QUIVIRA MINING COMPANY
AMBROSIA LAKE FACILITY

License No. SUA-1473
Docket No. 40-8905

RADON FLUX REPORT

NOVEMBER 30, 1996

RADON FLUX MONITORING RESULTS
QUIVIRA MINING COMPANY - AMBROSIA LAKE FACILITY

Pursuant to and in accordance with the requirements contained within Quivira's Source Material License No. SUA-1473, Quivira has completed the placement of the final radon barrier upon tailings impoundments #1 and #2. Placement of the radon barrier upon the impoundments was performed pursuant to the design specifications contained within the NRC approved reclamation plan for the Ambrosia Lake facility, which is incorporated into the facility license as Condition 37. After placement of the final radon barrier, radon flux measurements were obtained upon the impoundments in order to demonstrate that the radon barrier constructed upon the impoundments effectively limits radon emanation below the regulatory standard of 20 picocuries per square meter per second (pCi/m^2-s) contained within 10 CFR Part 40, Appendix A, Criterion 6.

The requirements in 10 CFR Part 40, Appendix A indicate that as soon as possible after the radon barrier has been placed and prior to the placement of the erosion protection layer, measurements must be performed to assure the radon flux, averaged over the entire surface of the pile, does not exceed 20 pCi/m^2-s. Radon flux measurements must be obtained in accordance with EPA Method 115 contained within 40 CFR § 61, Appendix B; or another method approved by the Commission.

EPA Method 115 requires the placement of a minimum of 100 sample locations over the surface of the impoundment. Samples are collected through the use of large area activated charcoal canisters (LAACC) which are placed on and exposed to the reclaimed surface of the tailings impoundment for twenty four hours. Method 115 stipulates that the procedure for making radon flux measurements using LAACCs is provided within Appendix A of EPA report 520/5-85-0029, "*Radon Flux Measurements on Gardinier and Royster Phosogypsum Piles Near Tampa and Mulberry, Florida.*" Upon collection and equilibration, the samples are then analyzed via gamma spectroscopy to determine the quantity of absorbed radioactivity. Compliance is determined by comparing the area weighted average flux to the 20 pCi/m^2-s standard.

Collection and analysis of the radon flux samples were performed in accordance with the technique provided within Appendix A of EPA report 520/5-85-0029. Quivira constructed LAACCs utilizing the above referenced EPA document specifications which resulted in providing an efficient mechanism for radon flux measurement. Quivira's

LAACCs consist of a ten inch diameter PVC end cap with a ¼-inch vent hole, fiberglass screen, plastic grid, and scrubber pads held in place with a retaining mechanism. Charcoal was prepared in accordance with EPA document methodologies and placed into seamless tin cans and sealed with vinyl tape.

Tests performed on various sample containers indicated that using plastic bags as sample containers would not be as reliable as the selected containers as conditions expected to be incurred during sampling and analysis could possibly damage the bag resulting in loss of charcoal which contains the adsorbed radon. In addition, consistent counting geometry was not possible with a non-rigid container; therefore, the use of plastic baggies was discounted. Plastic containers were also evaluated. However, Quivira elected not to maintain radium standards in thin "cottage cheese" containers due to potential problems in the event the plastic container was damaged.

Metal cans sealed with vinyl tape were deemed to be best suited for the application as they were a rigid, durable container which would provide consistent counting geometry between the radium standards and samples. Although not required by Method 115 or the EPA document, leak tests performed on the metal can in room temperature water indicated that placement of vinyl tape along the seal of the tin can provided an air tight container. Quivira's sampling procedures were prescribed to minimize unnecessary exposure of the charcoal to ambient atmosphere as the sealed sample containers were opened in the field at the actual sampling location and were again sealed with tape immediately upon transfer of the charcoal into the metal container at the conclusion of the sampling period.

Quivira obtained 115 radon flux measurements upon tailings impoundment #1 and 101 flux measurements upon tailings impoundment #2. The location of the impoundments are shown on Figure 1. Radon flux sample locations for impoundemnt #1 and #2 are depicted within Figures 2 and 3, respectively. Measurements were initiated in September 1995 and were completed in September 1996.

Results

Tailings Impoundment #1

Analytical results obtained from the radon flux measurements upon impoundment #1 are provided in Appendix 1, Table 1. The overall average radon flux rate for impoundment #1 was determined to be 1.33 pCi/m^2-s; which is less than 7% of the 10 CFR Part 40, Appendix A, Criteria 6 standard of 20 pCi/m^2-s.

Tailings Impoundment #2

Analytical results obtained from the radon flux measurements upon impoundment #2 are provided in Appendix 1, Table 2. The overall average radon flux rate for impoundment #2 was determined to be 1.19 pCi/m^2-s; which is less than 6% of the 10 CFR Part 40, Appendix A, Criteria 6 standard of 20 pCi/m^2-s.

Precision

Precision refers to the ability of a system to reproduce its own measurements. Method 115 requires that any radon flux sample indicating a result greater than 1 pCi/m^2-s must have a precision of 10%. No additional guidance regarding precision is provided within Method 115 or Appendix A of EPA report 520/5-85-0029, "*Radon Flux Measurements on Gardinier and Royster Phosogypsum Piles Near Tampa and Mulberry, Florida.*"

Quivira utilized the following formula to determine the precision of samples which indicated a flux value of greater than 1 pCi/m^2-s:

$$precision = \frac{standard\ \ deviation}{measured\ \ flux}$$

Using this formula, the precision was determined for each sample having a calculated flux value greater than 1.0 pCi/m^2-s and compared to the Method 115 requirement of 10%.

Impoundment #1

The precision results for samples measuring greater than 1.0 pCi/m^2-s from impoundment #1 are attached within Appendix 1, Table 3. All samples greater than 1 pCi/m^2-s met the criteria specified within Method 115.

Impoundment #2

The precision results for samples measuring greater than 1.0 pCi/m^2-s from impoundment #2 are attached within Appendix 1, Table 4. All samples greater than 1 pCi/m^2-s met the criteria specified within Method 115.

Accuracy

Accuracy is defined as the extent to which an observed value agrees with the "true" value of the sample. An example of accuracy is counting a reference standard and comparing the observed count to the actual value of the standard. Accuracy can only be determined when the true concentration is known.

The method that Quivira used in determining accuracy was to utilize the two charcoal radium standards. Values that were obtained from these standards were compared to the expected value for the standard. This was done by obtaining an observed count for each standard and calculating the total observed activity of the standard based on system efficiency:

$$Activity\ (pCi) = \frac{observed\ cpm}{efficiency} \times \frac{pCi}{2.22\ dpm}$$

This observed activitiy was then compared to the "true activity" of the standard by use of the equation below.

$$accuracy = \frac{(true\ value\ -\ measured\ value)}{true\ value} * 100$$

If the results were within ±10% of the true activity, the accuracy test was deemed to meet the Method 115 criteria.

Impoundment #1

Accuracy test results for impoundment #1 are contained within Appendix 1, Table 5. Tests were conducted on both radium charcoal standards each day samples from impoundment #1 were analyzed.

Table 5 shows that the accuracy test satisfied the Method 115 requirement of having accuracy within ±10% on each day samples from impoundment #1 were analyzed; and an overall average accuracy of ±3.7 and ±4.0 for LAACC standard #1 and LAACC standard #2, respectively.

Impoundment #2

Accuracy test results for impoundment #2 are contained within Appendix 1, Table 6. Tests were conducted on both radium charcoal standards each day samples from impoundment #2 were analyzed.

Table 6 demonstrates that the accuracy test satisfied the Method 115 requirement of having accuracy within ±10% on each day samples from impoundment #2 were analyzed; and an overall average accuracy of ±2.0 and ±4.1 for LAACC standard #1 and LAACC standard #2, respectively.

Discussion of NRC Report 40-8905/96-02)

While Quivira was performing the radon flux measurements, a representative of the NRC was on-site on July 24, 1996 to observe and evaluate the radon flux program implemented at the Ambrosia Lake facility. The September 9, 1996 inspection report (NRC Inspection Report 40-8905/96-02) states that the on site inspection revealed that the method used to perform the measurements complied with the requirements of 10 CFR Part 40, Appendix A. However, the inspector noted two differences between Method 115 and the procedures used by Quivira. These differences are discussed below.

NRC Comment 1

Method 115, Section 4.0 states, "A background count using unexposed charcoal should also be made at the beginning and at the end of each counting day to check for inadvertent contamination of the detector or other changes affecting the background." Our inspector noted that you were counting the unexposed charcoal only once, at the beginning of the day.

Quivira Response

Section 4.C of Method 115 describes the elements pertaining to calibration procedures and frequency for the instrumentation utilized to perform analyses of radon flux samples. Although the background check is described within Section 4.C, Quivira believes that performing a background count at the end of the day to check for inadvertent contamination of the detector or other changes affecting the

background is not a specific requirement; as Method 115 states that the background test **<u>should</u>** be performed. Other calibration procedures and tests listed within Section 4.C indicate that they **<u>shall</u>** be performed. Thus, Quivira believes that Method 115 *only suggests* that the background check be performed at the start and end of each day; but does not require it.

Further, the belief that the two background counts are not mandatory is supported by information contained within Appendix A of EPA report 520/5-85-0029, "*Radon Flux Measurements on Gardinier and Royster Phosogypsum Piles Near Tampa and Mulberry, Florida.*" This report provides a detailed measurement procedure to be utilized to perform radon flux measurements. This document provides no indication that blanks shall be counted at <u>both</u> the beginning and end of each day.

Quivira believes that its procedures which were used to determine flux measurements at the Ambrosia Lake facility actually improve upon those specified in Method 115 and the above referenced EPA report; which allows for a single background value to be utilized as the background value for each sample analyzed on a particular day.

To provide for a more representative background value for each sample, Quivira obtained a background count from each individual sample prior to exposure rather than a single background count for that day. Each pre-exposure background count was then utilized in obtaining the net counts of the exposed charcoal; which is then used to determine the flux for that sample. Individual background counts of charcoal from the same batch exhibited a range of actual observed counts; with some samples indicating counts which were twice as much as other samples within the same batch. Utilizing a single background value for a batch of samples could ultimately result in data which is not totally reflective of actual individual sample concentrations. By determining a background for each sample, it provides a background count which is more representative of the background activity of the actual sample; thereby resulting in a flux value which is also more representative of the actual conditions.

Additionally, Quivira believes that in the event contamination did occur during the day (possibly resulting from loss of charcoal from damaged containers), Quivira's reported values would be conservative as compared to radon flux values obtained if no contamination was present. For example, in the event the detector were to become contaminated; the counting system would show more activity than is actually present in the sample; and any data obtained would result in the samples being reported with higher flux values than that actually present within the sample.

Thus, Quivira believes that its radon flux procedures utilized at the Ambrosia Lake facility result in data which is more representative of actual flux values.

NRC Comment #2

The inspection disclosed that you have stored and manipulated raw sampling data in a computerized database. The verification and validation of the computer program results were found not to have been clearly discussed in the site procedures. Validation and verification of the computer results are deemed necessary to ensure that the computer program's output is reliable and accurate. Please discuss your actions taken to ensure that the computer output is reliable and accurate.

Quivira Response

Quivira utilized Lotus Symphony (release 2.0) computer software to calculate the flux values. The program developed to calculate the radon flux value simply uses the flux equation provided in Appendix A within the EPA document report 520/5-85-0029, "*Radon Flux Measurements on Gardinier and Royster Phosogypsum Piles Near Tampa and Mulberry, Florida.*" This equation is:

$$J = \frac{C\,\lambda^2}{K\,A\,E\,(1-e^{-\lambda t_1})[e^{-\lambda(t_2-t_1)} - e^{-\lambda(t_3-t_1)}]}$$

Where:

J =	Radon flux [pCi/m^2-sec]
C =	Net counts under bismuth 214 peak [cts]
λ =	Radon decay constant [2.097 e-6/sec]
A =	Area of collector [0.051 m^2]
E =	Efficiency of detector [cts per dis.]
K =	Conversion from dps to pCi [0.037 dps per pCi]
t_1 =	Exposure time [sec]
t_2 =	Time from start of collection to start of count [sec]
t_3 =	Time from start of collection to end of count [sec]

During development of the Symphony program and prior to its use, the equation was checked for accuracy to ensure the proper variables were extracted from the database and that the correct mathematical sequence was used in calculating the flux. This involved performing cross checks of the computer generated value to the value obtained on a hand held calculator. All checks showed the program's equation to be correct. No records of these checks were made, nor were they required. Once the calculation was deemed correct, each subsequent application of the equation should yield reliable results provided no additions or deletions occurred to the cell contents of the equation.

Nevertheless, Quivira performed additional cross checks of the computer output to re-verify the results obtained from the computer were accurate and reliable. Nine randomly selected samples from impoundment #1 were involved in the validation process which involved performing a hand calculation of the flux based on the input data and then comparing the output to that obtained from the Symphony program. The results of the comparison are shown in Appendix 1, Table 7.

The results within Table 7 demonstrate that the output from the computer program compared very favorably with hand calculations with the minor differences being attributable to rounding protcols within the computer software.

Based on the verification test performed on the data, the computer program results are accurate and reliable.

FIGURE 1

QUIVIRA MINING COMPANY - AMBROSIA LAKE FACILITY
SITE LAYOUT

FIGURE 2

QUIVIRA MINING COMPANY

AMBROSIA LAKE FACILITY

TAILINGS IMPOUNDMENT #1 - RADON FLUX SAMPLE POINTS

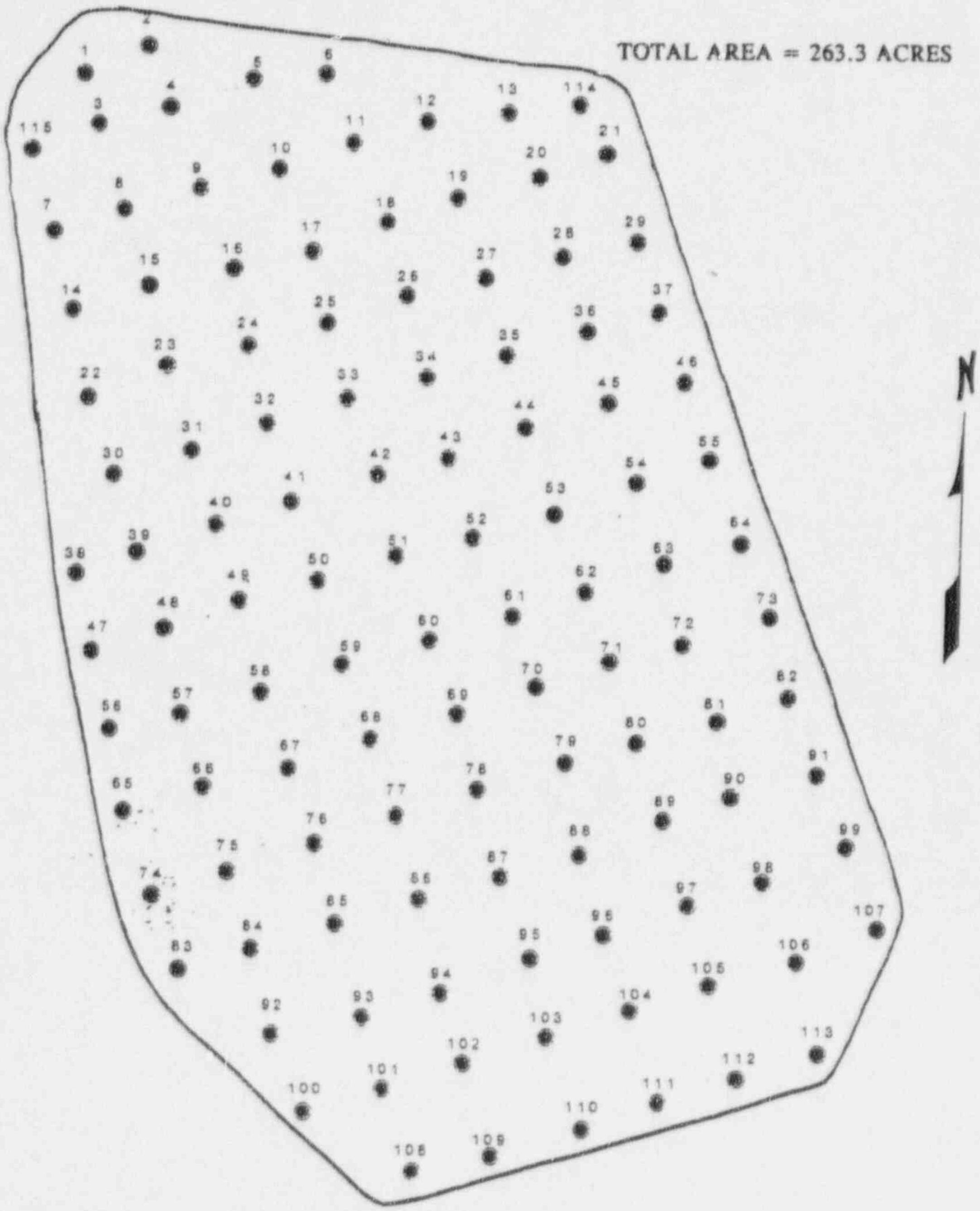
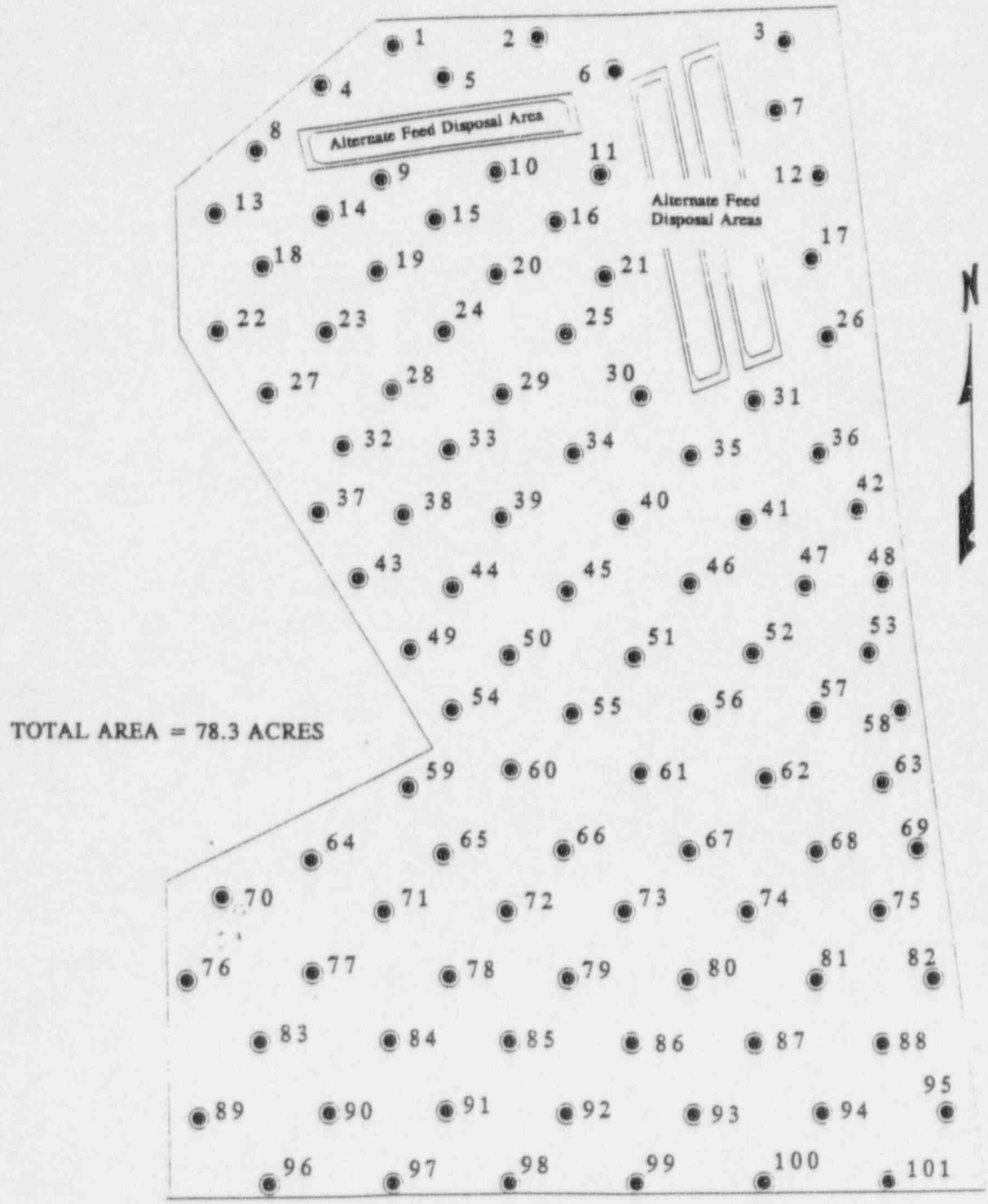


FIGURE 3

RADON FLUX LOCATIONS - IMPOUNDMENT #2



APPENDIX 1

TABLE 1

QUIVIRA MINING COMPANY
RADON FLUX RESULTS - IMPOUNDMENT #1

GRID	FLUX	GRID	FLUX	GRID	FLUX
1	5.67	40	0.04	79	0.29
2	0.85	41	0.23	80	0.27
3	0.22	42	0.41	81	0.50
4	0.44	43	1.94	82	0.53
5	0.37	44	0.70	83	0.20
6	2.41	45	0.53	84	1.82
7	0.13	46	2.63	85	0.97
8	0.68	47	0.10	86	0.55
9	0.18	48	0.62	87	0.09
10	0.36	49	0.23	88	0.17
11	0.73	50	0.63	89	1.32
12	0.41	51	0.31	90	0.46
13	4.83	52	0.30	91	0.28
14	0.24	53	0.30	92	1.96
15	2.85	54	0.50	93	1.02
16	1.35	55	1.52	94	0.83
17	0.26	56	0.36	95	0.47
18	0.37	57	3.45	96	0.25
19	0.43	58	0.43	97	0.23
20	0.67	59	0.20	98	0.42
21	0.64	60	0.27	99	7.11
22	0.22	61	0.34	100	4.87
23	0.89	62	0.29	101	0.30
24	0.27	63	0.63	102	0.22
25	0.50	64	1.51	103	0.66
26	0.04	65	0.24	104	0.11
27	0.33	66	2.39	105	<0.02
28	0.17	67	0.50	106	0.30
29	1.19	68	0.17	107	3.81
30	0.28	69	0.30	108	4.67
31	0.32	70	0.54	109	0.62
32	0.66	71	0.47	110	18.96
33	0.54	72	0.93	111	6.63
34	7.02	73	3.43	112	4.70
35	0.38	74	0.52	113	3.86
36	0.30	75	1.14	114	9.18
37	4.38	76	0.54	115	0.01
38	0.24	77	0.30		
39	1.40	78	0.28		

AVERAGE 1.33

TABLE 2

QUIVIRA MINING COMPANY
RADON FLUX RESULTS - IMPOUNDMENT #2

GRID	FLUX	GRID	FLUX	GRID	FLUX
1	0.73	35	0.23	69	0.22
2	3.53	36	2.08	70	0.60
3	0.41	37	1.01	71	1.42
4	7.19	38	2.07	72	0.56
5	4.61	39	0.27	73	0.81
6	0.29	40	0.17	74	0.80
7	1.03	41	0.58	75	1.26
8	0.96	42	1.16	76	0.24
9	3.40	43	0.68	77	0.41
10	0.42	44	1.30	78	0.46
11	0.65	45	0.43	79	0.64
12	0.41	46	0.00	80	0.22
13	23.68	47	0.60	81	0.23
14	0.50	48	0.66	82	0.48
15	0.92	49	0.59	83	0.67
16	0.33	50	0.79	84	0.35
17	6.13	51	0.59	85	1.34
18	0.43	52	0.45	86	0.56
19	0.60	53	0.83	87	0.87
20	1.13	54	0.07	88	2.73
21	2.63	55	0.32	89	0.19
22	0.59	56	0.00	90	0.34
23	1.51	57	0.26	91	0.32
24	0.25	58	0.85	92	0.43
25	0.26	59	1.13	93	0.62
26	0.96	60	0.25	94	0.20
27	0.37	61	0.15	95	0.26
28	1.22	62	0.25	96	0.36
29	0.32	63	1.26	97	0.10
30	0.81	64	0.63	98	0.44
31	0.33	65	0.61	99	0.62
32	10.99	66	0.76	100	0.49
33	0.61	67	0.53	101	0.56
34	0.28	68	0.18		
				AVERAGE	1.19

TABLE 3

RADON FLUX PRECISION CHECK
POND 1

Grid Location	Date	Radon pCi/M2-Sec	+/- 1(STD)	Precision
1	09/20/95	5.67	0.12	2.2
6	09/20/95	2.41	0.08	3.5
13	09/21/95	4.83	0.11	2.4
15	09/27/95	2.85	0.09	3.3
16	09/27/95	1.35	0.06	4.6
29	08/01/96	1.19	0.04	3.3
34	08/05/96	7.02	0.08	1.2
37	09/21/95	4.38	0.11	2.4
39	06/25/96	1.40	0.04	3.1
43	07/02/96	1.94	0.05	2.4
46	09/22/95	2.68	0.09	3.3
55	09/22/95	1.52	0.07	4.3
57	08/01/96	3.45	0.06	1.8
64	09/22/95	1.51	0.07	4.8
66	06/21/96	2.39	0.05	2.3
73	09/22/95	3.43	0.10	2.9
75	06/21/96	1.14	0.04	3.5
84	06/21/96	1.82	0.05	2.5
89	06/12/96	1.32	0.04	3.0
92	09/27/95	1.96	0.07	3.8
93	06/14/96	1.02	0.04	3.8
99	09/22/95	7.11	0.14	2.0
100	08/29/96	4.87	0.07	1.5
107	08/01/96	3.81	0.07	1.7
108	07/22/96	4.67	0.07	1.6
110	08/01/96	18.96	0.14	0.7
111	09/23/95	6.63	0.13	2.0
112	09/23/95	4.70	0.11	2.4
113	08/01/96	3.86	0.07	1.7
114	09/21/95	9.18	0.16	1.7

Note: Samples with flux value greater than 1 pCi/m^2-s must show precision of 10%. 26% of samples on Pond 1 had flux of 1 pCi/m^2-s or greater.

TABLE 4

RADON FLUX PRECISION CHECK
POND 2

GRID	SAMPLE DATE	RADON FLUX (pCi/m^2-s)	+/- 1(STD)	Precision in %
2	27-Aug-96	3.53	0.06	1.8
4	27-Aug-96	7.19	0.09	1.2
5	27-Aug-96	4.61	0.07	1.5
7	28-Aug-96	1.03	0.04	3.5
9	27-Aug-96	3.40	0.06	1.8
13	04-Sep-96	23.68	0.16	0.7
17	28-Aug-96	6.13	0.08	1.3
20	23-Jul-96	1.13	0.04	3.3
21	27-Aug-96	2.63	0.05	2.1
23	23-Jul-96	1.51	0.04	2.7
28	23-Jul-96	1.22	0.04	3.2
32	24-Jul-96	10.99	0.10	0.9
36	27-Aug-96	2.08	0.05	2.2
37	04-Sep-96	1.01	0.04	3.7
38	24-Jul-96	2.07	0.05	2.3
42	20-Aug-96	1.16	0.04	3.3
44	25-Jul-96	1.30	0.04	3.2
59	04-Sep-96	1.13	0.04	3.4
63	08-Aug-96	1.26	0.04	2.9
71	08-Aug-96	1.42	0.04	2.7
75	08-Aug-96	1.26	0.04	3.0
85	06-Aug-96	1.34	0.04	3.2
88	06-Aug-96	2.73	0.06	2.1

Note: Samples with flux value greater than 1 pCi/m^2-s must show precision of 10%. 23% of samples on Pond 2 had flux greater than 1 pCi/m^2-s.

TABLE 5

ACCURACY TEST - IMPOUNDMENT #1

DATE	LAACC#1 ACTIVITY (pCi)	LAACC#1 ACCURACY (%)	LAACC#2 ACTIVITY (pCi)	LAACC#2 ACCURACY (%)
9/21/95	40163.4	-9.1	71443.5	2.8
9/22/95	35849.9	2.7	80356.4	-9.3
9/23/95	38749.5	-5.2	77338.1	-5.2
9/24/95	37233.8	-1.1	78675.3	-7.1
9/28/95	38354.2	-4.2	76873.2	-4.6
9/30/95	36991.9	-0.5	80454.8	-9.5
6/12/96	37334.8	-1.4	70750.8	3.7
6/13/96	35788.3	2.8	73156.9	0.5
6/15/96	36501.5	0.9	72969.2	0.7
6/19/96	37882.9	-2.9	74891.1	-1.9
6/22/96	38296.5	-4.0	76900.1	-4.6
6/26/96	39344.8	-6.8	77346.4	-5.2
7/3/96	37120.9	-0.8	70919.7	3.5
7/8/96	38104.4	-3.5	72147.1	1.8
7/23/96	38525.8	-4.6	75675.7	-3.0
8/2/96	39303.8	-6.7	75090.1	-2.2
8/3/96	35972.2	2.3	71816.8	2.3
8/30/96	39434.9	-7.1	76830.5	-4.5
	AVERAGE	**± 3.7**	**AVERAGE**	**±4.0**

Note: LAACC#1 activity = 36824.4 pCi; LAACC#2 activity = 73493.1 pCi

TABLE 6

ACCURACY TEST - IMPOUNDMENT #2

DATE	LAACC#1 ACTIVITY (pCi)	LAACC#1 ACCURACY (%)	LAACC#2 ACTIVITY (pCi)	LAACC#2 ACCURACY (%)
7/23/96	38525.8	-4.6	75675.7	-3.0
7/24/96	37064.6	-0.7	70003.8	4.6
7/25/96	36891.9	-0.2	67563.8	8.1
7/26/96	37526.6	-1.9	77473.4	-5.4
7/31/96	37829.6	-2.7	77669.9	-5.7
8/6/96	35972.2	2.3	71816.8	2.3
8/7/96	37600.3	-2.1	77813.3	-5.9
8/8/96	36310.1	1.4	71126.1	3.2
8/9/96	35484.2	3.6	71565.3	2.6
8/21/96	36006.0	2.2	71024.8	3.4
8/28/96	36944.4	-0.3	72008.3	2.0
8/29/96	35870.9	2.6	69470.7	5.5
9/5/96	37235.9	-1.1	74660.1	-1.6
	AVERAGE	**±2.0**	**AVERAGE**	**±4.1**

Note: LAACC#1 activity = 36824.4 pCi; LAACC#2 activity = 73493.1 pCi

TABLE 7

COMPUTER CODE VERIFICATION - POND 1
(pCi/m^2-sec)

GRID	DATE COUNTED	CALCULATOR FLUX	COMPUTER FLUX
112	9/24/95	4.76	4.70
11	9/28/95	0.62	0.62
19	9/28/95	1.01	1.01
81	6/12/96	0.49	0.50
95	6/22/96	0.47	0.47
25	6/26/96	0.50	0.50
43	7/3/96	1.89	1.94
29	8/2/96	1.19	1.19
57	8/2/96	3.51	3.45