36 it had yielded tritium activities between 100 and 560 pCi/L in each year since 1984, except in 1987. The sample collected in June 2003, yielded a tritium activity of .005 ± 4 pCi/L. The migration mechanism and route are not currently known, although an analysis by Desert Research Institute indicated two feasible routes. One through the Printed Cliffs sandstones, and the other one through the Ojo Alamo sandstone, one of the principal aquifers in the region, (Chapman and Hokett, 1991). In either case, fractures extending from the cavity may be the primary or a contributing mechanism. The proximity of the well to the test cavity suggests the possibility that the activity increases may indicate migration from the test cavity; however, in 2003 the well was plugged, due to severe deterioration. DOE will drill several wells in the near future, placed in strategic locations designed to intercept migration of radionuclides, if they occur.

Gamma-ray spectral analysis results indicated that no man-made gamma-ray emitting radionuclides were present in any onsite and offsite samples above the MDC. Tritium concentrations at all locations except for one were below the MDC. The only sampling location that had a tritium concentration above the MDC was Well 28.3.33.233.South which had a reading of 10 ± 4.3 pCi/L (see Table 5, page 16).

Analysis Results for Water Samples Collected at the GASBUGGY Site - July 2006

TABLE 5

Sample Location	Collection Date	Enriched Tritium		Tritium		Gamma Spectrometry	
		pCi/L ± 2 SD	MDC	pCi/L ± 2SD	MDC	pCi/L ± 2 SD	MDC
Arnold Ranch Spring	7/12/06	1.9 ± 4.6 [a]	(7.5)			ND	(4.9)
Bubbling Springs	7/14/06			58 ± 147 [a]	(240)	ND.	(4.9)
Cave Springs	7/12/06			116 ± 148 [a]	(240)	ND	(4.9)
Cedar Springs	7/12/06			58 ± 147 [a]	(240)	ND	(4.8)
La Jara Creek	7/12/06			53 ± 147 [a]	(240)	ND	(4.9)
Lower Burro Canyon	7/12/06			0 ± 146 [a]	(240)	ND	(5.0)
Pond N. of Well 30.3.32.343	7/13/06			24 ± 146 [a]	(240)	ND	(4.9)
Jicarilla Well 1	7/13/06	6.0 ± 4.6 [a]	(7.3)			ND	(5.0)
Well 28.3.33.233 South	7/12/06	10 ± 4.3	(6.7)			ND	(4.7)
Well 30.3.32.343 North	7/13/06			24 ± 145 [a]	(240)	ND	(1.9)
Windmill #2	7/12/06			24 ± 146 [a]	(240)	ND	(4.8)
Arnold Ranch Well	7/12/06			19 ± 146 [a]		ND	(5.0)

(a) Indicate results are less than MDC (enriched or conventional method).
ND Non-detected.
MDC Minimum detectable concentration.

2.5.3 Conclusions

Tritium concentrations of water samples collected onsite and offsite are consistent with those of past studies at the GASBUGGY Site. No radioactive materials attributable to the Gasbuggy test were detected in samples collected in the offsite areas during July 2006.

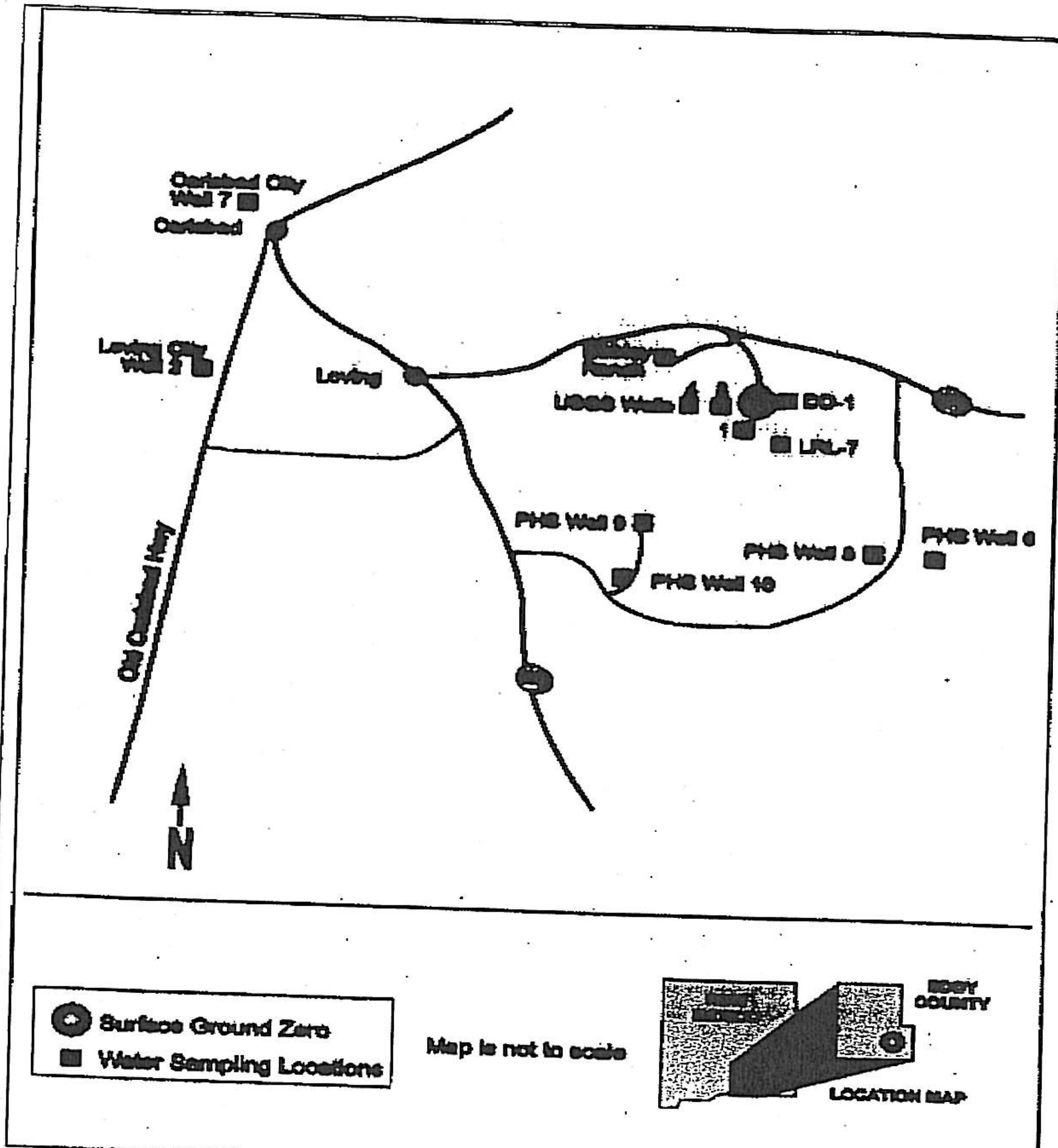

Figure 6. Gnome Site.

2.6 Sampling at Project GNOME, New Mexico

History

Project GNOME, conducted on December 10, 1961, near Carlsbad, New Mexico, was a multipurpose test emplaced at a depth of 370 m (1,216 ft) in the Salado salt formation. The explosive yield was slightly-more-than 3-KT. Oil and gas are produced from the geologic units below the working point. The overlying Rustler formation contains three water-bearing zones: brine located at the boundary of the Rustler and Salado formations, the Culebra Dolomite which is used for domestic and stock supplies, and the Magenta Dolomite which is above the zone of saturation (Chapman and Hokett, 1991). The ground water flow is generally to the west and southwest.

Radioactive gases were accidentally vented following the test. In 1963, USGS conducted a tracer study involving injection of 20 Ci tritium, 10 Ci ^{137}Cs, 10 Ci ^{90}Sr, and 4 Ci ^{131}I in the Culebra Dolomite zone using Wells USGS 4 and 8. During remediation activities in 1968-69, contaminated material was placed in the test cavity and the shaft up to within 7 ft of the surface. More material was slurried into the cavity and drifts in 1979. A potential exists for discharge of this slurry to the Culebra Dolomite and to Rustler-Salado brine. Potentially, this may increase as the salt around the cavity compresses, forcing contamination upward and distorting and cracking the concrete stem and grout.

2.6.1 Sample Collection

Annual sampling at Project GNOME was completed during July 18-19, 2006. The routine sampling sites, depicted in Figure 6, include ten monitoring wells in the vicinity of surface GZ and the municipal supplies at Loving and Carlsbad, New Mexico.

2.6.2 Water Analysis Results

No tritium activity was detected in the Carlsbad municipal supply or the Loving Station well. An analysis by Desert Research Institute (Chapman and Hokett, 1991) indicates that these sampling locations, which are on the opposite side of the Pecos River from the Project GNOME site, are not connected hydrologically to the site and, therefore, cannot become contaminated by Project GNOME radionuclides.

Tritium activity greater than the MDC was detected in a water sample from one of the 10 sampling locations in the immediate vicinity of GZ. The highest tritium concentration found onsite was 2.4 $x10^4$ pCi/L in Well USGS# 4. Offsite Well PHS#6 results were 17 ± 5.7 pCi/L with MDC 9.0 pCi/L. Well DD-#1, collects water from the test cavity; Well LRL-#7 collects water from a side drift; and Wells USGS-#4 and USGS-#8 were used in the radionuclide tracer study conducted by the USGS. None of these wells are sources of potable water and only, Well USGS#4 was sampled 2006, the remaining three were not at the recommendation of DOE.

Analysis Results for Water Samples Collected at the GNOME Site - July 2006

TABLE 6

Sample Location	Collection Date	Enriched Tritium		Tritium		Gamma Spectrometry	
		pCi/L ± 2 SD	MDC	pCi/L ± 2 SD	MDC	pCi/L ± 2 SD	MDC
Carlsbad City #7	7/18/06	3.3 ± 4.3 [a]	(7.0)			ND	(5.0)
Loving City #7	7/18/06			78 ± 148 [a]	(242)	ND	(4.1)
PHS 6	7/18/06	17 ± 5.7	(9.0)			ND	(4.6)
PHS 8	7/18/06			39 ± 147 [a]	(242)	ND	(4.6)
PHS 9	7/18/06			53 ± 148 [a]	(242)	ND	(4.9)
PHS 10	7/18/06			-9.7 ± 146 [a]	(242)	ND	(4.9)
USGS Well #1	7/19/06			92 ± 149 [a]	(242)	ND	(4.8)
USGS Well #4	7/19/06			24,300 ± 423	(242)	ND	(1.9)
USGS Welt #8						Not Sampled 06	
J. Mobley Ranch	7/19/06	4.3 ± 5.1 [a]	(8.2)			ND	(5.0)
Well DD-#1						Not Sampled 06	
Well LRL-#7						Not Sampled 06	

(a) Indicate results are less than MDC (enriched or conventional method).
ND- Non-detected
MDC- Minimum detectable concentration.
Note: The above sampling locations UGSG#8, Well LRL-#7, Well DD-#1 were not collected per request of DOE.

2.6.3 Conclusion

Tritium concentrations of water samples collected onsite and offsite are consistent with those of past studies at the Gnome Site. No radioactive materials attributable to the Gnome test were detected in samples collected in the offsite areas during July 2006.

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GLOSSARY OF TERMS

Background Radiation

The radiation in man's environment, including cosmic rays and radiation from naturally-occurring and man-made radioactive elements, both outside and inside the bodies of humans and animals. The usually quoted average individual exposure from background radiation is 125 millirem per year in mid-latitudes at sea level.

Curie (Ci)

The basic unit used to describe the rate of radioactive disintegration. The curie is equal to 37 billion disintegrations per second, which is the equivalent of 1 gram of radium. Named for Marie and Pierre Curie who discovered radium in 1898. One microcurie (μCi) is 0.000001 Ci.

Isotope

Atoms of the same element with different numbers of neutrons in the nuclei. Thus ^{12}C, ^{13}C, and ^{14}C are isotopes of the element carbon, the numbers denoting the approximate atomic weights. Isotopes have very nearly the same chemical properties, but have different physical properties (for example ^{12}C and ^{13}C are stable, ^{14}C is radioactive).

Enrichment Method

A method of electrolytic concentration that increases the sensitivity of the analysis of tritium in water. This method is used for selected samples if the tritium concentration is less than 800 pCi/L.

Minimum Detectable Concentration (MDC)

The smallest amount of radioactivity that can be reliably detected with a probability of Type I and Type II errors at 5 percent each (DOE 1981).

Offsite

Areas exclusive of the immediate Test Site Area.

Type I Error

The statistical error of accepting the presence of radioactivity when none is present. Sometimes called alpha error.

Type II Error

The statistical error of failing to recognize the presence of radioactivity when it is present. Sometimes called beta error.

Appendix A

Typical MDC Values for Gamma Spectroscopy
(100 minute count time)

Geometry*	Marinelli	Model	430G
Matrix	Water	Density	1.0 g/ml
Volume	3.5 liter	Units	pCi/L
Isotope	MDC	Isotope	MDC
Be-7	4.56E+01	Ru-106	4.76E+01
K-40	4.92E+01	Sn-113	8.32E+00
Cr-51	5.88E+01	Sb-125	1.65E+01
Mn-54	4.55E+01	I-131	8.28E+00
Co-57	9.65E+00	Ba-133	9.16E+00
Co-58	4.71E+00	Cs-134	6.12E+00
Fe-59	1.07E+01	Cs-137	6.43E+00
Co-60	5.38E+00	Ce-144	7.59E+01
Zn-65	1.24E+01	Eu-152	2.86E+01
Nb-95	5.64E+00	Ra-226	1.58E+01
Zr-95	9.06E+00	U-235	1.01E+02
		Am-241	6.60E+01

Disclaimer
The MDA's provided are for background matrix samples presumed to contain no known analytes and no decay time. All MDA's provided here are for one specific *Germanium detector and the geometry of interest. The MDA's in no way should be used as a source of reference for determining MDA's for any other type of detector. All gamma spectroscopy MDA may vary with different types of shielding, geometries, counting times and decay time of sample.

Appendix B

Standard Operating Procedures for the Center for Environmental Restoration, Monitoring & Emergency Response

CER-203 Standard Operating Procedure for the Long-Term Hydrological Monitoring Program.

Standard Operating Procedures for the Center for Radioanalysis & Quality Assurance

RQA-302 Standard Operating Procedures of Gamma-Ray Detector Systems.

RQA-602 Tritium Enrichment Procedure.

RQA-603 Standard Operating Procedure for ^{89}Sr and ^{90}Sr in Water, Air Filters and Milk.

RQA-604 Standard Operating Procedure of Convention Tritium in Water.

RQA-606 Analysis of Plutonium, Uranium and Thorium in Environmental Samples by Alpha Spectroscopy.