Location Number FC00031

REPORT OF INCLUSION SURVEY AT LOCATION FC00031
BARGMANN TRACT
KARNES COUNTY, TEXAS

Investigation Team

C. A. Little - Environmental Technology Section Head
J. A. Rice - Project Coordinator
M. L. Espegren - Survey Team Leader

D. S. Foster
M. K. Jensen
A. R. Jones
C. A. Muhr
G. A. Pierce
J. R. Sauvage
S. M. Smith
J. L. Zutman

September 1996

Work performed by the Environmental Assessments Group
Environmental Technology Section
Health Sciences Research Division

Prepared by the
Oak Ridge National Laboratory
Grand Junction Office
Grand Junction, Colorado 81502
Managed by
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
for the
U. S. DEPARTMENT OF ENERGY
under Contract DE-AC05-96OR22464

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

DOE	U.S. Department of Energy
EA	environmental assessment
EPA	U. S. Environmental Protection Agency
cm	centimeter
ft	feet
GPS	Global Positioning System
HOG	highest outdoor gamma
kcpm	thousand counts per minute
m	meter
μg/g	micro grams per gram
μR/h	micro roentgens per hour
ORNL	Oak Ridge National Laboratory
pCi/g	picocuries per gram
PIC	pressurized ionization chamber
UMTRA	Uranium Mill Tailings Remedial Action

SUMMARY

A radiological survey was performed on the Bargmann Tract, Karnes County, Texas, to evaluate the property for inclusion in the Uranium Mill Tailings Remedial Action Project. The Bargmann Tract is located approximately 900 m (3000 ft) southeast of the site of the repository and the site of a remediated former uranium mill and associated tailings piles.

Elevated ^{226}Ra was found in the surface and subsurface soils in several locations on the property. A major portion of the investigation centered on determining whether the elevated radium was due to mill tailings or to naturally occurring radioactive soils in the geologic formations at the site.

The Bargmann Tract is situated in an area that has been the focus of uranium exploration since the 1950s. This has resulted in abundant and thorough geologic and stratigraphic characterizations of the site. Historical data combined with later radiological surveys and results of the inclusion survey support the following conclusions:

- Uranium to radium ratios in soil samples are not a reliable method of distinguishing uranium ore from mill tailings for an inclusion/exclusion recommendation on this property. Several publications have documented that uranium-radium disequilibrium commonly exists in soils of this region as a result of preferential leaching of uranium.

- Visual inspection of the soil and pre-mill site descriptions of the stratigraphy confirm that naturally occurring radioactivity was historically present on the Bargmann Tract. A 1955 aerial radiometric survey identified and mapped anomalously high gamma activity in several locations on the property. These gamma anomalies clearly pre-date the Falls City mill.

- There is no physical evidence that tailings containing ^{226}Ra in concentrations exceeding Environmental Protection Agency standards have migrated from the former mill site onto the Bargmann Tract. The means by which tailings could be transported away from the piles are wind, surface water, and motor vehicle. Samples collected using windblown sampling protocols along the east property line (closest to the former tailings piles) did not indicate the presence of windblown contamination. Although elevated ^{226}Ra was found in the sediments of Tordilla Creek, the highest concentration was located in undisturbed soil taken from the layers of Quaternary alluvium that comprise the creek banks. This indicates that radium was deposited in the alluvial soils by natural processes of erosion and deposition of uranium- and radium-bearing formations. Tailings sand hauled by motor vehicle and dumped on the property would exhibit elevated gamma exposure rates. Most sand found on the Bargmann Tract had gamma exposure rates within the background range of non-uranium-bearing soils. Sand associated with elevated gamma was identified as either a weathering feature of a sandstone outcrop or as a component in a clay matrix. Because much of the soil on the property is a sandy clay, the presence of sand in clay is not a presumptive indication of mill tailings. All soil samples containing elevated ^{226}Ra had a physical appearance consistent with the stratigraphic sequence historically present on the property.

- Because all elevated ^{226}Ra in the soil samples and all elevated gamma exposure rates on the property are accounted for by the presence of naturally occurring radioactivity, the Bargmann Tract (FC00031) is recommended for exclusion from further consideration by the UMTRA Project.

REPORT OF INCLUSION SURVEY AT LOCATION FC00031
Bargmann Tract, Karnes County, Texas

1. INTRODUCTION

The U.S. Department of Energy (DOE) or its contractors perform inclusion radiological surveys and remedial actions under the Uranium Mill Tailings Remedial Action (UMTRA) Project in accordance with the Environmental Protection Agency (EPA) standards as stated in the *Federal Register, Cleanup of Lands and Buildings Contaminated with Residual Radioactive Material from Inactive Uranium Processing Sites*, 40 CFR 192.12, 192.20-23 (U.S. EPA 1983). The law applies to properties contaminated with ^{226}Ra in mill tailings or other material from an inactive uranium mill at which uranium was produced for sale to the federal government. The standards limit the concentration of ^{226}Ra, when averaged over any area of 100 m^2, to 5 pCi/g above background in the first 15 cm of soil below the surface and to 15 pCi/g above background in any subsequent 15-cm-thick layer.

In December 1995 and January 1996, Oak Ridge National Laboratory (ORNL) conducted an inclusion radiological survey on the Bargmann property, a 460-hectare (1100-acre) tract in Karnes County, Texas. General information about the property is provided in Table 1 and Fig. 1.

2. SITE HISTORY

Uranium was discovered near Tordilla Hill approximately 1.3 km (0.8 miles) south of the Bargmann Tract in 1954 during an aerial radiometric survey for oil structures (Steinhauser and Beroni 1955). In 1955, an aerial radiometric survey found several areas of elevated gamma activity on the Bargmann property that were associated with uranium deposits (MacKallor et al. 1962) (Fig. 2). By the end of 1955, extensive prospecting had been done on at least 12 nearby farm properties (including the Bargmann Tract) and uranium minerals or high radioactivity reported on several more. Before 1957, Superior Oil Company excavated a prospect pit about 60 m (200 ft) long and 2.7 m (9 ft) deep on the northeast portion of the Bargmann Tract. "Yellow uranium minerals [were] disseminated through the upper 5 feet of sands in this pit and in some places the fossil cavities are filled with the minerals" (Eargle and Snider 1957). Mining of uranium minerals in the area began in 1960.

2.1 Falls City Mill

The Falls City uranium mill was constructed 1.3 km (0.8 miles) northeast of the Bargmann Tract and began operations in 1961. The mill closed in 1973 after processing about 2.3 million metric tons (2.5 million tons) of ore averaging 0.16% uranium. The tailings were contained in seven piles in an area totaling about 60 hectares (146 acres) (Fig 3). By 1976, all piles except piles 2

Table 1. Location Information

Property Information	
Location:	Bargmann Tract, Karnes County, Texas
Occupant/Tenant:	None
Telephone:	Not applicable
Property Classification:	Vacant Land
Total Area of Property:	460 hectares (1100 acres)
Structures on Property:	Non-permanent trailer houses
Owner Information	
Owner:	Concord Oil Attn: Reagan S. McCoy, Vice President
Address:	Alamo National Building 105 S. St. Mary's Street, Suite 1500 San Antonio, Texas 78205-2898
Telephone:	N/A (H) (210) 224-4455 (B)

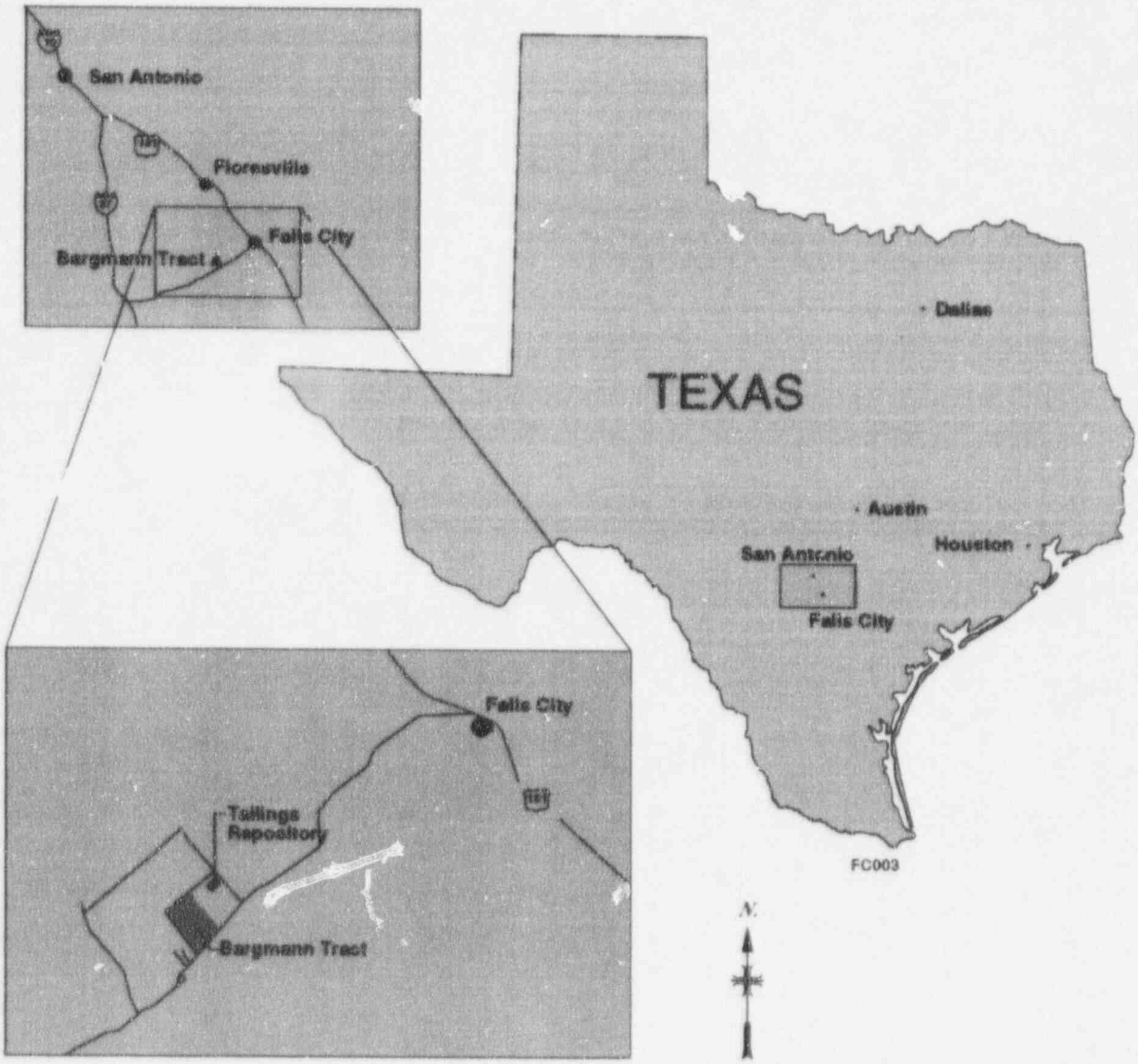
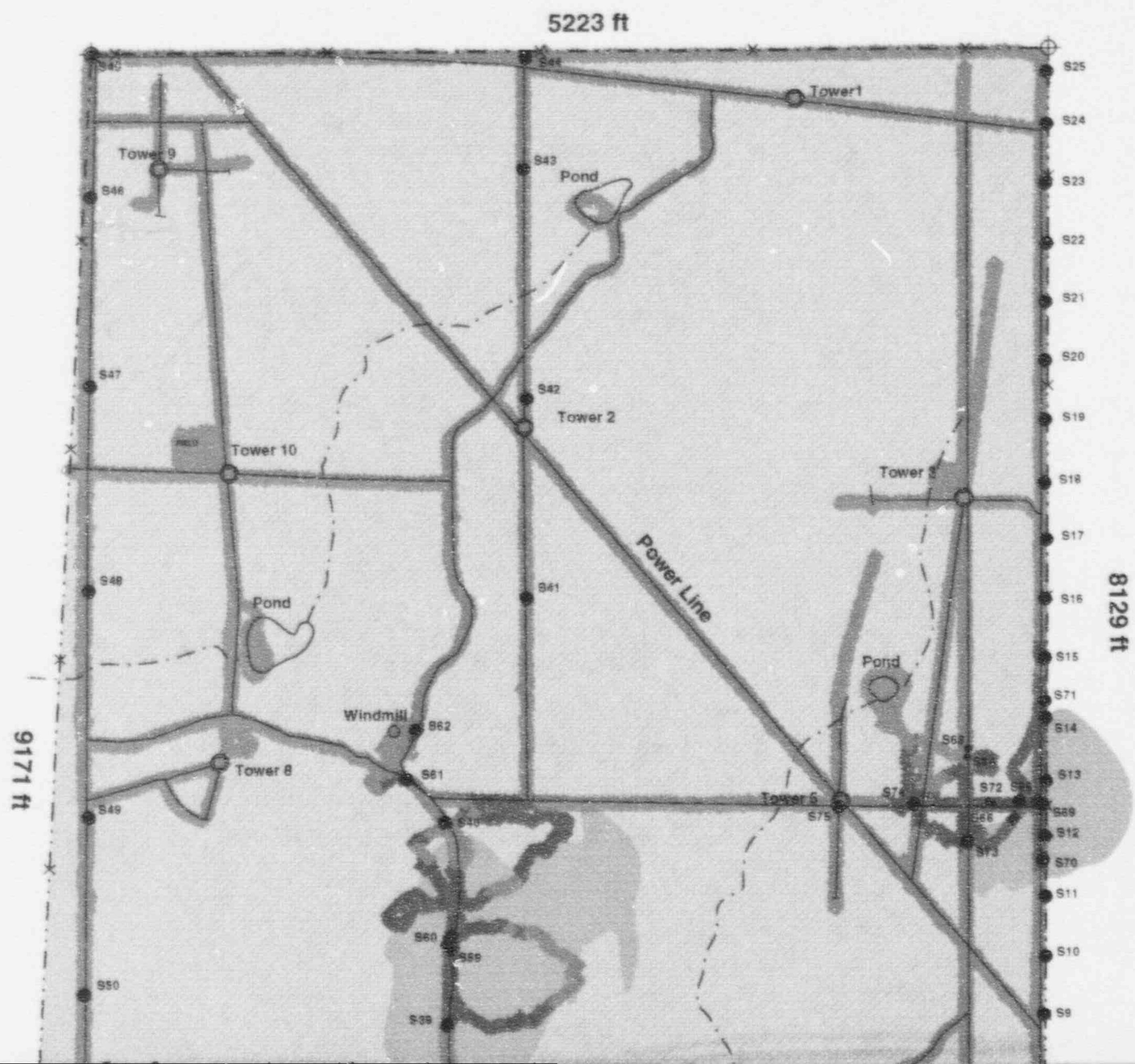


Fig. 1. Location of FC00031, the Bargmann Tract.

Location Number FC00031



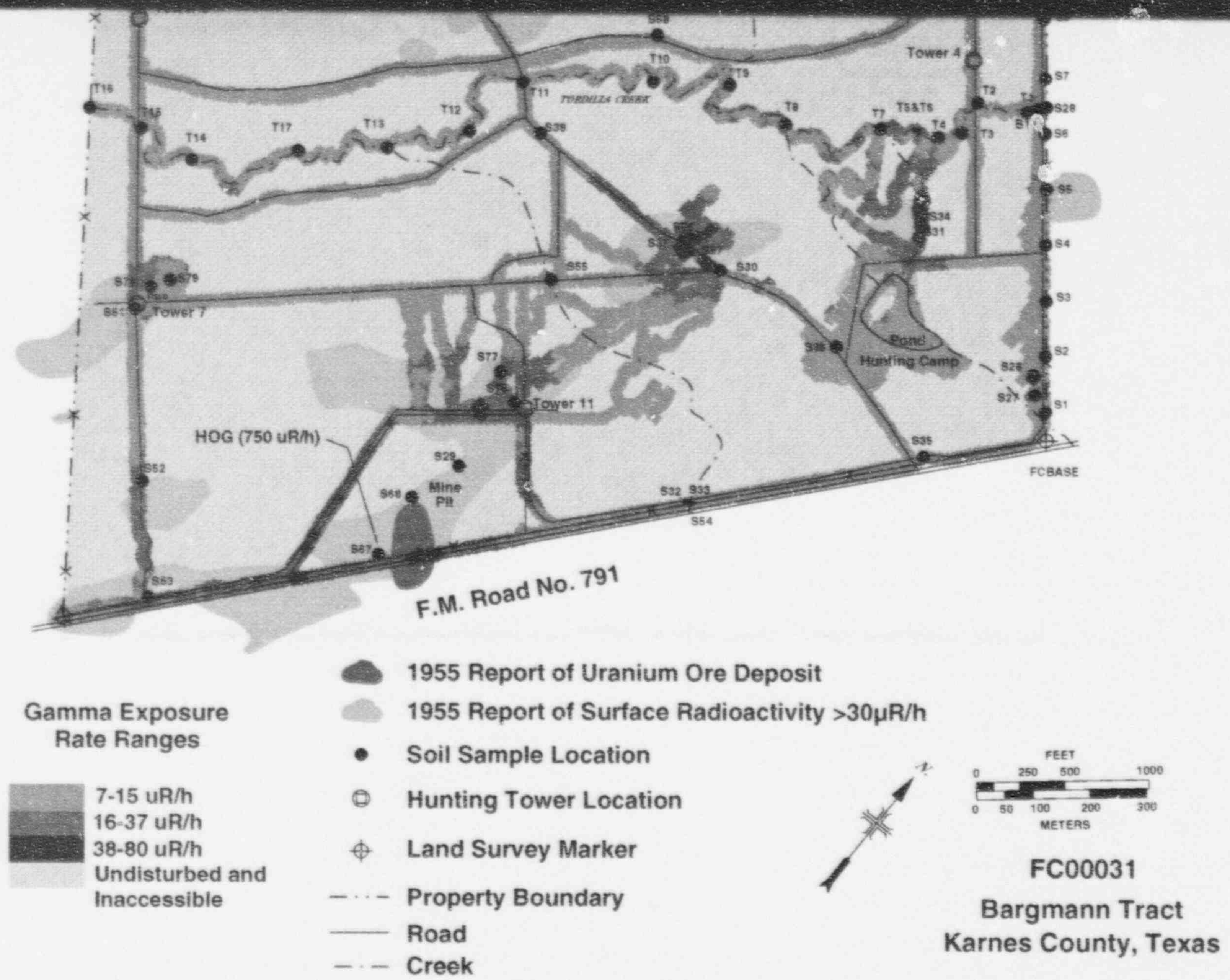


Fig. 2. FC00031, gamma screening results and sample location map.

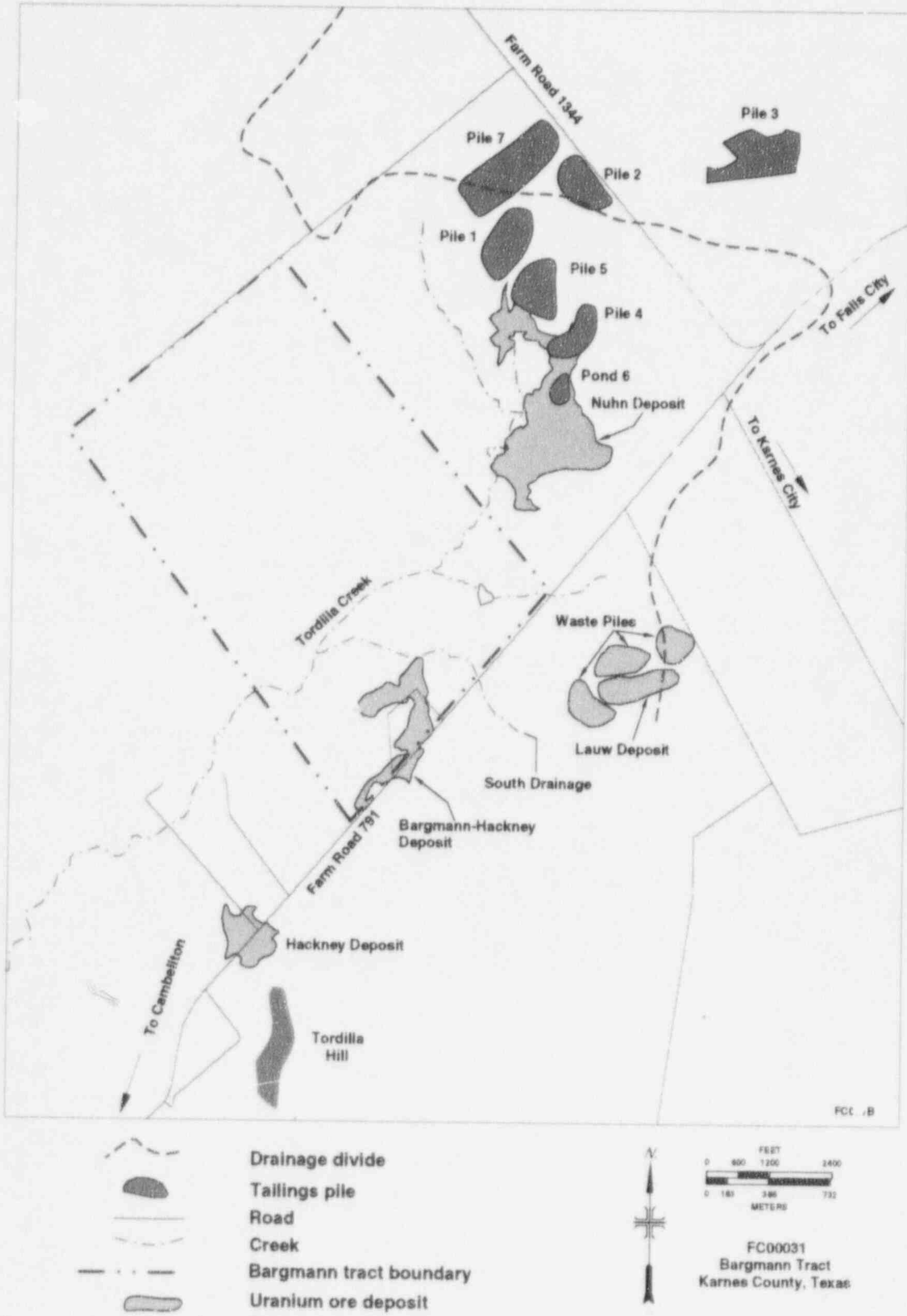


Fig. 3. Bargmann Tract, former mill tailings piles, drainage divide, and area ore deposits. *Source:* Mackallor et al. 1962; USGS map MF-1029; U.S. DOE 1979.

and 7 had been stabilized with at least two feet of cover and seeded; pile 2 was reported to be about 50% covered and pile 7 about 30% covered (U.S. DOE 1981). By 1986, the remaining piles had been seeded and covered (U.S.DOE 1991). An environmental assessment (EA) was prepared in 1979 to evaluate impacts to the environment during and after proposed remedial action to the mill site (U.S.DOE 1979). In 1980 an aerial radiological survey was conducted of the mill site and surrounding area (EG&G 1982). A full-scale radiological characterization was conducted at the mill site from November 1985 through January 1986 (Marutzky et al. 1986). The repository for the tailings piles is located in the northeast portion of the mill site property. Remedial action of the Falls City mill site was completed in 1995.

2.1.1 Description of Tailings from the Falls City Mill

Lithologic logs from the 1986 radiologic survey describe the tailings as "primarily sand with thin layers of interbedded clay (slime) underlain by a predominant clay (slime) layer". The clays (slimes) are gray to dark brown (Marutzky et al. 1986).

2.2 Uranium/Radium Disequilibrium

Radioactive disequilibrium of the uranium-bearing formations was a problem from the beginning of uranium prospecting in the area. Scott and Dodd (1960) summarized the uranium decay series by listing the parent and 14 daughters in two groups: the uranium group (^{238}U through ^{230}Th) and the radium group (^{226}Ra to ^{206}Pb). They noted that "When equilibrium exists, about 2 percent of the gamma ray intensity arises from the uranium group and 98 percent from the radium group. Therefore, when members of the uranium group are leached from the soil, the gamma-ray intensity may change very little, even though the uranium concentration is greatly reduced". The presence of uranium was inferred from elevated gamma activity in rocks of the Gulf Coastal Plain. Field estimates of uranium concentration were expressed as percent equivalent uranium, i.e., the ratio of gamma activity of uranium and daughters in a sample compared to a uranium ore standard in which all the decay products are in equilibrium. However, chemical analysis of soil and rock samples collected at locations of high gamma measurements often revealed that uranium was present in sub-ore concentrations and that the ratios of uranium to daughters ranged from greater than three to one to as low as 0.03 to one (Steinhauser and Beroni 1955). A 1958 Atomic Energy Commission report on the Nuhn Lease uranium deposit between the Bargmann Tract and the mill site describes the ore as "mostly in disequilibrium, both radiometrically and chemically..." (Hodgens 1958).

Beginning with the EA of the mill site, there was difficulty in differentiating ^{226}Ra associated with tailings from naturally occurring radium. The EA concluded that it was not possible to quantitatively compare naturally occurring ^{226}Ra to radium from the tailings piles (U.S. DOE 1979). In addition to detecting gamma radiation from tailings piles and mining pits, the 1980 aerial radiological survey detected gamma anomalies over undisturbed areas on and around the Bargmann Tract. The anomalies were attributed to uranium ore deposits near the surface. A 1986 radiological

survey also found that determining the extent of radium contamination from tailings at the mill site was complicated by the presence of naturally occurring uranium (Marutzky et al. 1986). To distinguish tailings contamination from naturally occurring radium, the 1986 survey used two indicators based on the results of soil sample analysis: 1) results of analyses of the uranium ore bodies below two tailings piles indicated ^{238}U:^{226}Ra ratios from 1.5 to greater than 26; and 2) analysis of tailings within the piles indicated that the ^{238}U:^{226}Ra ratio for 90% of the samples was less than 0.60. Using these criteria, the 1986 survey determined that contamination occurred on the mill site property from wind dispersion and from buried pipes along the roads. The survey also identified an ore body that exists beneath the mill site and surfaces in some areas. Difficulty arose when examining the south, southeast, and east drainages, including Tordilla Creek where it enters the Bargmann Tract. Based on the criterion used (^{238}U:^{226}Ra ratio <0.60), tailings possibly existed in the south and southeast drainage areas; however, the investigators were not certain whether the anomalies were due to the natural uranium/radium disequilibrium or if tailings were actually waterborne. The study concluded that natural uranium-bearing soils in these drainages would mask the presence of tailings. Due to the disequilibrium of uranium and its daughters in the area, the ratio used in the 1986 survey is considered inconclusive for the inclusion survey investigation.

Analysis for total uranium and ^{226}Ra was performed on 30 samples taken at 30 locations off the property and 53 samples taken at 22 locations on the property (Table 2). The range of ^{238}U to ^{226}Ra ratios from the samples taken outside the property (Fig. 4), PIC1 through PIC30, was 0.17 to 1.3. The sample with the lowest ratio was a piece of sandstone collected away from the road base material next to the open pit mine on the Bargmann Tract. The range of ^{238}U to ^{226}Ra ratios from the samples taken on the property was 0.081 to 3.4 (Table 2). One of the lowest ratios of ^{238}U to ^{226}Ra from the property came from sample S34, which was collected from the weathered surface of a sandstone unit of the Conquista Clay. This evidence of variable ^{238}U to ^{226}Ra ratios in naturally occurring uranium- and radium-bearing outcrops, in combination with historical literature and later radiological surveys, provides sufficient instances of disequilibrium in the area to render uranium-radium ratios unreliable as an investigative tool for an inclusion survey of the Bargmann Tract.

3. PHYSICAL DESCRIPTION

3.1 Geology

Extensive prospecting and drilling has shown that uranium minerals or radioactive rocks exist in at least seven different stratigraphic positions from the base of the upper part of the Jackson Formation to the Goliad Sand. Uranium minerals were identified at a number of localities including the Bargmann Tract over an area that extends for about 190 miles, ranging from central western Duval County northeast to Fayette County (Eargle and Snider 1957).

Location Number FC00031

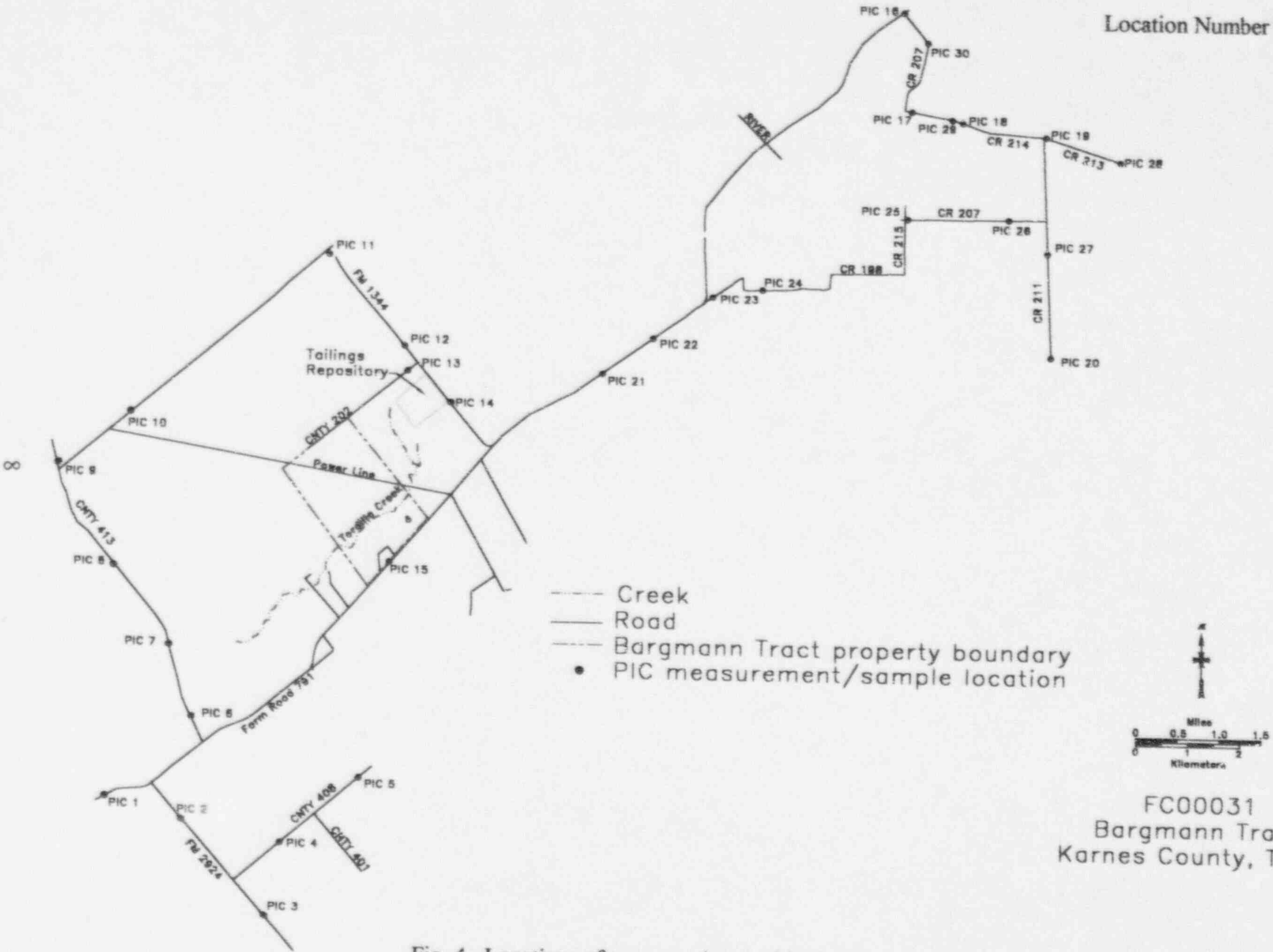


Fig. 4. Locations of area samples outside the Bargmann Tract.

Table 2. Uranium-radium ratios of samples

Sample number	Total U $\mu g/g$ [a]	^{238}U pCi/g [b]	^{226}Ra pCi/g [a]	Ratio ^{238}U:^{226}Ra
B1	42	14	14	1.0
PIC 1	3.5	1.2	1.3	0.90
PIC 2	6.5	2.2	2.7	0.81
PIC 3	2.5	0.84	1.1	0.76
PIC 4	7.1	2.4	3.3	0.73
PIC 5	2.9	0.97	1.5	0.65
PIC 6	4.7	1.6	2.2	0.73
PIC 7	4.8	1.6	4.0	0.40
PIC 8	5.5	1.8	2.3	0.78
PIC 9	3.0	1.0	1.6	0.62
PIC 10	3.3	1.1	1.6	0.69
PIC 11	4.7	1.6	2.0	0.80
PIC 12	6.5	2.2	5.0	0.44
PIC 13	3.6	1.2	1.7	0.70
PIC 14	10	3.4	9.8	0.35
PIC 15	33	11	63	0.17
PIC 16	3.2	1.1	1.7	0.65
PIC 17	1.9	0.63	0.93	0.68
PIC 18	2.3	0.77	0.79	0.97
PIC 19	3.8	1.3	1.4	0.93
PIC 20	3.1	1.0	1.5	0.67
PIC 21	3.0	1.0	1.1	0.91
PIC 22	3.3	1.1	2.3	0.47
PIC 23	5.8	1.9	2.2	0.86
PIC 24	4.7	1.6	3.3	0.49
PIC 25	2.8	0.94	1.1	0.85
PIC 26	2.3	0.77	0.61	1.3
PIC 27	3.5	1.2	1.2	1.0

Table 2. Uranium-radium ratios of samples (continued)

Sample number	Total U µg/g [a]	^{238}U pCi/g [b]	^{226}Ra pCi/g [a]	Ratio ^{238}U:^{226}Ra
PIC 28	2.4	0.80	0.97	0.82
PIC 29	2.8	0.94	0.94	1.0
PIC 30	2.6	0.87	1.2	0.72
S11A	5.5	1.8	6.8	0.26
S11B	4.2	1.4	4.7	0.30
S11C	3.8	1.3	4.9	0.27
S12A	8.0	2.7	14	0.19
S12B	5.8	1.9	11	0.17
S12C	11	3.7	9.9	0.37
S13A	12	4.0	17	0.24
S13B	12	4.0	18	0.22
S13C	12	4.0	13	0.31
S14A	12	4.0	11	0.36
S14B	11	3.7	8.0	0.46
S14C	13	4.3	14	0.31
S17A	4.3	1.4	2.0	0.70
S17B	3.9	1.3	2.4	0.54
S17C	3.4	1.1	1.8	0.61
S28A	69	23	21	1.1
S28B	69	23	25	0.92
S34	48	16	100	0.15
S37A	43	14	25	0.56
S37B	45	15	29	0.52
S37C	48	16	30	0.53
S4A	6.0	2.0	2.8	0.71
S4B	7.9	2.6	3.1	0.84
S4C	10	3.3	2.6	1.3
S60A	20	6.7	36	0.19
S60B	20	6.7	42	0.16
S60C	21	7.0	44	0.16
S67	1100	370	530	0.69
S68A	1200	400	390	1.0
S68B	410	140	170	0.8

Table 2. Uranium-radium ratios of samples (continued)

Sample number	Total U µg/g [a]	^{238}U pCi/g [b]	^{226}Ra pCi/g [a]	Ratio ^{238}U:^{226}Ra
S69A	19	6.3	14	0.45
S69B	110	37	11	3.3
S70A	6.5	2.2	10	0.22
S70B	7.0	2.3	6.7	0.34
S71A	23	7.7	11	0.70
S71B	100	33	9.6	3.5
S72A	14	4.7	43	0.11
S73A	3.8	1.3	16	0.081
S74A	17	5.7	34	0.17
S74B	68	23	54	0.43
S75A	3.7	1.2	3.2	0.38
S75B	4.6	1.5	5.1	0.29
S78A	56	19	28	0.68
S78B	59	20	27	0.74
S78C	26	8.7	12	0.72
S9A	4.7	1.6	4.7	0.34
S9B	4.5	1.5	3.8	0.39
S9C	4.6	1.5	3.7	0.41
T14A	12	4.0	6.7	0.60
T14B	10	3.4	5.9	0.58

[a] Analytical results are from the Department of Energy Grand Junction Projects Office Analytical Laboratory, Project 6R0004210, January 4, 1996, February 14, 1996, and March 4, 1996.

[b] Formula used:

$$A = (M_T \times K)(SA)$$

where

A = ^{238}U activity, pCi/g of soil
M_T = mass of total U, µg/g of soil
K = conversion factor, 10^{-6} g/µg
SA = specific activity of ^{238}U, 3.34×10^5 pCi/g

The most important host rock of the shallow, oxidized uranium deposits in the Tordilla Hill-Deweesville area was identified by the United States Geologic Survey and several mineral exploration companies as the Eocene-Age Deweesville Sandstone member of the Whitsett Formation. The Deweesville consists primarily of siltstone, sandstone, and clay. The formation ranges from 20 to 50 ft in thickness and forms an outcrop band 250 to 300 ft wide, encompassing much of the southern boundary of the Bargmann Tract, including the open-pit mine area identified as the Bargmann/Hackney deposit (Bunker and MacKallor 1973) (Fig. 5). Underlying the Deweesville Sandstone member is the Conquista Clay member. According to Bunker and MacKallor (1973), the lower part of the Deweesville and the upper few feet of the Conquista contain all of the uranium ore deposits in the Bargmann Tract area. Even where no ore is present, radioactivity is reportedly greater along the contact area than in the rocks stratigraphically above and below the contact. This is supported by observations and samples taken during the inclusion survey in January 1996.

Soil on the Bargmann Tract consists of weathered Conquista Clay, with several outcrops of weathered Deweesville in the southern portion of the property and Quaternary alluvium in the drainages. The Dilworth Sandstone underlies the Conquista clay and outcrops in the northwest corner of the property (Fig. 5). Weathering of the formations has produced sandy clay to clayey sand; some sand is present from weathering of the lightly-cemented sandstone outcrops. The majority of the soil is dark grey and dark brown.

3.2 Physical Characteristics

The property is situated in the low, rolling hills characteristic of southeast Texas in the Gulf of Mexico coastal plain area. Dense vegetation in the form of oak, mesquite, grasses, prickly pear cactus, and several varieties of thorny shrubs cover much of the property, rendering many areas inaccessible (Fig. 2). Most of the land surface is undisturbed. Figures 6a through 6h are photographs of various locations on the property. The following areas were accessible and were scanned for gamma radiation:

- A primary dirt road running north and south through the center of the property (Fig. 6e);
- approximately 12 secondary vehicle trails used for access to hunting towers;
- a dirt road that follows a power line;
- a hunting camp with motor homes and non-permanent trailers (Fig. 6a);
- three dry ponds and one pond partially filled with water;
- four clearings used for hunting.

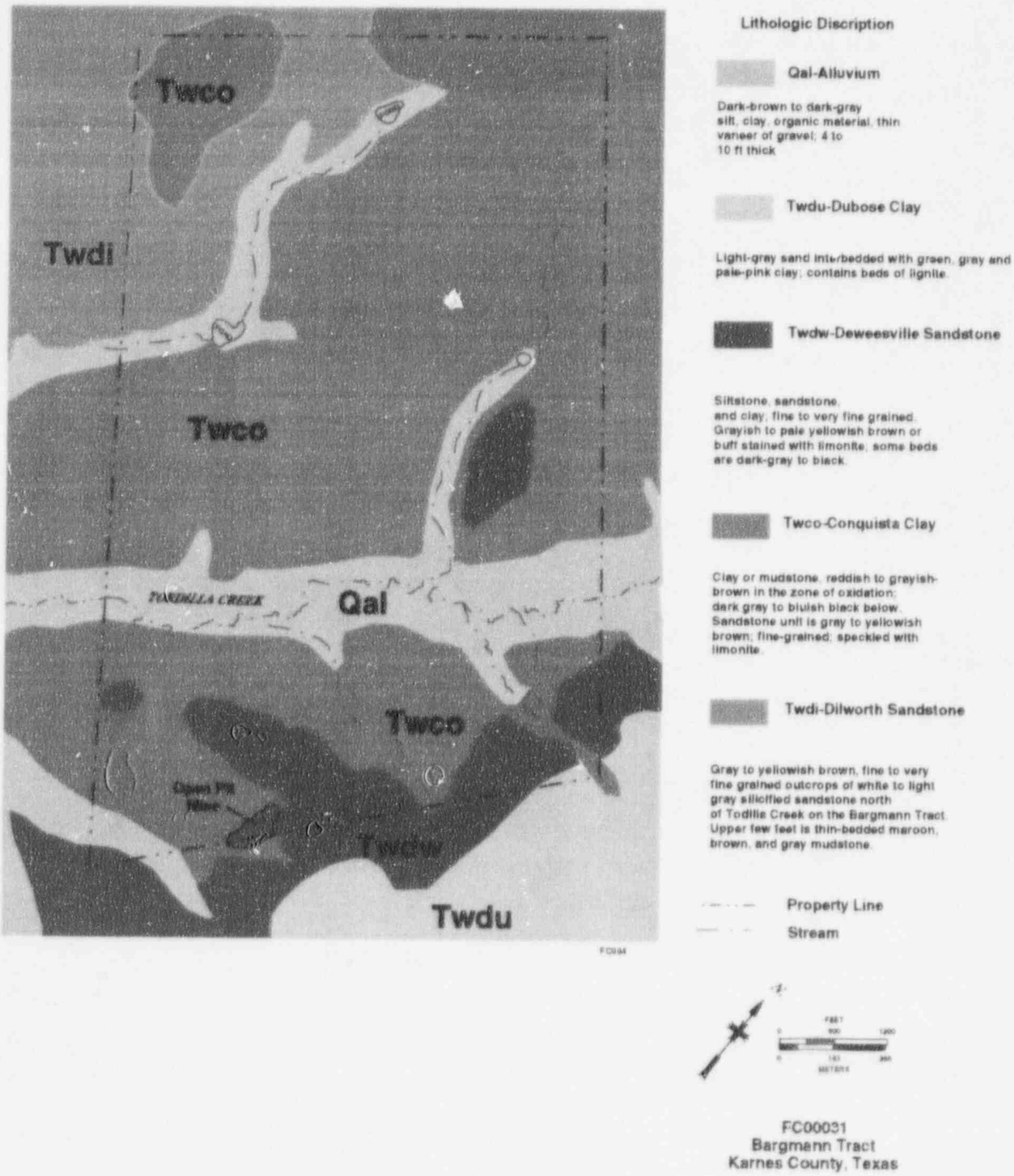


Fig. 5. Geological map of the Bargmann Tract. *Source:* USGS Map MF-1029.

Fig.6a. Pond and hunting camp.

Fig. 6b. Mine pit.

Fig. 6c. Looking downstream from the east boundary at Tordilla Creek.

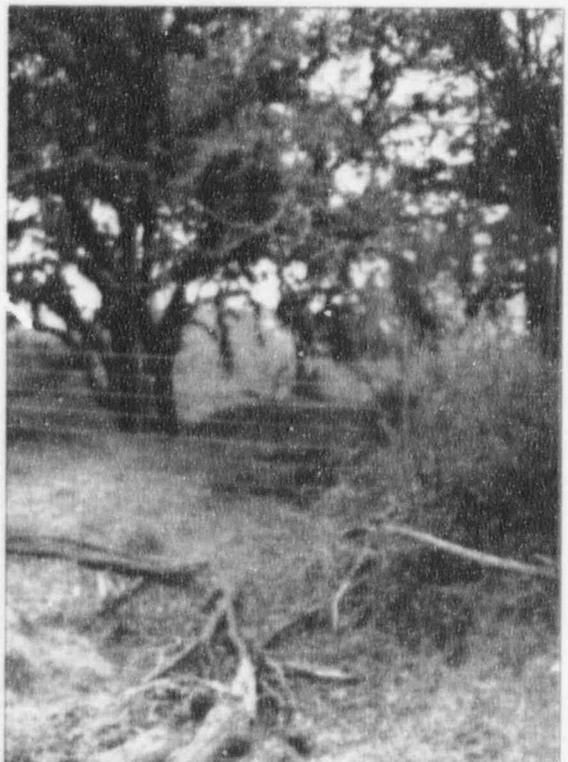


Fig. 6d. Looking northeast at Tordilla Creek as it enters the Bargmann Tract.

Fig. 6e. Central road on the Bargmann Tract.

Fig. 6f. Conducting a gamma radiation survey on the Bargmann Tract.

Fig. 6g. Soil sampling with a bucket auger.

Fig. 6h. Side wall of the mine pit.

A drainage divide trending northwest to southeast is located adjacent to the Bargmann Tract on the site of the former mill (Fig. 3). Surface drainage from former tailings piles 2, 3, and the northern portion of former pile 7 is to the northeast, away from the Bargmann Tract. Drainage in the vicinity of former piles 1, 4, 5, 6, and the southern portion of pile 7 is southwest toward Tordilla Creek, which flows through the Bargmann property (U.S. DOE 1979). Tordilla Creek is an ephemeral stream originating on the former mill site property. It intersects a surface deposit of uranium ore in at least two locations between 200 and 500 m (about 700 and 1600 ft) before entering the Bargmann Tract, then trends southwest across the property (Fig. 3). The creek varies in width from about 3 to 8 m (10 to 26 ft); the banks reach heights of 1.5 to 2.5 m (about 5 to 8 ft) through most of the property. Flood debris in the upper portions of the creek banks and in the vegetation beside the creek indicates that intense rain has caused localized flooding.

Wind direction at Beeville, 43 miles southeast of the mill, is reported to be representative of the prevailing patterns of the area. "Dominant low-level air flow throughout the year is from the south or southeast. Northerly winds occur briefly following the passage of winter cold fronts, but the normal southerly air flow is soon reestablished" (U.S. DOE 1979).

4. INCLUSION SURVEY METHODS

The following methods were employed for the inclusion survey. Gamma exposure rate measurements and soil sample collection followed procedures defined in the *Vicinity Properties Management and Implementation Manual* (U.S. DOE 1988), and the *ORNL Environmental Technology Section (Formerly Pollutant Assessment Group) Procedures Manual,* (ORNL 1993).

4.1 Literature Search

Historical literature describing the geologic, stratigraphic, and radiometric features of the Bargmann Tract and former mill site was examined along with radiological investigations of the former mill site.

4.2 Gamma Exposure Rates

Pressurized ionization chamber measurements were taken at 30 locations off the property (Fig. 4). Linear regression established a curve to convert gamma scintillometer measurements in thousand counts per minute (kcpm) to gamma exposure rates in μR/h.

Conversion formula: $y = mx + b$

where

y = exposure rate in μR/h
x = scintillometer measurement in kcpm
m = slope of the curve = 0.989
b = y-intercept of the curve = 5.30

4.3 Satellite Telemetry

The gamma survey employed data-logging gamma scintillometers linked to laptop computers carried in backpacks. A satellite Global Positioning System (GPS) tracked the surveyors' locations on the property to within one meter. Each day the computers' internal clocks were set to Greenwich Mean Time and synchronized with the GPS. Data from the scintillometers were merged with the GPS data to combine surveyors' locations with gamma activity on the property.

Gamma exposure rates in Tordilla Creek were measured during two walk-through surveys. Due to the presence of thick overhead foliage, continuous GPS tracking was combined with fixed-point data.

4.4 Soil Sampling

All samples were analyzed for ^{226}Ra; selected samples were also analyzed for total uranium. Samples were collected with a bucket auger (Fig. 6g).

4.4.1 Systematic Sampling

Samples taken systematically were collected from pre-established sampling points, usually at measured distances apart, irrespective of gamma exposure rates. Soil samples were collected systematically every 100 m along the east boundary of the property, at approximately 300-m intervals beside a road near the west boundary, beside a central road and Tower 2 road in the lower and upper portion of the property, and at various intervals along Tordilla Creek.

4.4.1.1 Systematic Sampling for Windblown Contamination

Systematic surface samples from the east border were collected using procedures designed to test for the presence of windblown contamination. If ^{226}Ra-bearing tailings were carried by wind from the former mill site to the Bargmann Tract, it was assumed that contamination would reside in the upper few centimeters of soil. At each systematic sampling location along the east fence line, one sample was collected from the 0- to 2.5-cm depth interval and the next was taken from 2.5 to 15 cm.

4.4.2 Biased Sampling

When accessible areas had been surveyed for gamma activity, biased samples were collected at the locations of the highest gamma measurements; these included the areas of anomalously high gamma activity identified in the 1955 aerial survey.

4.4.2.1 120-cm Auger Holes

To confirm the presence of the Conquista Clay member in a gamma anomaly on the east property line, six holes were drilled to depths up to 120 cm using a Little Beaver gas-powered auger. Composite samples were collected from auger cuttings.

4.5 Lithologic and Stratigraphic Descriptions

Lithology and stratigraphy of surface soils and outcrops were described during the survey and correlated with historical data.

4.6 Soil Sample Analysis

^{226}Ra analyses were performed by gamma spectrometry in the ORNL Grand Junction radiometric laboratory. Samples that were selected for both total uranium and ^{226}Ra analysis were analyzed by the DOE Grand Junction Projects Office Analytical Laboratory. Radium was analyzed by gamma spectrometry; uranium was analyzed by acid digestion/inductively coupled plasma-mass spectrometry.

5. SURVEY RESULTS

The majority of the Bargmann Tract was undisturbed land and contained dense vegetation that rendered portions of the property inaccessible. Based on potential transport mechanisms for depositing mill tailings on the property (i.e., wind, motor vehicle, and surface water), areas selected for soil sampling included the east and west boundaries, major roads and drainages, and locations at which the inclusion survey identified anomalously high gamma activity. The systematic and biased sampling locations have been grouped into seven general areas for discussion. These areas are shown on Fig. 7.

Myrick et al. (1981) determined the Texas background concentration of ^{226}Ra in soil to be 0.89 pCi/g. The 1986 radiological characterization of the Falls City mill site derived a background concentration for nearby non-uranium-bearing soils that ranged from 1.5 to 3.7 pCi/g and averaged 2.4 pCi/g (Marutzky et al. 1986). In this report, soil samples containing less than 5 pCi/g

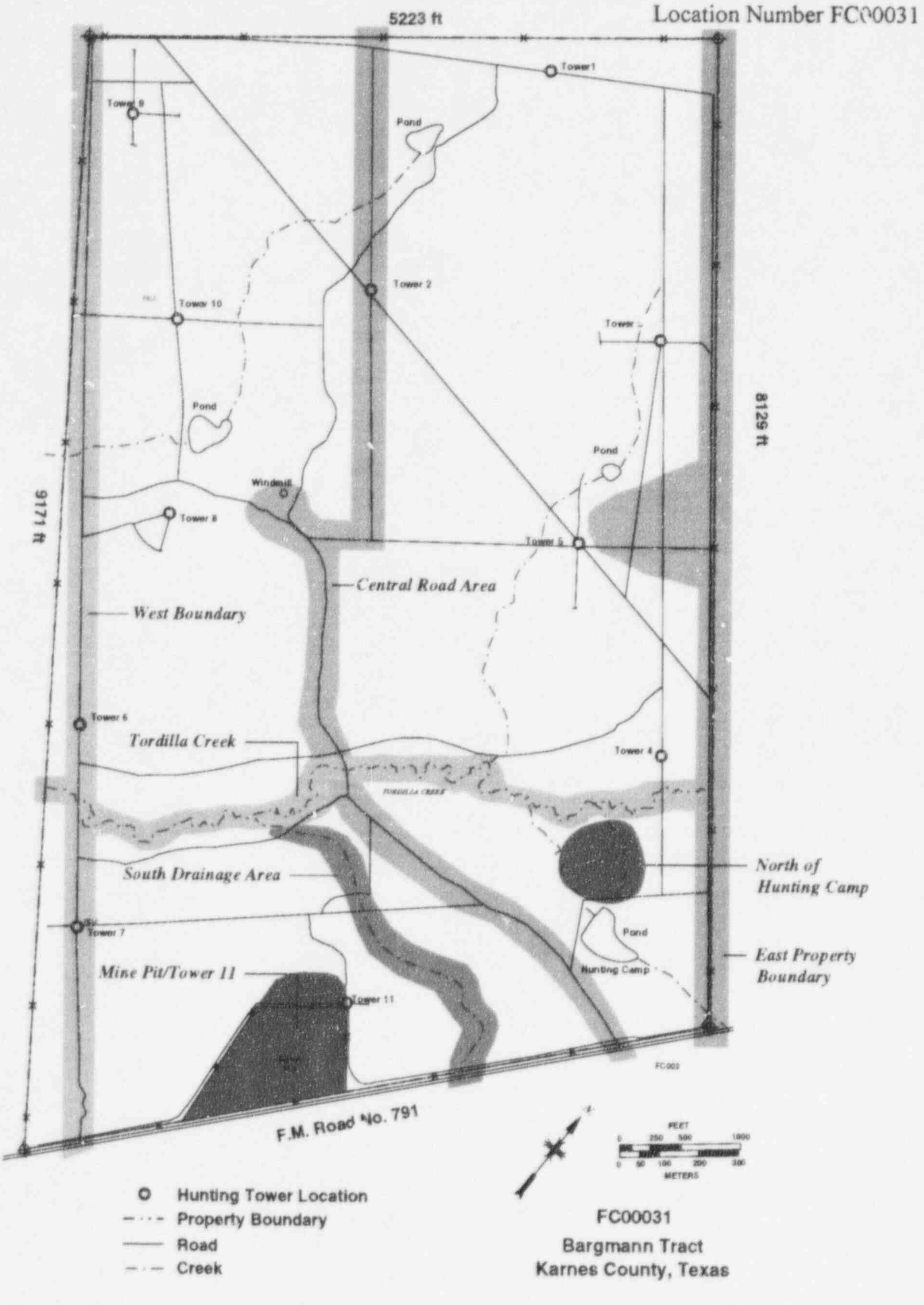


Fig. 7. Section 5 discussion areas.

^{226}Ra are considered to be within background range; samples containing 5 or more pCi/g are described as "elevated." This value was used because it corresponds to an UMTRA Project standard for surface soil.

Background gamma exposure rates on the mill site property ranged from about 10 to 13 μR/h (Marutzky et al. 1986). Excluding naturally occurring uranium-bearing soils and outcrops, background gamma exposure rates on the Bargmann Tract found during the inclusion survey ranged from 7 to 15 μR/h.

5.1 East Property Boundary

The east property boundary area is shown on Fig. 7, soil sample analytical results and gamma exposure rates at the sample locations are shown in Table 3, gamma exposure rates in the study area are indicated by color on Fig. 2. Samples associated with the east boundary include those taken systematically along the fence line to test for windblown contamination (S1 through S25), samples taken with the gas-powered auger (S69 through S75), and biased samples collected in areas of elevated gamma activity (S26, S27, and S63 through S66) (Fig. 2).

5.1.1 Systematic Sampling for Windblown Contamination

Surface gamma exposure rates at the systematic sampling points ranged from 9 to 20 μR/h. The east boundary of the property is closest to the location of the former tailings piles, the near edge of which was about 900 m (3000 ft) northeast of the property line. Samples from the fence line were collected every 100 m (330 ft). Concentrations of ^{226}Ra in the samples taken from the 0- to 2.5-cm depth interval were compared to the concentrations in the 2.5- to 15-cm interval. A statistical comparison conducted on 25 pairs of samples from the east fence line produced the following results:

- The median ^{226}Ra concentration in the 0- to 2.5-cm interval is not significantly shifted above the median concentration in the 2.5- to 15-cm interval (Fig. 8).

- Concentrations of ^{226}Ra in the 0- to 2.5-cm interval are well correlated to those in the 2.5- to 15-cm interval; i.e., elevated concentrations in the upper interval are associated with elevated concentrations in the lower interval and low concentrations in the upper interval are associated with low concentrations in the lower interval (Fig. 9). There were no cases in which a sample had a high concentration in the upper interval and a low concentration in the lower interval as would be expected if windblown tailings were underlain by soil containing background concentrations of ^{226}Ra.

- Five of the ten largest ^{226}Ra concentrations are from the 2.5- to 15-cm interval. If windblown contamination were present, a disproportionate share of the higher values would be expected in the upper soil interval.

Table 3. East property boundary

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, μR/h
S1 A	0 to 2.5	3.0	surface	12
S1 B	2.5 to 15	2.8	2.5	12
S1 C	15 to 30	2.5	15	13
			30	14
S2 A	0 to 2.5	1.5	surface	10
S2 B	2.5 to 15	1.5	2.5	11
S2 C	15 to 30	<1.5	15	11
			30	12
S3 A	0 to 2.5	3.4	surface	11
S3 B	2.5 to 15	2.3	2.5	11
S3 C	15 to 30	3.1	15	13
			30	15
S4 A	0 to 2.5	2.8	surface	11
S4 B	2.5 to 15	3.1	2.5	12
S4 C	15 to 30	2.6	15	13
			30	18
S5 A	0 to 2.5	8.0	surface	15
S5 B	2.5 to 15	8.8	2.5	16
S5 C	15 to 30	10	15	19
			30	20
S6 A	0 to 2.5	4.3	surface	13
S6 B	2.5 to 15	4.1	2.5	14
S6 C	15 to 30	4.7	15	15
			30	18
S7 A	0 to 2.5	4.2	surface	12
S7 B	2.5 to 15	3.9	2.5	13
S7 C	15 to 30	5.6	15	17
			30	18
S8 A	0 to 2.5	3.1	surface	12
S8 B	2.5 to 15	3.6	2.5	14
S8 C	15 to 30	4.2	15	16
			30	19
S9 A	0 to 2.5	4.7	surface	12
S9 B	2.5 to 15	3.8	2.5	13
S9 C	15 to 30	3.7	15	15
			30	15

Table 3. East property boundary (continued)

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, μR/h
S10 A	0 to 2.5	2.4	surface	10
S10 B	2.5 to 15	2.4	2.5	11
S10 C	15 to 30	2.5	15	11
			30	12
S11 A	0 to 2.5	6.8[a]	surface	12
S11 B	2.5 to 15	4.7[a]	2.5	13
S11 C	15 to 30	4.9[a]	15	13
			30	16
S12 AA	0 to 2.5	14	surface	17
S12 BA	2.5 to 15	11	2.5	19
S12 CA	15 to 30	9.9[a]	15	22
			30	26
S13 A	0 to 2.5	17	surface	20
S13 B	2.5 to 15	18	2.5	20
S13 C	15 to 30	13	15	30
			30	35
S14 A	0 to 2.5	11	surface	18
S14 B	2.5 to 15	8.0[a]	2.5	18
S14 C	15 to 30	14	15	25
			30	35
S15 A	0 to 2.5	8.4	surface	14
S15 B	2.5 to 15	7.6	2.5	14
S15 C	15 to 30	8.0	15	17
			30	20
S16 A	0 to 2.5	6.5	surface	12
S16 B	2.5 to 15	6.3	2.5	12
S16 C	15 to 30	6.7	15	15
			30	18
S17 A	0 to 2.5	2.0	surface	10
S17 B	2.5 to 15	2.4	2.5	10
S17 C	15 to 30	1.8	15	11
			30	12
S18A	0 to 2.5	2.4	surface	9
S18 B	2.5 to 15	2.2	2.5	10
S18 C	15 to 30	2.2	15	11
			30	12

Table 3. East property boundary (continued)

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, $\mu R/h$
S19 A	0 to 2.5	2.2	surface	9
S19 B	2.5 to 15	1.9	2.5	9
S19 C	15 to 30	1.9	15	10
			30	11
S20 A	0 to 2.5	1.8	surface	9
S20 B	2.5 to 15	1.9	2.5	9
S20 C	15 to 30	1.6	15	10
			30	12
S21 A	0 to 2.5	1.6	surface	9
S21 B	2.5 to 15	<1.5	2.5	9
S21 C	15 to 30	<1.5	15	10
			30	11
S22 A	0 to 2.5	<1.5	surface	9
S22 B	2.5 to 15	<1.5	2.5	9
S22 C	15 to 30	<1.5	15	11
			30	11
S23 A	0 to 2.5	1.9	surface	10
S23 B	2.5 to 15	1.8	2.5	10
S23 C	15 to 30	2.1	15	11
			30	13
S24 A	0 to 2.5	2.2	surface	10
S24 B	2.5 to 15	2.3	2.5	10
S24 C	15 to 30	2.5	15	11
			30	12
S25 A	0 to 2.5	2.3	surface	10
S25 B	2.5 to 15	2.2	2.5	11
S25 C	15 to 30	2.4	15	12
			30	13
S26 A	0 to 15	150	surface	49
S26 B	15 to 30	81	15	63
			30	58
S27 A	0 to 15	130	surface	48
S27 B	15 to 30	68	15	70
			30	55

Table 3. East property boundary (continued)

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, μR/h
S63 A	0 to 15	10	surface	16
S63 B	15 to 30	12	15	21
S63 C	30 to 45	18	30	28
			45	32
S64 A	0 to 15	12	surface	17
S64 B	15 to 30	21	15	25
S64 C	30 to 45	19	30	35
			45	37
S65 A	0 to 15	34	surface	27
S65 B	15 to 30	41	15	43
S65 C	30 to 45	32	30	52
			45	62
S66 A	0 to 15	37	surface	30
S66 B	15 to 30	45	15	52
S66 C	30 to 45	75	30	79
			45	130
S69 A	0 to 91	14[a]	surface	19
S69 B	91 to 120	11[a]	91	30
			120	32
S70 A	0 to 91	10[a]	surface	15
S70 B	91 to 120	6.7[a]	46	23
			81	26
			107	21
S71 A	0 to 91	11[a]	surface	15
S71 B	91 to 120	9.6[a]	61	33
			120	32
S72 A	0 to 99	43[a]	surface	22
			30	84
			61	110
			99	65
S73 A	0 to 91	16[a]	surface	18
			45	37
			66	30
			91	25

Table 3. East property boundary (continued)

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, μR/h
S74 A	0 to 91	34[a]	surface	18
S74 B	91 to 120	54[a]	5	35
			15	55
			53	84
			76	110
			130	100
S75 A	0 to 76	3.2[a]	surface	10
S75 B	76 to 91	5.1[a]	30	15
			76	20
			91	20

[a] Analytical results are from the Department of Energy Grand Junction Projects Office Analytical Laboratory, Project 6R0004210, January 4, 1996, February 14, 1996, and March 4, 1996.

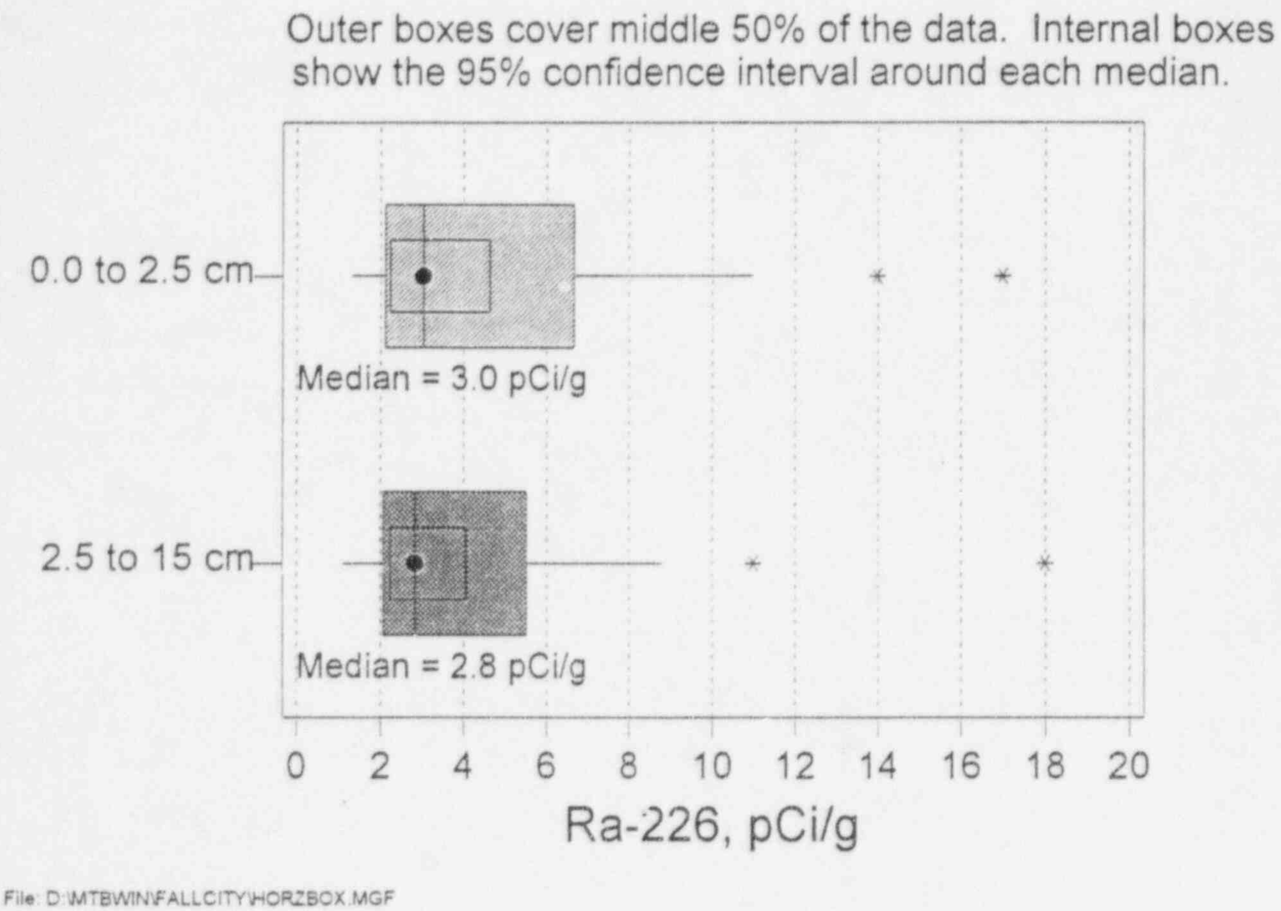


Fig. 8. Box plot illustrating median concentration in soil samples tested for windblown contamination along the east fence line.

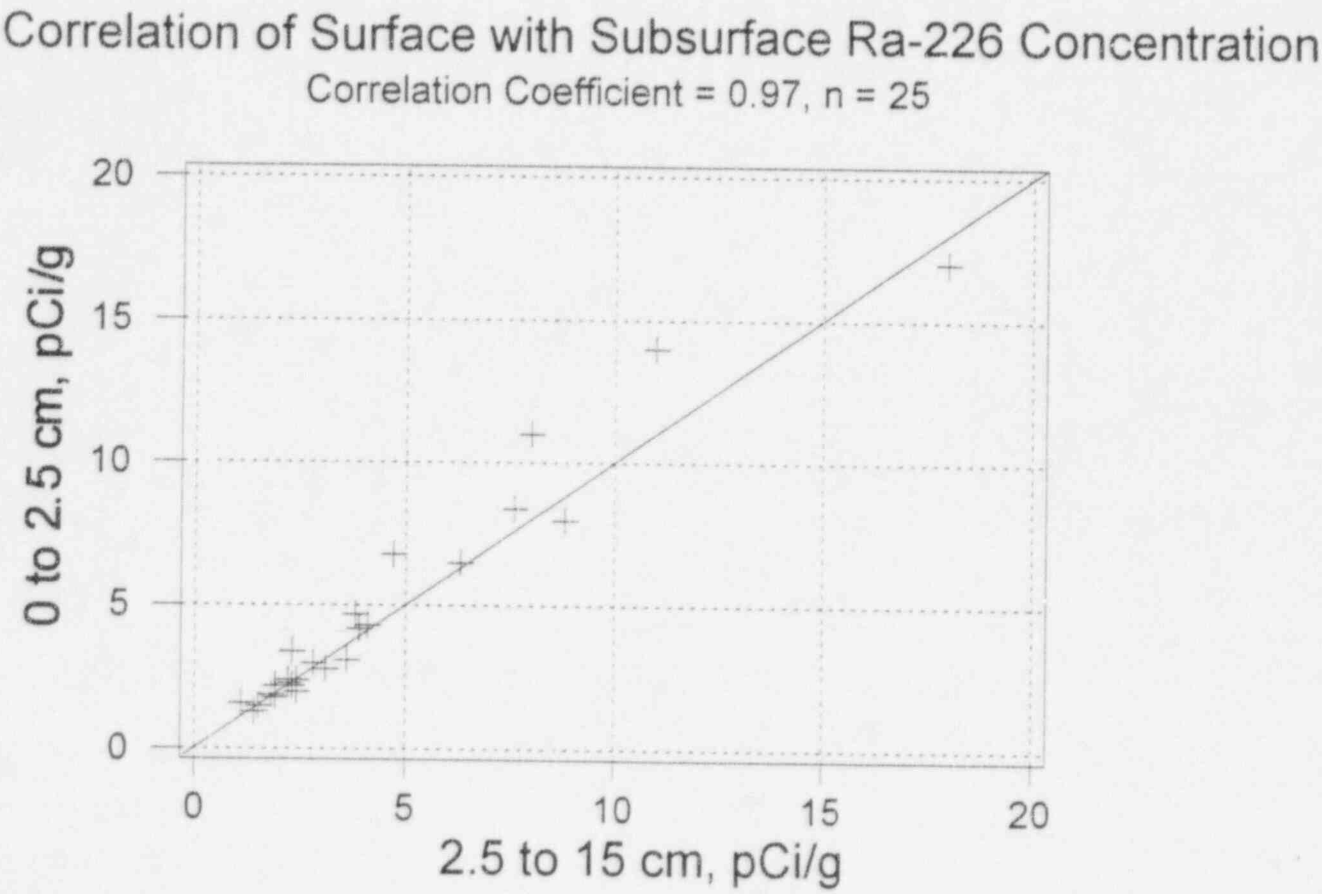


Fig. 9. Correlation of 0 to 2.5 and 2.5- to 15-cm intervals in samples tested for windblown contamination along the east fence line.

Two areas of high gamma activity identified in the 1955 aerial radiometric survey are located on the east property line (Fig.2). Four sampling points on the east fence line grid that were situated on these anomalies contained ^{226}Ra in concentrations ranging from 8 to 18 pCi/g (Table 3).

5.1.2 Biased Samples from 120-cm Auger Holes

Surface gamma exposure rates at the sample locations ranged from 10 to 22 μR/h. Samples S69 through S75 were collected from the larger anomalous area at depths up to 120 cm (Fig. 2). Holes were drilled with a gas-powered auger. The soil consisted of dark-gray clay grading into a light reddish-brown to reddish-yellow weathered siltstone at about 90 cm below the surface. Contact with the indurated Conquista Clay member occurred at about 120 cm. Radium-226 in soil samples from the anomalous area ranged from 10 to 43 pCi/g in the upper 91 cm and 6.7 to 54 pCi/g in the bottom 30 cm. A sample collected at Tower 5, approximately 120 m west of the anomalous area, contained 3.1 pCi/g in the upper 76 cm of soil and 5.1 pCi/g in the 76- to 91-cm interval. The occurrence of elevated concentrations of radium at depths up to 120 cm in undisturbed soil indicates that the material is naturally occurring.

5.1.3 Biased Samples from Tower 3 and Tower 5 Roads

Four biased samples (S63 through S66) were collected from the edges of the roads to Towers 3 and 5 and contained ^{226}Ra in concentrations ranging from 10 to 75 pCi/g (Fig. 2). Concentrations increased in all four samples in the subsurface 15- to 45-cm depth intervals. Surface gamma exposure rates at the sample locations ranged from 16 to 30 μR/h.

5.1.4 Biased Samples in the Southeast Corner

Bulldozing and scraping of the road in the southeast corner of the property left several piles of debris consisting of soil and rocks mixed with weeds and brush. Concentrations of ^{226}Ra in soil samples S26 and S27 collected from these piles ranged from 68 to 150 pCi/g (Fig. 2). Gamma exposure rates around the piles and in an area of undisturbed soil extending to the east property line ranged from 16 to 49 μR/h. The soil in the debris piles and the surrounding undisturbed soil was a dark brown sandy clay indistinguishable from sediments found elsewhere on the property. Samples S1 and S2 collected from the fence line approximately 12 m east of the debris piles contained background concentrations of radium.

5.1.5 Evaluation of Data from Areas of the East Property Boundary

Analytical results and a statistical comparison of samples from the east fence line do not indicate that windblown contamination is present. All samples containing ^{226}Ra in concentrations higher than background are in or near regions of known uranium deposits. The physical appearance of the soil where samples were collected from 120-cm auger holes, Tower 5 road, and the southeast corner is consistent with historical descriptions of the area and with undisturbed sediments encountered during this survey. Radioactivity in these areas of study is attributed to naturally occurring materials in the Conquista Clay/Deweesville sequence and Quaternary alluvium.

5.2 Central Road Area

The main access through the property is along a road that begins in the southeast corner at Farm Road 791 and trends west and northwest through the central portion of the tract (Fig. 7). Samples were taken systematically at the edge of two roads: the main access road in the lower portion of the area and the road to Tower 2 in the upper portion. The roads pass through two gamma anomalies identified in the 1955 aerial radiometric survey and confirmed during the inclusion survey. Samples were taken systematically at the edge of the road throughout the length of the property; biased samples were collected in the gamma anomalies and in an area of elevated gamma activity detected near a windmill (Fig. 2).

5.2.1 Systematic Samples from the Road

Samples S35 through S44 were collected systematically from the side of the road at depths up to 45 cm (Table 4). Samples S35 and S36, from the road between Farm Road 791 and the first gamma anomaly, contained background concentrations of radium; where the road passed over the first anomaly, radium concentrations increased, ranging from 25 to 30 pCi/g in the 0- to 45-cm depth intervals in sample S37. Sample S38, collected next to the road approximately 100 m (330 ft) south of Tordilla Creek, contained 16 pCi/g ^{226}Ra in the surface 15-cm depth interval and 4.1 pCi/g in the 15- to 30-cm interval. Soil at this sampling location is a dark brown clay typical of alluvium in the Tordilla Creek drainage. Samples S39 and S40 were collected where the road passed over the second gamma anomaly. Radium concentrations in these samples ranged from 4.2 to 7.6 pCi/g. Samples S41 through S44, collected from the road at points between the second gamma anomaly and the north property line, had background concentrations of radium. Surface gamma exposure rates at the systematic sampling locations ranged from 9 to 26 μR/h.

5.2.2 Biased Samples from the Central Road and Tower 7 Road Junction

South of Tordilla Creek, the central road intersects a gamma anomaly identified in the 1955 aerial survey (Fig. 2). Samples S30, S56, and S57 were collected in this anomaly, where gamma exposure rates ranged from 16 to 47 μR/h. Radium concentrations in the soil samples ranged from 18 to 75 pCi/g at depths up to 60 cm. Soil at the sample locations had the physical appearance of Conquista clay.

5.2.3 Biased Samples on the Central Road Between Tordilla Creek and Tower 5 Road

North of Tordilla Creek, the central road intersects another gamma anomaly identified in the 1955 aerial survey (Fig. 2). Elevated gamma activity was also confirmed in this area during the 1996 inclusion survey. Radium concentrations in samples S59 and S60 ranged from 33 to 44 pCi/g in depth intervals of 0 to 45 cm (Table 4). Soil at the sample locations in this area also had the physical appearance of Conquista Clay. Surface gamma exposure rates ranged from 16 to 35 μR/h.

Table 4. Central road area

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, $\mu R/h$
S30 A	0 to 15	56	surface	47
S30 B	15 to 30	75	15	100
S30 C	30 to 45	60	30	100
			45	100
S35 B	0 to 15	2.5	surface	10
S35 C	15 to 30	2.5	15	12
			30	13
S36 A	0 to 15	2.7	surface	11
S36 B	15 to 30	4.5	15	14
			30	16
S37 A	0 to 15	25[a]	surface	26
S37 B	15 to 30	29[a]	15	36
S37 C	30 to 45	30[a]	30	55
			45	55
S38 A	0 to 15	16	surface	12
S38 B	15 to 30	4.1	15	17
			30	17
S39 A	0 to 15	7.6	surface	15
S39 B	15 to 30	6.3	15	18
			30	18
S40 A	0 to 15	5.9	surface	14
S40 B	15 to 30	4.2	15	17
			30	17
S41 A	0 to 15	3.0	surface	10
S41 B	15 to 30	3.7	15	12
S41 C	30 to 45	3.3	30	14
			45	15
S42 A	0 to 15	3.7	surface	11
S42 B	15 to 30	3.8	15	14
			30	15
S43 A	0 to 15	1.8	surface	10
S43 B	15 to 30	2.0	15	10
			30	12
S44	0 to 15	<1.5	surface	9
			15	10

Table 4. Central road area (continued)

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, μR/h
S30 A	0 to 15	56	surface	47
S30 B	15 to 30	75	15	100
S30 C	30 to 45	60	30	100
			45	100
S56 A	0 to 15	26	surface	25
S56 B	15 to 30	34	15	35
S56 C	30 to 45	45	30	55
S56 D	45 to 60	39	45	70
			60	63
S57 A	0 to 15	27	surface	23
S57 B	15 to 30	23	15	35
S57 C	30 to 45	18	30	48
S57 D	45 to 60	19	45	55
			60	60
S59 A	0 to 15	40	surface	35
S59 B	15 to 15	38	15	48
S59 C	30 to 45	33	30	65
S60 A	0 to 15	36[a]	surface	35
S60 B	15 to 30	42[a]	15	60
S60 C	30 to 45	44[a]	30	77
			45	94
S61 A	0 to 15	17	surface	20
S61 B	15 to 30	25	15	38
S61 C	30 to 45	44	30	60
			45	94
			60	94
S62 A	0 to 15	18	surface	20
S62 B	15 to 30	28	15	40
S62 C	30 to 45	30	30	55
			45	67

[a] Analytical results are from the Department of Energy Grand Junction Projects Office Analytical Laboratory, Project 6R0004210, January 4, 1996, February 14, 1996, and March 4, 1996.

5.2.4 Biased Samples Near the Windmill

An area of elevated gamma activity ranging from 16 to 20 μR/h was detected during the inclusion survey in the vicinity of a windmill north of the intersection of the central road and Tower 5 road (Fig. 2). Radium concentrations in samples S61 and S62 ranged from 17 to 44 pCi/g at depths up to 45 cm (Table 4). The gamma survey of the windmill area also included a nearby disturbed area where stock tanks and corrals had been placed. No surface elevated gamma activity was found at this location. Soil in the windmill area consisted of weathered Conquista Clay.

5.2.5 Evaluation of Central Road Area Data

Elevated ^{226}Ra in soil samples from gamma anomalies identified in the 1955 aerial survey is attributable to naturally occurring radionuclides in the soil. None of the sample locations are in a topographical area that receives drainage from the former mill site property. Soil at all sample locations had a physical appearance typical of the Conquista Clay/Deweesville sequence and alluvium identified on the property. There is no reason to assume that tailings were transported by motor vehicle and deposited on this portion of the property. All elevated ^{226}Ra in the central road area is attributed to naturally occurring radionuclides.

5.3 West Boundary

An access road beginning near Farm Road 791 about 140 m (470 ft) east of the southwest corner of the property runs northwest to the northwest corner (Fig. 7). The road runs through three gamma anomalies found in the 1955 aerial radiometric survey and confirmed during the inclusion survey. Samples collected systematically from the road included samples from the two lower anomalies; biased samples were collected at locations of the highest gamma measurements in the gamma anomaly near Tower 7 (Fig. 2). Sample analytical results are shown in Table 5.

5.3.1 Systematic Samples from the Road

Samples S45 through S50, collected beside the road north of the Tordilla Creek crossing, contained background concentrations of ^{226}Ra. Samples S51 through S53 were located in the gamma anomalies and contained ^{226}Ra in concentrations ranging from 9 to 17 pCi/g at depths of 0 to 45 cm (Fig. 2). Surface gamma exposure rates on the road ranged from 8 to 17 μR/h.

5.3.2 Biased Samples from the Gamma Anomaly Near Tower 7

Elevated gamma exposure rates in the Tower 7 area, identified in the inclusion survey and in the 1955 aerial survey, ranged from 7 to 20 μR/h. Radium concentrations in samples S78 and S79 ranged from 7.3 to 28 pCi/g at depths of 0 to 45 cm (Fig. 2).

Table 5. West property boundary

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, $\mu R/h$
S45	0 to 15	1.6	surface	9
			15	10
S46	0 to 15	<1.5	surface	9
			15	10
S47	0 to 15	<1.5	surface	10
			15	11
S48	0 to 15	<1.5	surface	10
			15	11
S49	0 to 15	<1.5	surface	8
			15	9
S50 A	0 to 15	2.0	surface	10
S50 B	15 to 30	2.1	15	12
			30	15
S51 A	0 to 15	9.0	surface	15
S51 B	15 to 30	10	15	17
S51 C	30 to 45	13	30	22
			45	25
S52 A	0 to 15	15	surface	17
S52 B	15 to 30	17	15	21
S52 C	30 to 45	14	30	25
			45	30
S53 A	0 to 15	11	surface	16
S53 B	15 to 30	9.3	15	20
S53 C	30 to 45	9.9	30	27
			45	35
			60	50
S78 A	0 to 15	28[a]	surface	20
S78 B	15 to 30	27[a]	15	35
S78 C	30 to 45	12[a]	30	40
			45	39
S79 A	0 to 15	7.3	surface	15
S79 B	15 to 30	7.3	15	17
S79 C	30 to 45	9.0	30	20
			45	25

[a] Analytical results are from the Department of Energy Grand Junction Projects Office Analytical Laboratory, Project 6R0004210, January 4, 1996, February 14, 1996, and March 4, 1996.

5.3.3 Evaluation of Data

All samples from the west boundary area that contained ^{226}Ra in elevated concentrations were located in areas of anomalously high gamma activity identified in the 1955 aerial survey. The fact that elevated ^{226}Ra concentrations and gamma exposure rates were found at depths up to 45 cm indicates that the samples were collected in soil containing radium-bearing minerals. All elevated ^{226}Ra in the soil of this study area is attributed to naturally occurring radionuclides.

5.4 Tordilla Creek

Tordilla Creek begins on the north central portion of the former mill site property and drains southeast past the former tailings piles and the overburden of a former open-pit mine in the Nuhn ore body (Fig. 3) at a distance of approximately 300 m (1000 ft) west of the piles, then turns west and enters the east boundary of the Bargmann Tract about 600 m (2000 ft) north of Farm Road 791 and traverses the property (Figs. 3 and 7). Drainage in the location of former tailings piles 1, 4, 5, 6, and the southern portion of pile 7 is southwest toward Tordilla Creek (U.S. DOE 1979) (Fig. 3). Soil samples were collected systematically from the stream bed on the Bargmann Tract; biased samples were collected at locations where elevated gamma exposure rates were detected in the stream bed and side walls of the stream bank. Sample analytical results are shown in Table 6.

5.4.1 Systematic Sampling in the Stream Bed

Soil samples T1 through T3 and T7 through T17 were collected systematically in the stream bed from the east property line to the point where the stream exits the property at the west boundary. Surface gamma exposure rates at the systematic sampling points ranged from 12 to 15 μR/h. Samples T1, T8, T9, T14 and T15 contained radium in concentrations up to 11 pCi/g at depths of 0 to 30 cm; radium concentrations in sample T7 ranged up to 7.2 pCi/g at a depth of 60 cm. Sample T8 was collected from a delta deposit of sand where a small drainage channel joins Tordilla Creek. Gamma exposure rates at the sampling location ranged from 15 μR/h on the surface to 18 μR/h at a depth of 30 cm.

5.4.2 Biased Sampling

Samples B1, S28, T4, T5, and T6 were collected in areas of the stream where gamma activity ranged from 15 to 32 μR/h (Fig. 2). Sample S28 was taken in the stream bed at the intersection of the creek and the east property line where the gamma exposure rate was 30 μR/h (Fig. 6d). Concentrations of ^{226}Ra were 21 pCi/g in the 0- to 15-cm interval and 25 pCi/g in the 15- to 30-cm interval. The soil at sample location S28 was a dark-gray sandy clay with organic material.

Sample T4, collected in the stream bed approximately 240 m (800 ft) downstream from the point of entrance to the property, contained 39 pCi/g ^{226}Ra in the 0- to 15-cm interval. Gamma exposure rates at sample location T4 were 25 μR/h on the surface, 32 μR/h at 5 cm, and 30 μR/h at 15 cm.

Table 6. Tordilla Creek area

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, $\mu R/h$
T1 A	0 to 15	5.5	surface	14
T1 B	15 to 30	6.6	15	17
			30	17
T2 A	0 to 15	4.9	surface	15
T2 B	15 to 30	4.2	15	16
			30	17
T3 A	0 to 15	2.4	surface	13
T3 B	15 to 30	2.3	15	13
			30	15
T4	0 to 15	39[a]	surface	25
			5	32
			15	30
T5 A	0 to 15	49	surface	32
T5 B	15 to 30	11	15	45
			30	30
T6	side wall of bank	59[a]		31
T7 A	0 to 15	4.4	surface	15
T7 B	15 to 30	6.3	15	16
T7 C	30 to 45	3.8	30	19
T7 D	45 to 60	7.2	45	22
			60	23
T8 A	0 to 15	6.1	surface	15
T8 B	15 to 30	5.6	15	17
			30	18
T9 A	0 to 15	6.7[a]	surface	15
T9 B	15 to 30	4.5[a]	15	15
			30	17
T10 A	0 to 15	4.2	surface	15
T10 B	15 to 30	3.9	15	15
			30	18
T11 A	0 to 15	3.3	surface	14
T11 B	15 to 30	2.9	15	15
			30	17

Table 6. Tordilla Creek area (continued)

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, μR/h
T12 A	0 to 15	4.5	surface	13
T12 B	15 to 30	4.4	15	17
			30	17
T13 A	0 to 15	3.2	surface	12
T13 B	15 to 30	3.1	15	13
			30	13
T14 A	0 to 15	11[a]	surface	14
T14 B	15 to 30	5.9[a]	15	19
			30	18
T15 A	0 to 15	5.7	surface	14
T15 B	15 to 30	4.8	15	15
			30	16
T16 A	0 to 15	2.3	surface	12
T16 B	15 to 30	3.1	15	13
T16 C	30 to 45	4.4	30	17
			45	17
B1	side wall of bank	14		15
T17 A	0 to 15	4.1	surface	13
T17 B	15 to 30	4.6	15	17
			30	17
S28 A	0 to 15	21[a]	surface	30
S28 B	15 to 30	25[a]	15	35
			30	40
			45	27
S58 A	0 to 15	3.3	surface	12
S58 B	15 to 30	2.8	15	17
			30	17

[a] Analytical results are from the Department of Energy Grand Junction Projects Office Analytical Laboratory, Project 6R0004210, January 4, 1996, February 14, 1996, and March 4, 1996.

In many locations throughout the length of the creek on the Bargmann Tract, a 30-cm-wide band of elevated (15 to 31 μR/h) gamma exposure rates was detected approximately 75 cm below the top of the bank. The band is not distinguishable by color but has a slightly higher sand content than the surrounding soil of the creek bank, which is a brown to dark-gray clay and sandy clay. Samples B1 and T6 were collected by digging horizontally into the bank in the band of elevated gamma. These samples contained 14 and 59 pCi/g ^{226}Ra. Sample T5, collected from a sloping portion of the bank directly below T6, contained 49 pCi/g in the 0- to 15-cm interval and 11 pCi/g in the 15- to 30-cm interval. The surface gamma exposure rate at the T5 sampling point was 32 μR/h.

Sample S58 was collected from a deposit of sand beside a road approximately 70 m (230 ft) north of the creek. Radium concentrations in the sample were 3.3 and 2.8 pCi/g in the 0- to 15- and 15- to 30-cm intervals. Gamma exposure rates were 12 μR/h on the ground surface and 17 μR/h at depths of 15 and 30 cm.

5.4.3 Evaluation of Data from Tordilla Creek

The creek bed soil is clay to sandy clay of low permeability, as evidenced by occasional mud cracks and pools of standing water. Flood debris high in the bank and in the vegetation above the bank indicates that intense rains have flooded the creek on occasion. Except for deposits of fine sand at the confluences of small tributaries, the stream bed has no appreciable deposition. Although no data were available regarding discharge rates and the frequency of flooding, the appearance of the bed indicates that through time flood events result in a net scouring rather than deposition. Consequently, it is likely that any material carried into the stream from the former mill site property before the tailings piles were stabilized in 1986 has since been carried downstream off the Bargmann Tract. Identifying a potential contribution of mill tailings to the elevated ^{226}Ra and gamma activity in the stream bed is made nearly impossible by the fact that Tordilla Creek intersects a surface uranium ore body (the Nuhn deposit) in at least two locations between the former tailings piles and the Bargmann Tract (Fig. 3). Elevated ^{226}Ra concentrations occurring in undisturbed sediments of the stream bank (samples B1, T5, and T6) and at depths of up to 60 cm in the scoured stream bed (samples T1, T4, T8, T9, T14, T15, and T28) strongly indicate that radium was deposited in the creek by naturally occurring radionuclides in the Conquista Clay/-Deweesville Sandstone sequence.

5.5 Mine Pit/Tower 2 Area

The southern boundary of the Bargmann Tract crosses a gamma anomaly identified in the 1955 aerial survey; a portion of the anomaly contains a uranium ore body known as the Bargmann-Hackney deposit (Figs. 2 and 7). An abandoned open-pit mine is located in the deposit (Fig. 2).

Sample S67, taken from the wall of the pit approximately 3 m below ground surface, contained 530 pCi/g ^{226}Ra. Sample S68, taken from fill material that formed a ramp for vehicle access to the interior of the pit, contained 390 pCi/g ^{226}Ra in the top 15 cm and 170 pCi/g in the 15- to 30-cm interval (Table 7). Sample S29, collected from a pile of soil and rock possibly excavated from the

Table 7. Mine pit/Tower 2 area

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, $\mu R/h$
S29 A	0 to 15	64	surface	45
S29 B	15 to 30	63	15	70
			30	81
S67	0 to 15	530[a]	surface	750
S68 A	0 to 15	390[a]	surface	150
S68 B	15 to 30	170[a]	15	210
			30	180
S76 A	0 to 15	31	surface	20
S76 B	15 to 30	24	15	27
S76 C	30 to 45	27	30	35
			45	45
S77 A	0 to 15	47	surface	35
S77 B	15 to 30	47	15	61
S77 C	30 to 45	70	30	84
			45	150

[a] Analytical results are from the Department of Energy Grand Junction Projects Office Analytical Laboratory, Project 6R0004210, January 4, 1996, February 14, 1996, and March 4, 1996.

mine, contained 64 pCi/g ^{226}Ra. The highest outdoor gamma (HOG) exposure rate in the accessible areas of the Bargmann Tract was measured on the south wall of the mine pit, where exposure rates ranged up to 750 μR/h.

Tower 2 is situated approximately 150 m (500 ft) north of the mine pit in a gamma anomaly identified in the 1955 aerial survey. Concentrations of ^{226}Ra in samples S76 and S77 ranged from 24 to 70 pCi/g at depths up to 45 cm (Table 7). These samples were collected to confirm that elevated gamma measurements in the vicinity of Tower 2 were not due solely to gamma radiation emanating from the mine pit. Gamma exposure rates around Tower 2 ranged from 20 to 84 μR/h.

5.5.1 Evaluation of Data

All samples in this study area were collected from a uranium ore deposit and a gamma anomaly associated with the ore deposit; the physical appearance of the soil at the sampling locations was consistent with the Deweesville Sandstone/Conquista Clay sequence. Elevated ^{226}Ra in the soil of this area is attributed to naturally occurring radioactive minerals.

5.6 North of the Hunting Camp

An area of elevated gamma activity north of a pond and hunting camp in the southeast portion of the property is a gamma anomaly identified in the 1955 aerial radiometric survey and confirmed during the inclusion survey (Fig. 7). Elevated gamma measurements in this area are associated with a 60-cm-thick outcrop of a sandstone unit of the Conquista Clay. The material consists of fine-grained, well-sorted, light-gray sandstone with thin lenses of limonite. The outcrop was exposed by a small drainage channel downcutting through the formation. Gamma exposure rates ranged up to 79 μR/h on contact with the sandstone. Soil samples S31 and S34, consisting of sandy soil collected directly from the weathered surface of the outcrop, had ^{226}Ra concentrations of 49 and 105 pCi/g in the 0- to 15-cm interval (Table 8 and Fig. 2).

5.6.1 Evaluation of Data

All alluvium and consolidated material in this study area are composed of soil of the Deweesville Sandstone and Conquista Clay sequence; elevated gamma activity and ^{226}Ra are attributed to naturally occurring radionuclides in the soil.

5.7 South Drainage Area

A small ephemeral drainage trends west and northwest through the southern boundary of the property and terminates at Tordilla Creek (Fig. 7). Elevated gamma exposure rates ranging from 12 to 30 μR/h were detected at the junction with an access road. Most of the stream bed was inaccessible (Fig. 2). Samples S32 and S33, collected from the stream sediment where the drainage washes across the access road, contained ^{226}Ra in concentrations of 61 and 53 pCi/g in the 0- to 15-cm

Table 8. North of hunting camp

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, $\mu R/h$
S31	0 to 15	49	surface	63
			15	100
S34	0 to 15	105[a]	surface	79
			15	140

[a] Analytical results are from the Department of Energy Grand Junction Projects Office Analytical Laboratory, Project 6R0004210, January 4, 1996, February 14, 1996, and March 4, 1996.

Table 9. South drainage area

Soil sample number	Sample depth, cm	^{226}Ra, pCi/g	Depth of gamma rate measurement, cm	Gamma exposure rate, $\mu R/h$
S32 A	0 to 15	61	surface	28
S32 B	15 to 30	20	15	60
			30	59
S33 A	0 to 15	53	surface	30
S33 B	15 to 30	48	15	58
			30	56
S54 A	0 to 15	4.2	surface	12
S54 B	15 to 30	5.1	15	17
			30	18
S55 A	0 to 15	5.3	surface	12
S55 B	15 to 30	4.3	15	15
			30	17
T13 A	0 to 15	3.2	surface	12
T13 B	15 to 30	3.1	13	13
			13	13

depth interval and 20 and 48 pCi/g in the 15- to 30-cm interval (Table 9). Sample S54 was collected from the channel sediment where downcutting had resumed immediately below the juncture with the access road. The samples were collected from sandy soil where water and sediment wash from a culvert that drains from the south side of Farm Road 791. Sample S55, taken from the drainage bed near Tower 7 road, contained 5.3 and 4.3 pCi/g respectively in the 0- to 15-cm and 15- to 30-cm intervals. Sample T13 was taken at the confluence with Tordilla Creek and contained 3.1 and 3.2 pCi/g in the surface and subsurface intervals. These results indicate that radioactive material is not moving downstream. An open pit mine in a body of uranium ore known as the Lauw deposit is located on the south side of Farm Road 791 approximately 640 m (2100 ft) upstream from the sample locations (Fig. 3). The mine and associated ore body are topographically about 18 m (60 ft) higher than the drainage channel at the juncture with Farm Road 791. All surface runoff from the west and southwest faces of the ore deposit in the mine area drains into the south drainage area.

5.7.1 Evaluation of Data

Drainage from the former mill site property does not pass through the south drainage channel on the Bargmann Tract. There is no evidence that suggests tailings were hauled by motor vehicle to the south drainage area. The physical appearance of the soil is consistent with historical descriptions of the lithologic sequence in the area. Consequently, elevated ^{226}Ra in the drainage channel is likely to be associated with naturally occurring minerals from the Lauw deposit and various outcrops of the Deweesville Sandstone/Conquista Clay contact zone.

6. SIGNIFICANCE OF FINDINGS

The presence of naturally occurring elevated gamma activity and uranium-bearing minerals on the Bargmann Tract was documented before mining and milling began in the area. Gamma anomalies identified during the 1955 aerial radiometric survey correlated well with areas of elevated gamma found during the inclusion survey.

Three transport mechanisms were considered for deposition of mill tailings from the former mill site onto the Bargmann Tract: wind, motor vehicle, and surface water.

- **Windblown contamination:** Because the east property line is closest to the former tailings piles, it is assumed that windblown mill tailings entering the Bargmann Tract must do so through the east boundary. A statistical analysis of 25 samples from the east fence line indicates that no windblown contamination is present.

- **Motor vehicle:** Sandy soil encountered on the property either had no elevated gamma associated with it or was derived from the Deweesville Sandstone/ Conquista Clay sequence. The physical appearance of the surface soil and soil samples was consistent with the lithology of the geologic formations and alluvium known to be at the Bargmann Tract. Historically, tailings material was hauled from a mill site to a property for a practical purpose, often because of its utility as a fill material. There is no discernable reason to haul tailings to the Bargmann Tract.

- **Surface water:** As discussed in Sect 2.1, by 1976 all the tailings piles except piles 2 and 7 had been stabilized; pile 2 was reported to be about 50% covered and pile 7 about 30% covered. According to the EA, pile 2 and the northern portion of pile 7 drain northeast, and therefore should not contribute sediments to the Tordilla Creek drainage. After 1976, only the southern portion of pile 7 had the potential to deliver material into Tordilla Creek. Although it cannot be demonstrated conclusively with present data that radium-bearing mill tailings have not been transported through the site by Tordilla Creek, evidence supports the following conclusions:

    1. Flooding of Tordilla Creek appears to result in a net scouring rather than deposition. Tailings flowing into the stream bed from the former mill site property are likely to have been carried downstream off the Bargmann Tract in the years after the piles were stabilized.

    2. All elevated ^{226}Ra in Tordilla Creek can be accounted for by the presence of naturally occurring radioactive material found in undisturbed sediments where the creek has downcut through uranium- and radium-bearing formations.

    3. Downstream from the former tailings piles and before entering the Bargmann Tract, Tordilla Creek flows through a portion of a surface uranium ore body (the Nuhn deposit). Tailings deposited in the creek on the Bargmann Tract would be indistinguishable from naturally occurring radionuclides transported by erosion of the ore body.

The EPA standard in 40 CFR 192.12 of 5 and 15 pCi/g above background for surface and subsurface soils applies to ^{226}Ra present on a property as a result of residual radioactive materials from any designated processing site (U.S. EPA 1983). Data collected during the inclusion survey effort indicate that all elevated gamma exposure rates and all elevated concentrations of ^{226}Ra encountered on the property can be accounted for by the presence of naturally occurring radioactive minerals in the geologic formations and Quaternary alluvium of the site. Consequently, this property does not meet the criteria for inclusion in the UMTRA Program.

Based on these findings, it is recommended that FC00031, the Bargmann Tract, be excluded from further consideration by the UMTRA Project.

7. RECOMMENDATION

Recommended for:	Exclusion
Recommendation Basis:	All elevated ^{226}Ra and gamma exposure rates on the property are due to naturally occurring radionuclides.

8. REFERENCES

Bunker, C. M., and J. A. MacKallor. 1973. *Geology of the Oxidized Uranium Ore Deposits of the Tordilla Hill-Deweesville Area, Karnes County, Texas, A Study of a District Before Mining.* Geological Survey Professional Paper 765. United States Government Printing Office, Washington DC.

Eargle, D. H., and J. L. Snider. 1957. *A Preliminary Report on the Stratigraphy of the Uranium-Bearing Rocks of the Karnes County Area, South-central Texas.* Report of Investigations–No. 30. Bureau of Economic Geology, The University of Texas, Austin, Texas.

EG&G. 1982. *An Aerial Radiological Survey of the Falls City Mill Site and Surrounding Area, Falls City, Texas.* EP-U-012. EG&G Energy Measurements Group, Inc., Las Vegas, Nevada.

Hodgens, R. G. 1958. *Geology of the Nuhn Lease Uranium Deposit, Western Karnes County, Texas.* RME-1085. U.S. Atomic Energy Commission, Grand Junction Operations Office, Production Evaluation Division, Denver Branch.

Marutzky, S. J., S. L. Knutson, and R. Colby. 1986. *Radiological Characterization of the Falls City, Texas, Uranium Mill Tailings Remedial Action Site* (GJ-47). U. S. Department of Energy, Grand Junction, Colorado.

MacKallor et al. 1996. *Radioactivity and Geologic Map of the Tordilla Hill-Deweesville Area, Karnes County, Texas.* U. S. Geological Survey, Geophysical Inv. Map GR-199.

Myrick, T. E., B. A. Bervin, and F. F. Haywood. 1981. *State Background Radiation Levels: Results of Measurements Taken During 1975-1979.* ORNL/TM-7343. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

ORNL. 1993. *Environmental Technology Section (Formerly Pollutant Assessment Group) Procedures Manual.* ORNL-6645/R2. Oak Ridge National Laboratory, Grand Junction, Colorado.

Scott, J. H., and P. H. Dodd. 1960. *Gamma-Only Assaying for Disequilibrium Corrections.* RME-135. U.S. Atomic Energy Commission, Grand Junction Operations Office, Production Evaluation Division, Grand Junction, Colorado.

Steinhauser, S. R., and E. P. Beroni. 1955. *Preliminary Report on Uranium Deposits in the Gulf Coastal Plain Region, Southwest Texas.* U.S. Atomic Energy Commission, Division of Raw Materials, Denver Exploration Branch, Denver, Colorado.

U.S. DOE. 1979. *Environmental Assessment of the Falls City Site and Associated Properties, Falls City, Texas* (Draft). Prepared for the U. S. Department of Energy by Ford, Bacon, and Davis Utah, Inc., Salt Lake City, Utah.

U.S. DOE. 1981. *Background Report for the Uranium Mill Tailings Sites Remedial Action Program.* DOE/EP-0011. U.S. Department of Energy, Washington, DC.

U.S. DOE. 1988. *Vicinity Properties Management and Implementation Manual.* UMTRA-DOE/AL-050601. U. S. Department of Energy, Albuquerque, New Mexico.

U.S. DOE. 1991. *Environmental Assessment of Remedial Action at the Falls City Uranium Tailings Site, Falls City, Texas.* DOE/EA-0468. U.S. Department of Energy, Albuquerque, New Mexico.

U. S. EPA. 1983. Cleanup of Lands and Buildings Contaminated with Residual Radioactive Material from Inactive Uranium Processing Sites (40 CFR 192). *Federal Register*. U.S. Environmental Protection Agency.