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Final Radon Barrier Design
ARCO Bluewater Mill Main Tailings Pile

December 1993

Submitted to:

U. S. Nuclear Regulatory Commission
Region IV
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EXECUTIVE SUMMARY

Atlantic Richfield Company (ARCO) has completed the consolidation of off-pile materials with the Main Tailings Pile (MTP) according to the Reclamation Plan (ARCO, 1990). The off-pile material, including windblown tailings, evaporation pond residues, and other miscellaneous contamination, has been placed primarily on the Slimes Area as loading for slimes consolidation. The volume of off-pile materials was found to be approximately 43 percent larger than the original estimate, amounting to an additional 705,000 cubic yards. In addition, the average Ra-226 concentration was believed to be much different than that assumed in the original design. These changes in the radiological source term for the MTP led ARCO to conclude that a final radon barrier design was necessary.

The revised regulations (40 CFR Part 192 and 10 CFR Part 40) require verification through testing that the design and construction of the final radon cover is effective in limiting the radon emissions to a flux of 20 pCi/m^2s. ARCO took this opportunity to characterize the as-built MTP to develop a new radiological source term for the final design as well as collect the additional data necessary to calibrate the RAECOM model to the MTP. This was desirable and considered necessary to provide a high level of confidence that the final design would meet the flux standard.

An extensive field program was initiated to obtain Ra-226 concentrations and moisture content for the upper 8 feet of the pile. Ninety-three corings down to 8 feet were done on the MTP with four 24-inch samples taken at each location. The 372 samples were analyzed for moisture and Ra-226 at ARCO's on-site laboratories. In order to calibrate the model, 113 flux measurements were made. Bare-tailings flux was made for the three areas of the MTP and the flux was measured at 33 evenly spaced locations on the radon barrier cover that had been placed on the Sands Area. In addition, the current moisture in the radon cover was measured at the test locations. Several hundred dry density measurements had been made as part of the contractor's

QA/QC program on the off-pile material and the radon barrier material. These data were used to accurately and precisely define the current properties of each 24-inch layer in the top eight feet of the pile.

The RAECOM model was calibrated to the MTP by using an extensive data base for the cover and tailings as described above. Flux predictions from the model were compared with actual measurements. The model was found to overpredict the flux from both the tailings as well as through the radon barrier. The source diffusion coefficient was adjusted for each of the three areas of the MTP in order to obtain consistency between the measured and calculated flux. A small adjustment to the cover diffusion coefficient was also required. The calibrated model was then used for the design calculations.

The final MTP cover design requires a radon barrier thickness of 39 cm, 27 cm, and 0 cm for the Sands Area, Mixed Area, and Slimes Area, respectively. Final radon barrier has been placed on the Sands Area to a depth of 73 cm which already exceeds the 39 cm requirement. ARCO plans to place 1 foot (30.5 cm) of final cover on the Mixed Area. The erosion protection layer as specified in the Reclamation Plan will be placed over the radon barrier. In order to place the erosion protection layer on the Slimes Area, ARCO will first place an additional cover of six-inch thickness to serve as a working surface layer. This will reduce the radon flux further while preventing the mixing of the erosion protection layer with the off-pile materials that are currently on the surface. The above plan adds a degree of conservatism to the design since the area-weighted long-term flux over the MTP is predicted to be only 11.6 pCi/m^2s, which is 58 percent of the allowable limit of 20 pCi/m^2s.

ARCO has retained one evaporation pond, IIIA, for continued use for receiving run-off from the MTP and water from the decontamination of construction equipment. This pond will be required until at least one lift of clean material has been placed on the MTP and all contaminated material has been consolidated with the Acid Tailings, scheduled for midsummer. At that time the evaporation pond will be decommissioned and the residues and contaminated soil placed on the Acid Tailings Pile. Only at that time, can an accurate radiological source term be measured and a final cover design prepared.

ARCO has included in this report a protocol for design of the Acid Tailings Pile and an extension to the Carbonate Tailings Pile for NRC's approval. The protocol is consistent with the technical approach used in preparing the final design for the MTP. The approval of the protocol rather than the actual design is necessary for ARCO to meet its current deadline of having all radon barrier in place by December 28, 1994. The sampling and analysis of the Acid Pile Tailings and off-pile material is expected to take six to eight weeks. Considering the additional time necessary to do the engineering and contract modification, ARCO believes that there will be no time for regulatory review and approval prior to the start of construction. ARCO therefore requests that NRC approve the protocol at this time along with the final design of the MTP.

The protocol calls for characterizing the radiological source term by continuous coring and sampling and analysis of the top eight feet of material. Four samples will be taken at twenty-four inch intervals. Corings will be done at a density of approximately one per two acres of surface area. All samples will be analyzed for Ra-226. Other as-built data such as density will be used to define the diffusion coefficient measurement requirement. These data and other site characterization data will be used to calculate the radon cover requirements at the long-term moisture conditions as specified in the Reclamation Plan.

FINAL RADON BARRIER DESIGN
ARCO BLUEWATER MILL MAIN TAILINGS PILE

1.0 INTRODUCTION

The Bluewater Uranium Mill Site is located approximately 10 miles from Grants, New Mexico. It is owned by Atlantic Richfield Company. Figure 1-1 shows the current site features including the Plant Site, the Tailings Areas, the Evaporation Pond, and the Ore Storage Area.

Reclamation of the tailings areas began in 1991, when engineered fill was placed on the Plant Site and the mill building debris engineered fill areas. Work continued in 1992 when contaminated dikes and wind-blown tailings areas were excavated and the material placed on the Main Tailings Pile (MTP). Other off-pile materials that were placed on the MTP included contaminated soils and residues from four evaporation ponds. Some of the MTP recontouring activities were completed including regrading the side slopes. Wicks were installed in the slimes area in order to dewater and consolidate the slimes.

During 1993, work continued with additional contaminated material removal, removal of all but one evaporation pond, placement of engineered fill over the ore storage area, revegetation of the disturbed areas, and the placement of radon barrier material on the Carbonate Tailings Pile and the southern portion of the MTP.

The radon barrier design for the reclamation of the MTP is presented in the ARCO Reclamation Plan (ARCO, 1990). The MTP is divided into three sections, the Sands Area, the Mixed Area, and the Slimes Area as shown in Figure 1-2. Estimates of the volumes and average Ra-226 concentrations for the off-pile materials (evaporation pond, berm sands, and windblown contaminated materials) were made based on characterization data obtained prior to remediation. The radon barrier design assumed that these materials were placed on the various areas of the pile at prescribed thicknesses and compactions.

FIGURE 1-1
BLUEWATER URANIUM MILL
SITE MAP

ANDERSON ENGINEERING CO., INC.
CIVIL ENGINEERS CONSTRUCTION MANAGERS

ATLANTIC RICHFIELD COMPANY

NOT TO SCALE

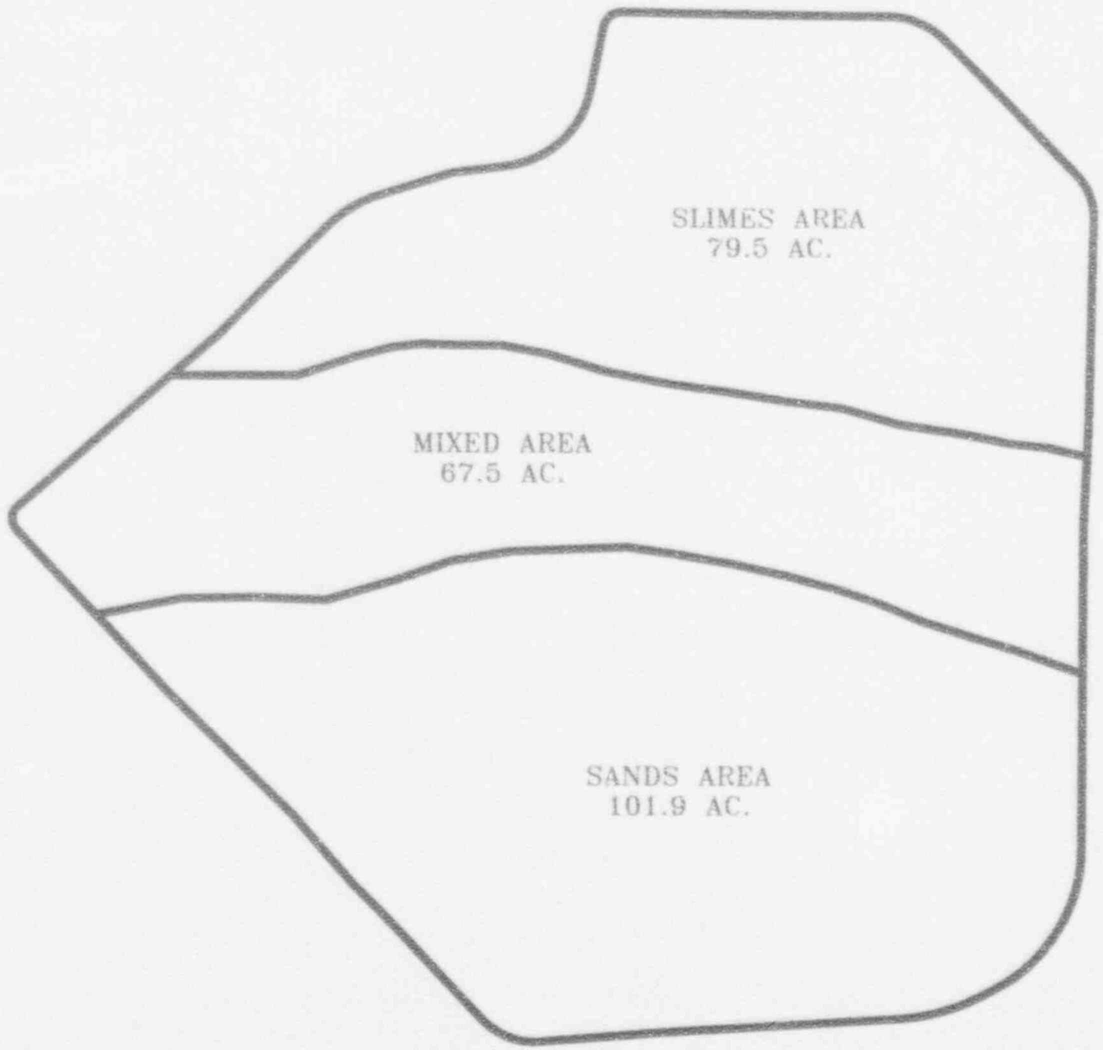


FIGURE 1-2
MAIN TAILINGS PILE
AREAS

ANDERSON ENGINEERING CO., INC.
Salt Lake City Utah
CIVIL ENGINEERS CONSTRUCTION MANAGERS

ATLANTIC RICHFIELD COMPANY
BLUEWATER MILL

DRAWN BY:	RT
CHECKED:	SA
APPROVED:	CS
DATE:	11/11/93
HORIZ. SCALE:	NOT TO SCALE
VERT. SCALE:	
REFERENCE:	

During the reclamation, volumes of off-pile materials were found to be quite different than those estimated in the original design. This subsequently changed the Ra-226 source term and made the original design inappropriate. Therefore ARCO reevaluated the radon barrier design based on the as-built configuration. In addition, it was believed that the current pile configuration afforded an opportunity to calibrate the RAECOM model to the ARCO MTP since radon barrier had been placed on a portion of the MTP. The calibration of the model was considered necessary since current revised regulations require performance measurements to verify the adequacy of the design. This will provide confidence that the designed cover will comply with the flux standard of 20 pCi/m^2s.

A MTP characterization plan was recently implemented to provide substantial data for updating the radiological source term and calibrating the RAECOM Model to develop a new radon barrier design. A meeting was held with NRC's Uranium Recovery Field Office Staff in Denver, CO on November 16, 1993 where preliminary results were presented. Encouragement from the NRC staff led to the development of this formal submittal of a final radon barrier design for the MTP.

2.0. TECHNICAL APPROACH

The current Reclamation Plan (ARCO,1990) was approved by the NRC on August 10, 1990. The design consisted of consolidating the off-pile materials by placing them on top of the Mixed and Slimes Areas of the MTP. Higher activity materials would be placed first followed by the lower activity materials in order to minimize the radon barrier cover requirements. Layer-thickness estimates and average Ra-226 concentrations were based on site characterization data. Radon diffusion measurements were made at compactions and long-term moistures that were anticipated for the materials.

The reclamation activities for the MTP generally followed the plan. However, as the off-pile materials exceeded the design estimates, the areal extent and thickness of the off-pile materials were increased in order to maintain an acceptable pile topography. Field gamma measurements indicated that the Ra-226 concentrations of the off-pile materials were significantly lower than that assumed in the original design. Other changes include higher off-pile layer and radon barrier compactions than expected and some placement of off-pile materials in low portions of the Sands Area to prepare for radon cover placement. These changes all affect the radon source term and must be accounted for in the final design of the radon cover.

ARCO retained the services of Dr. Kenneth R. Baker of Environmental Restoration Group, Inc. and Dr. Vern Rogers of Rogers and Associates Engineering Corporation to assist in completing a new design. Dr. Baker was responsible for the radiological characterization and radon barrier designs for many of the UMTRA Project sites and assisted ARCO with various portions of the Reclamation Plan. Dr. Rogers did extensive research during the 1970's on radon diffusion through earthen structures. His efforts led to the development of a mathematical model and laboratory measurement technique for measuring diffusion coefficients. He later advanced the model to the currently used RAECOM model by incorporating diffusion through the moisture layer as well as pore space. Radon diffusion coefficients for most of the reclaimed uranium mill tailings sites have been measured in his laboratory. He performed the initial site characterization work at the Bluewater Mill Site. These data were used for the radon barrier design in the

Reclamation Plan.

It was decided to conduct a extensive field study that would provide the data for evaluating the predictive capability of the RAECOM model for current conditions at the MTP as well as provide the data on which to base a new radon cover design. The technical approach for achieving those goals follows.

2.1 Design Parameters

The radon barrier thickness required to limit the radon flux to 20 pCi/m^2s is calculated using the computer code RAECOM (NRC, 1984). The one-dimensional code considers a tailings pile as a multiple layer system of any specified depth with the radon barrier normally being the top layer. The physical parameters for each layer are specified as the mean volume-weighted average for the layer as determined by measurements or by using default values. The layer thickness is constrained to thicknesses that do not introduce errors in the predicted flux due to intralayer inhomogeneities of the material. Typical tailings layer thicknesses are less than 100 cm for the layers in the top 8-10 feet of the pile.

The seven input parameters for each layer of the tailings pile system are:

- o Layer thickness
- o Dry bulk density
- o Porosity
- o Moisture content
- o radon emanation fraction
- o radon diffusion coefficient
- o Ra-226 concentration

A sensitivity analysis (Smith, 1985) was done to determine the parameters of greatest significance in the prediction of the cover thickness for typical uranium mill tailings piles. Considerations were made for both the mathematical formulation of the code as well as the normal range and variability of each parameter in tailings and cover material. The most influential parameters in order of decreasing importance were found to be, radon barrier moisture content, radon barrier diffusion coefficient, tailings radium concentration, and tailings radon emanation fraction. In addition, most of the characterization efforts should be made for the top layers since layers below 8 feet typically are not influential in affecting the flux from a pile surface.

2.2 Reclamation Plan Design for the Main Tailings Pile

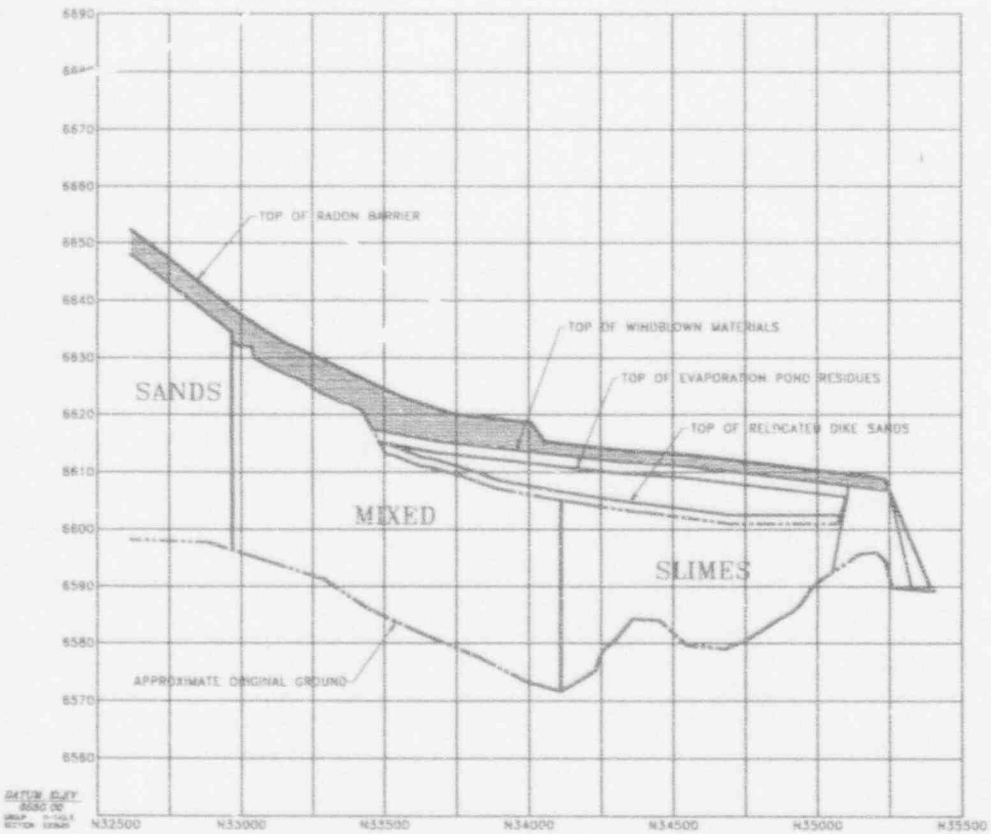
The ARCO Reclamation Plan (ARCO, 1990) consisted of estimated volumes of dike sands, evaporation pond residues, and windblown contaminated materials that were to be consolidated and placed on the Main Tailings Pile (MTP) prior to placement of the radon barrier cover. The placement of the much lower Ra-226 contaminated material above the tailings allowed the low activity material to serve as a barrier to the radon generated in the tailings. This effectively reduced the required thickness of the radon barrier while accomplishing the goal of reducing the flux from the tailings.

The MTP consists of three different types of tailings as shown in Figure 1-2. The Sands Area, containing the large particle tailings sands, is located to the south and is approximately 102 acres in size. The 80-acre Slimes Area consists of the small particle fraction of the tailings. The 68-acre zone between the sands and slimes is referred to as the Mixed Area which contains a mixture of all particle size fractions. The design calls for placement of an average of 3.4, 5.0, and 1.8 feet of radon barrier on the Sands, Mixed, and Slimes Areas, respectively.

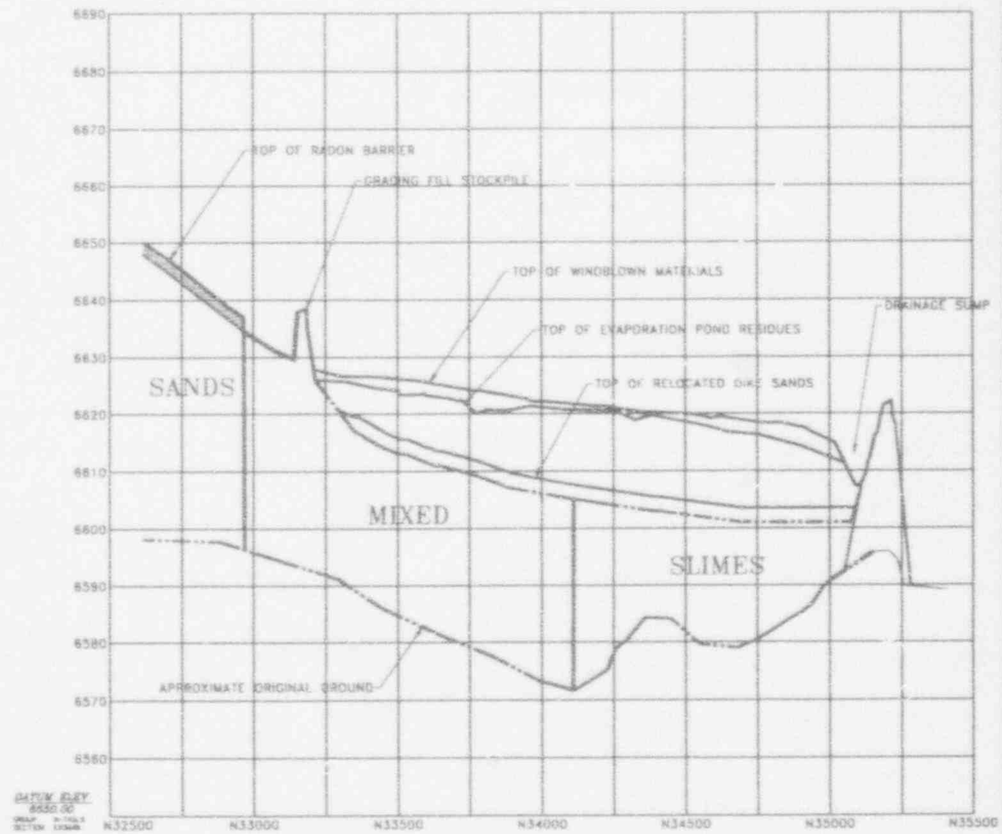
The left half of Figure 2-1 shows a typical north-south cross-section of the remediated MTP as indicated in the ARCO Reclamation Plan. The dike sands were to have been placed on the slimes portion of the MTP followed by the evaporation pond material and then the windblown material.

2.3 Current Configuration of the Main Tailings Pile

During the remediation, the Reclamation Plan was followed but it soon became apparent that the



RECLAMATION PLAN



AS BUILT

FIGURE 2-1
MAIN TAILINGS PILE
TYPICAL SECTION

ANDERSON ENGINEERING CO., INC.

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ATLANTIC RICHFIELD COMPANY

NOT TO SCALE

evaporation pond material and the windblown material volumes had been significantly underestimated. The thickness and areal extent of the slightly contaminated off-pile material placed on the MTP therefore increased. Upon completion of the MTP, material volumes increased above the original estimates of 1.6 million cubic yards by approximately 705,000 cubic yards.

While good assay data were not available for the material placed on the MTP, field gamma-ray measurements indicated that the average Ra-226 concentration was probably much less than originally estimated.

The right half of Figure 2-1 shows the same north-south cross-section as in the left half but with as-built layer thicknesses rather than thicknesses as estimated in the Reclamation Plan. A comparison of the left and right halves of the figure shows that the thicknesses of the layers have significantly increased in the slimes area thus resulting in a change in the radon source term. In addition, the areal extent of the mixed area that is covered by these materials has increased.

The as-built compaction data indicate that compactions of the off-pile layers on the Slimes and Mixed Areas as well as the existing radon barrier on the Sands Area were higher than originally specified in the Reclamation Plan. Since the diffusion coefficient is a function of the dry bulk density, this change will reduce the cover diffusion coefficient and therefore the required cover thickness.

2.4 Plan for Final Radon Cover Design

A change in the thicknesses of the off-pile layers, a change in average Ra-226 content for the off-pile layers, and an change in off-pile material compaction, all act to change the radon barrier thickness required to meet the design standard of 20 pCi/m^{2}s. ARCO therefore believed that a new design was necessary based on as-built data.

At the time that the Reclamation Plan was developed, the NRC accepted the radon cover design based on the RAECOM model prediction that the flux limits would be met. However, in order to meet the current 10 CFR Part 40 and 40 CFR Part 192 requirements, radon flux measurements are required after the placement of cover to verify compliance with the standard. This essentially requires a design-based as well as a performance-based cover design.

In order to assure compliance during the performance verification of the flux standard, ARCO decided to assess how well the RAECOM code predicts the flux at the MTP and, if necessary, calibrate the model to the MTP. The current moistures and Ra-226 concentrations of the off-pile materials would provide a good measure of the current radon source term. Other essential data that were missing were the flux measurements .

A plan to characterize the as-built pile was developed. Ra-226 concentrations and moisture content in the top eight feet would be measured. The diffusion coefficient (D) of the radon barrier would be measured at the current compaction. Other design parameters would be corrected for the current configuration if necessary.

In order to "calibrate the model" to the ARCO MTP, radon flux measurements from the radon source term were planned for the Sands Area, the Mixed Area, and the Slimes Area of the MTP. Source term parameters at the existing conditions would be input into the model and the flux calculated. The predicted flux would be compared to the measured flux. Where necessary, the source diffusion coefficients (Ds) would be adjusted so that the predicted flux matched the measured flux. Since radon barrier had been applied to the Sands Area, removal of existing radon cover would be required at the measurement locations.

As a further check, the cover would be characterized for moisture content, and diffusion coefficients would be measured at the current moisture and compaction conditions. Flux measurements on top of the current cover would then be compared to the model predictions as another check of the model prediction.

After RAECOM was calibrated to the MTP, the updated radiological source term for the tailings and off-pile materials along with MTP material properties corrected to the long-term moisture design conditions would be used to calculate the radon cover thicknesses required to meet radon flux criterion of the standard.

Details of the work plan are presented in the Appendix A.

3.0 DATA COLLECTION

A seven-week field program was initiated on September 8, 1993 to obtain the extensive amount of data for characterizing the three areas of the MTP and calibrating the RAECOM model. Ninety-three holes were augered into contaminated material and tailings and continuously sampled to a depth of eight feet at 24-inch intervals. This resulted in 372 samples being analyzed for Ra-226 and moisture content. An additional 73 samples of radon barrier were taken and analyzed for moisture.

A backhoe was used to remove the radon barrier cover from a 20-ft by 20-ft area at 20 test locations on the Sands Area. This was necessary to prepare for the radon flux measurements on the bare tailings sands. Since removal to the interface resulted in the removal of a small amount of tailings, the excavated material was removed and transported to an uncovered portion of the MTP. After completion of the data collection, these 20 areas were restored to the original condition using clean radon barrier cover.

Radon flux measurements were made at all test locations prior to the drilling and sampling of the tailings. This was necessary since the flux from the undisturbed tailings was compared to that predicted from the RAECOM model. The discussion of data collection that follows is presented in the sequence in which the field activities were performed.

3.1 Radon Flux Measurements

At the time of the study, the Sands Area had been graded to meet slope requirements and radon barrier had been placed to a depth ranging from 0.6 to 2.7 feet. Radon flux measurements were made at 33 evenly spaced locations on the radon cover on September 8-9, 1993 as shown in Figure 3-1. A land survey was done at the measurement points in order to determine the cover thickness at each point. The average exit flux from the radon barrier was only 1.27 pCi/m^2s. Individual flux values and cover thicknesses are given in Table 3-1.

After the initial flux measurements were made on top of the of the radon cover of the Sands

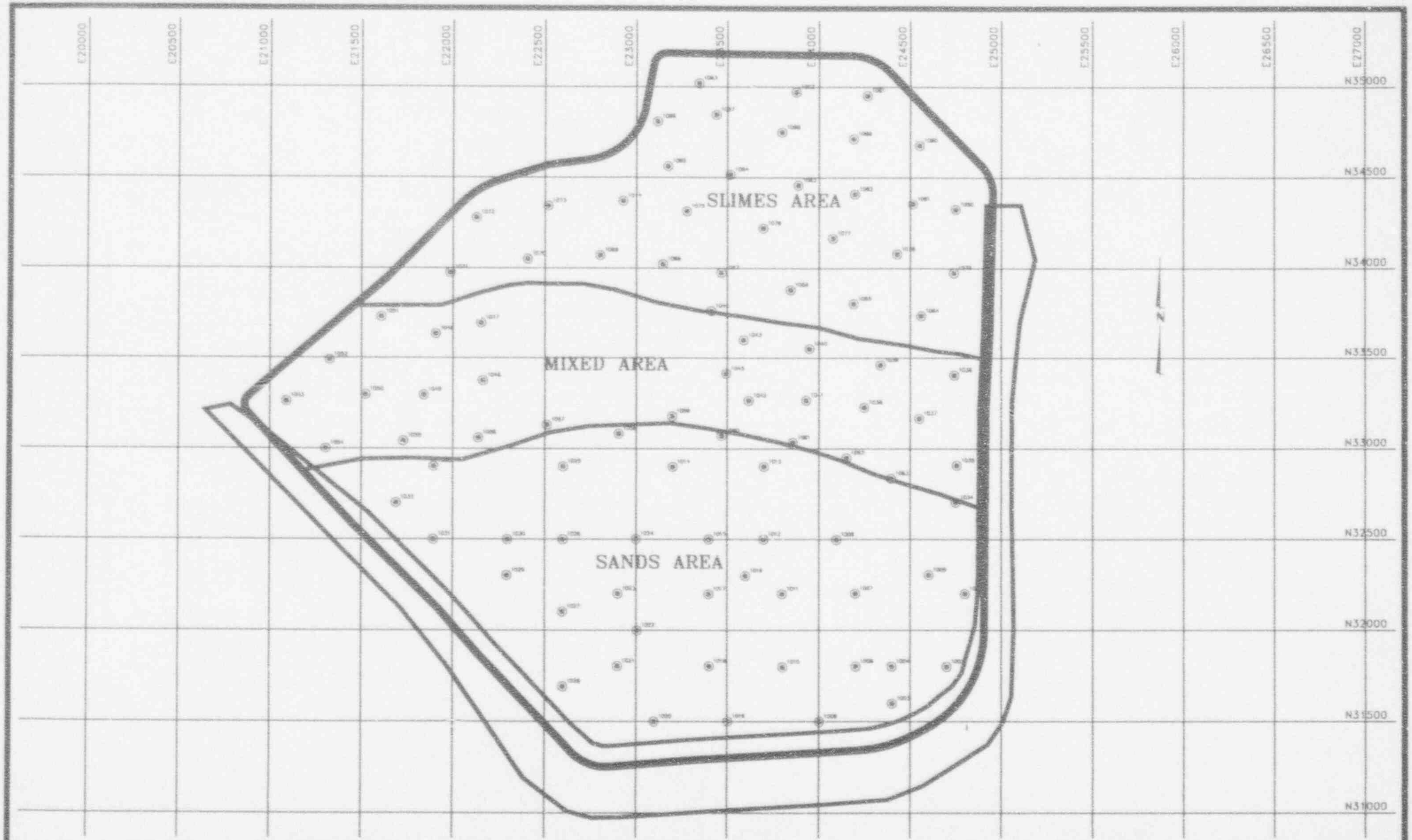

FIGURE 3-1
MAIN TAILINGS PILE
SAMPLING LOCATIONS

ANDERSON ENGINEERING CO., INC.
CIVIL ENGINEERS
CONSTRUCTION MANAGERS

ATLANTIC RICHFIELD COMPANY

DATE: 11/11/93
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Table 3-1

ARCO Bluewater Mill Main Tailings Pile
Sands Area

Location I. D. No.		Depth of Sample (ft) Below Radon Barrier 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226	Cover Thickness(ft)	Avg Cover Moisture
1021	Ra-226 (pCi/g)	34.4	18.2	114.1	124.4	5.84		72.8	2.7	10.4
	Percent Moisture	13.2	6.6	16.7	10.6		11.8			
1027	Ra-226 (pCi/g)	126.5	121.4	111.0	138.9	1.00		124.5	1.7	12.5
	Percent Moisture	10.2	8.4	7.3	14.4		10.1			
1023	Ra-226 (pCi/g)	27.9	128.7	64.8	104.2	1.30		81.4	2.4	11.1
	Percent Moisture	9.1	5.0	12.4	11.4		9.5			
1011	Ra-226 (pCi/g)	71.8	110.2	116.1	117.4	0.21		103.9	2.2	10.4
	Percent Moisture	7.5	14.1	12.3	12.6		11.6			
1003	Ra-226 (pCi/g)	8.6	98.2	69.0	89.3	0.12		66.3	2.2	11.2
	Percent Moisture	9.1	8.3	11.2	10.3		9.7			
1004	Ra-226 (pCi/g)	17.2	26.9	127.1	73.2	0.47		61.1	2.5	10.4
	Percent Moisture	7.8	8.3	9.6	4.0		7.4			
1001	Ra-226 (pCi/g)	7.2	22.0	17.2	21.8	-0.40		17.1	2.3	13.2
	Percent Moisture	15.5	15.5	12.3	13.5		14.2			
1010	Ra-226 (pCi/g)	48.1	129.8	104.4	139.8	0.10		105.5	1.9	11.8
	Percent Moisture	12.5	15.9	9.2	13.1		12.7			
1012	Ra-226 (pCi/g)	111.8	61.7	124.7	138.1	0.13		109.1	1.7	11.6
	Percent Moisture	9.2	6.5	7.0	7.5		7.6			
1030	Ra-226 (pCi/g)	83.4	110.8	149.1	255.8	0.25		149.8	1.5	12.2
	Percent Moisture	9.4	10.0	20.0	28.2		16.9			

Table 3-1

ARCO Bluewater Mill Main Tailings Pile
Sands Area

Location I. D. No.		Depth of Sample (ft) Below Radon Barrier 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226	Cover Thickness(ft)	Avg Cover Moisture
1025	Ra-226 (pCi/g)	95.7	156.4	193.2	164.1	11.36		152.4	0.9	11
	Percent Moisture	9.9	12.3	27.6	13.0		15.7			
1031	Ra-226 (pCi/g)	2.6	7.8	82.9	106.8	1.51		50.0	0.3	15
	Percent Moisture	16.6	9.4	14.4	7.6		12.0			
1026	Ra-226 (pCi/g)	96.8	95.7	186.0	152.4	0.33		132.7	1.5	11.5
	Percent Moisture	9.2	20.8	25.5	23.1		19.7			
1006	Ra-226 (pCi/g)	1.6	6.3	99.5	161.4	0.20		67.2	1.9	11.8
	Percent Moisture	12.8	11.4	10.0	14.3		12.1			
1002	Ra-226 (pCi/g)	12.3	6.2	114.4	149.2	0.73		70.5	2	12.9
	Percent Moisture	8.8	7.7	6.0	12.1		8.7			
1033	Ra-226 (pCi/g)	23.4	21.6	5.8	119.6	0.24		42.6	0.6	13.6
	Percent Moisture	12.8	15.5	3.2	7.4		9.7			
1024	Ra-226 (pCi/g)	85.7	122.7	142.3	176.8	0.19		131.9	1.9	13
	Percent Moisture	8.9	11.0	15.2	17.3		13.1			
1007	Ra-226 (pCi/g)	56.3	85.4	161.7	112.4	0.05		104.0	1.4	10.9
	Percent Moisture	6.0	5.6	9.7	7.6		7.2			
1013	Ra-226 (pCi/g)	29.0	27.9	240.7	110.0	0.22		101.9	1.1	12.9
	Percent Moisture	16.8	23.7	12.4	7.9		15.2			
1032	Ra-226 (pCi/g)	41.5	146.2	104.7	129.2	0.39		105.4	0.9	16.9
	Percent Moisture	17.9	12.2	12.9	13.6		14.2			

Table 3-1

ARCO Bluewater Mill Main Tailings Pile
Sands Area

Location I. D. No.		Depth of Sample (ft) Below Radon Barrier 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226	Cover Thickness(ft)	Avg Cover Moisture
1008	Ra-226 (pCi/g)	54.8	79.9	100.9	100.0	0.24		83.9	1.5	12.7
	Percent Moisture	7.1	8.6	9.0	10.5		8.8			
1014	Ra-226 (pCi/g)	26.5	132.9	175.2	154.0	9.74		122.2	1.7	11
	Percent Moisture	14.0	10.6	15.6	17.2		14.4			
1005	Ra-226 (pCi/g)	4.2	28.6	10.6	68.8	0.53		28.1	2.1	6.6
	Percent Moisture	6.7	10.3	11.0	11.0		9.8			
1015	Ra-226 (pCi/g)	90.2	76.1	128.1	145.7	0.49		110.0	1.7	14.6
	Percent Moisture	8.4	7.9	7.4	14.8		9.6			
1022	Ra-226 (pCi/g)	61.5	107.8	138.5	111.3	3.55		104.8	2.4	13
	Percent Moisture	11.0	11.1	12.9	7.1		10.5			
1029	Ra-226 (pCi/g)	76.0	85.5	96.1	155.4	0.30		103.3	1.4	15.6
	Percent Moisture	11.2	6.5	9.7	22.0		12.4			
1016	Ra-226 (pCi/g)	115.3	199.5	104.8	82.2	0.29		125.5	1.8	11.6
	Percent Moisture	10.3	10.1	12.2	12.4		11.3			
1009	Ra-226 (pCi/g)	57.2	42.3	123.2	164.9	0.06		96.9	1.1	11.3
	Percent Moisture	8.6	7.5	11.3	9.8		9.3			
1020	Ra-226 (pCi/g)	68.5	49.7	112.5	177.0	0.36		101.9	1.1	12.3
	Percent Moisture	13.1	13.5	11.8	15.5		13.5			
1028	Ra-226 (pCi/g)	126.4	92.1	126.5	191.9	1.18		134.2	1.2	10.5
	Percent Moisture	10.0	11.6	9.5	24.5		13.9			

Table 3-1

ARCO Bluewater Mill Main Tailings Pile
Sands Area

Location I. D. No.		Depth of Sample (ft) Below Radon Barrier 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226	Cover Thickness(ft)	Avg Cover Moisture
1018		31.4	36.4	187.5	199.4	0.08		113.7	2.5	12.6
	Percent Moisture	11.0	11.8	18.3	18.8		15.0			
1017	Ra-226 (pCi/g)	63.1	119.4	115.5	124.5	0.84		105.6	2.1	11.8
	Percent Moisture	7.9	12.6	16.3	12.4		12.3			
1019	Ra-226 (pCi/g)	83.3	38.5	110.6	92.2	0.11		81.2	1.3	9.9
	Percent Moisture	8.6	9.0	10.8	10.6		9.8			
	Average Cover Thickness								1.68	
	Average Ra-226	55.76	78.57	116.93	131.88			95.79		
	Average Flux					1.27				
	Average Moisture	10.64	10.89	12.45	13.22		11.80			12.05

Area, the radon barrier material was excavated at 20 locations. These 20 locations were evenly distributed across the pile as shown in Figure 3-2. The excavations were of sufficient dimension (20-ft by 20-ft) to minimize any effects of the radon barrier on the flux measured at the center of the excavated area. Samples of the radon barrier cover were taken at 6-inch intervals and analyzed for moisture content. This work was completed by September 17, 1993. The excavated areas were then allowed to come into equilibrium with the new configurations. Radon flux measurements were made on the bare tailings or other fill on September 29-30, 1993. Table 3-2 presents the results of the bare tailings flux measurements at these 20 locations. They are presented as the cover Entrance Flux while the corresponding Exit Flux from the cover (from Table 3-1) are given for comparison.

No final radon barrier, as described in the Reclamation Plan, has been placed on the Mixed or Slimes Area. However significant quantities of low activity off-pile materials had been placed over the Slimes and portions of the Mixed Area. Thirty flux measurements were made at evenly-spaced points over each of the Slimes and Mixed Areas as shown in Figure 3-1. The results of surface flux measurements are presented for the Mixed Area and Slimes Area in Table 3-3 and Table 3-4, respectively. The average measured flux for the Mixed Area and Slimes Area was 14.4 and 9.7 pCi/m^2s, respectively. Radon flux data reports are provided in Appendix C. Land survey data showing coordinates for each sampling point and existing radon barrier thicknesses are included as Appendix D.

Radon flux measurements were made in full compliance with 40 CFR Part 61, Monitoring for Radon Emissions (Method 115). Methods and procedures used by the Environmental Restoration Group, Inc. (ERG) are provided in Appendix B. The ERG Radon Flux Canister and procedures have been reviewed and approved for use by the U. S. Environmental Protection Agency. Figure 3-3 shows an ERG Canister placed on top of the radon barrier while Figure 3-4 shows a canister placed in the area where the radon barrier had been removed.

Method 115 stipulates that flux measurements may not be made within 24 hours after a rain or when the temperature falls below 32 degrees Fahrenheit. There was no recorded precipitation

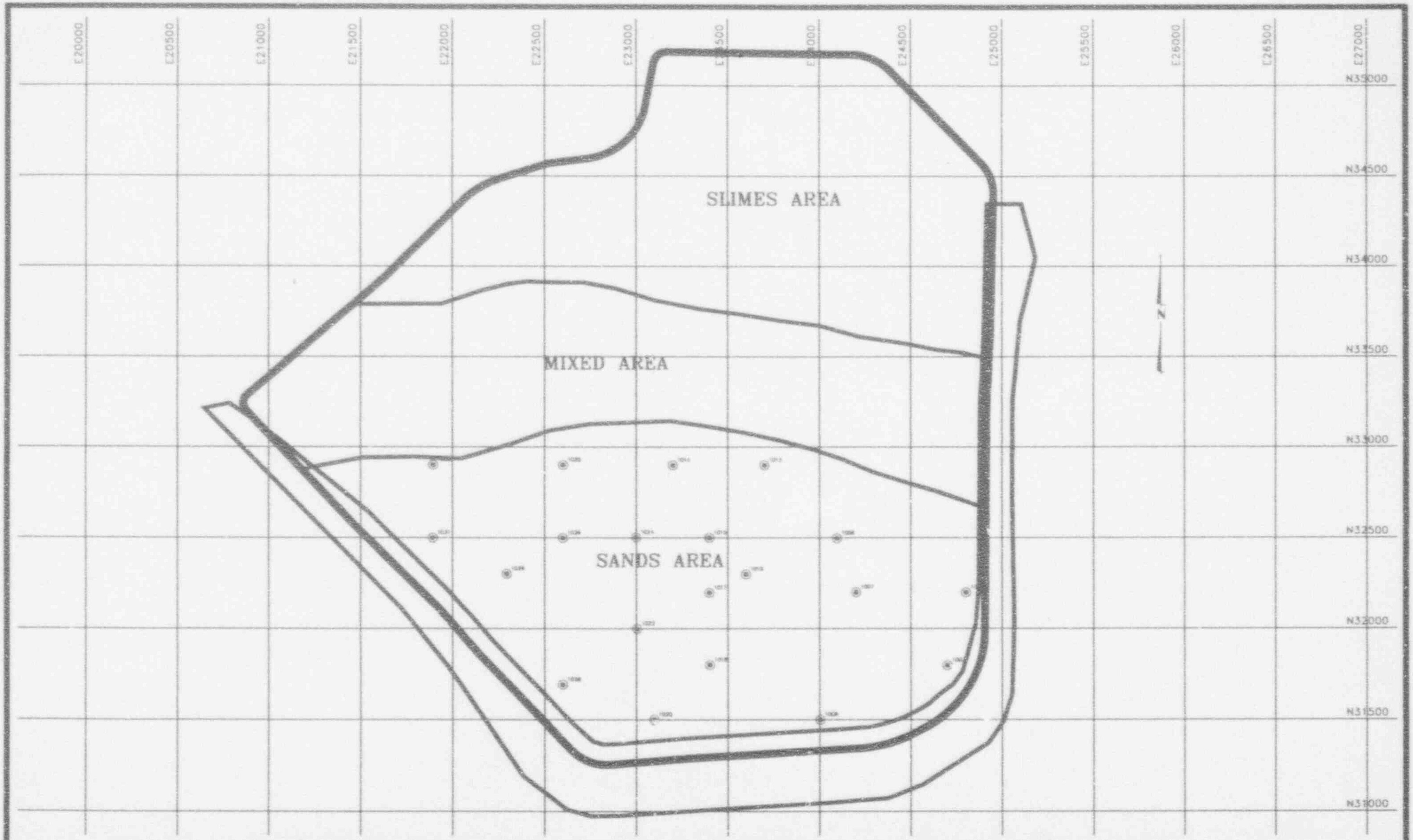

FIGURE 3-2
MAIN TAILINGS PILE - RADON FLUX MEASUREMENT
LOCATIONS ON BARE TAILING SANDS

ANDERSON ENGINEERING CO., INC.
CIVIL ENGINEERS CONSTRUCTION MANAGERS

ATLANTIC RICHFIELD COMPANY

Table 3–2

ARCO Bluewater Mill Main Tailings Pile
Sands Area Radon Barrier Measurements

Location	Exit Flux		Cover Moisture (%) at Depth			Entrance Flux		Cover
I. D.	Can.No.	Flux (pCi/m2s)	0.5 ft	1.0 ft	1.5 ft	Can.No.	Flux (pCi/m2s)	Thickness(ft)
1008	200	0.24	16.4	14.7	7.1	86	26.58	1.5
1007	99	0.05	9.8	13.8	9.0	69	77.36	1.4
1001	202	−0.40	15.4	11.7	12.4	2	34.56	2.3
1002	203	0.73	16.8	13.6	8.4	70	34.29	2
1009	107	0.06	14.5	11.2	8.2	54	24.94	1.1
1016	108/110*	0.29	10.9	12.0	12.0	92	31.05	1.8
1015	40	0.49	14.3	16.2	13.2	79	26.86	1.7
1017	102	0.84	12.3	10.7	12.5	33	22.2	2.1
1018	22	0.08	13.2	14.6	10.1	15	19.81	2.5
1020	62	0.36	11.0	12.3	13.6	66	54.41	1.1
1022	27/23*	3.55	15.1	12.5	11.4	81	30.1	2.4
1024	106	0.19	12.7	13.4	12.9	96	26.96	1.9
1014	30	9.74	11.5	12.0	9.5	3	4.2	1.7
1013	103	0.22	10.0	14.5	14.3	97	17.91	1.1
1025	35	11.36	11.1	10.7	11.1	98	9.02	0.9
1033	28	0.24	14.5	12.6		89	20.35	0.6
1031	43	1.51	13.0	17.0		82	1.51	0.3
1029	31	0.30	14.6	14.2	18.0	87	11.84	1.4
1028	26	1.18	8.1	13.3	10.0	77	70.61	1.2
1026	39	0.33	10.3	11.6	12.7	100	43.54	1.5
	Mean	1.6	12.8	13.1	11.5		29.4	1.5

* Canisters placed side by side

Table 3−3

ARCO Bluewater Mill Main Tailings Pile
Mixed Area

Location I. D. No.		Depth of Sample (ft) 0'−2'	2'−4'	4'−6'	6'−8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra−226
1046	Ra−226 (pCi/g)	47.1	20.7	51.3	255.1	13.7		93.6
	Percent Moisture	11.2	20.4	14.3	44.2		22.5	
1049	Ra−226 (pCi/g)	63.7	82.4	73.4	129.9	52.5		87.4
	Percent Moisture	10.8	12.3	27.9	25.7		19.2	
1051	Ra−226 (pCi/g)	18.3	13.3	32.7	17.1	1.1		20.4
	Percent Moisture	17.3	10.1	11.5	18.4		14.3	
1053	Ra−226 (pCi/g)	18.9	8.9	6.7	88.0	4.3		30.6
	Percent Moisture	13.5	16.5	18.8	11.7		15.1	
1052	Ra−226 (pCi/g)	2.9	7.6	13.3	6.4	5.3		7.6
	Percent Moisture	9.3	16.0	22.4	17.7		16.4	
1050	Ra−226 (pCi/g)	6.7	16.4	26.7	28.7	6.0		19.6
	Percent Moisture	13.3	19.1	34.0	13.3		19.9	
1048	Ra−226 (pCi/g)	−[illegible]	9.2	7.8	21.9	9.5		9.6
	Percent Moisture	11.5	14.0	19.0	19.4		16.0	
1047	Ra−226 (pCi/g)	18.6	0.9	21.9	31.1	12.2		18.1
	Percent Moisture	7.6	7.0	17.9	16.1		12.2	
1044	Ra−226 (pCi/g)	15.8	9.6	14.2	15.4	11.6		13.8
	Percent Moisture	9.6	14.4	20.3	22.4		16.7	
1043	Ra−226 (pCi/[illegible]	12.3	3.5	13.1	15.9	7.4		11.2
	Percent Mo[illegible]	8.6	14.1	15.6	20.0		14.6	

Table 3-3

ARCO Bluewater Mill Main Tailings Pile
Mixed Area

Location I. D. No.		Depth of Sample (ft) 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226
1040	Ra-226 (pCi/g)	20.4	7.9	10.1	7.1	0.9		11.4
	Percent Moisture	15.0	22.7	19.7	12.3		17.4	
1039	Ra-226 (pCi/g)	15.3	14.1	28.5	18.1	1.3		19.0
	Percent Moisture	11.1	10.9	16.9	21.5		15.1	
1036	Ra-226 (pCi/g)	15.5	11.8	11.4	14.0	1.0		13.2
	Percent Moisture	10.9	9.6	9.0	18.2		11.9	
1035	Ra-226 (pCi/g)	3.6	3.0	4.3	58.1	0.7		17.3
	Percent Moisture	19.2	15.9	7.4	16.0		14.6	
1034	Ra-226 (pCi/g)	14.4	11.3	9.3	105.6	2.8		35.2
	Percent Moisture	13.1	15.0	10.1	6.8		11.3	
1054	Ra-226 (pCi/g)	10.9	72.8	149.4	288.8	6.8		130.5
	Percent Moisture	26.3	17.7	29.5	48.8		30.6	
1045	Ra-226 (pCi/g)	6.2	8.9	13.2	200.5	4.5		57.2
	Percent Moisture	8.1	11.1	11.3	44.3		18.7	
1042	Ra-226 (pCi/g)	10.5	17.9	130.0	274.5	16.5		113.2
	Percent Moisture	12.3	13.3	22.5	25.5		18.4	
1041	Ra-226 (pCi/g)	6.0	18.5	4.2	87.1	5.4		29.0
	Percent Moisture	15.5	15.5	14.8	13.7		14.9	
1038	Ra-226 (pCi/g)	5.9	1.6	12.7	31.1	6.1		12.8
	Percent Moisture	9.5	6.6	14.0	22.9		13.3	

Table 3-3

ARCO Bluewater Mill Main Tailings Pile
Mixed Area

Location I. D. No.		Depth of Sample (ft) 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226
1037	Ra-226 (pCi/g)	14.4	3.3	9.7	19.4	4.7		11.7
	Percent Moisture	16.6	11.8	16.2	15.9		15.1	
1055	Ra-226 (pCi/g)	22.7	86.1	203.0	258.7	6.4		142.6
	Percent Moisture	14.3	26.4	54.7	49.1		36.1	
1056	Ra-226 (pCi/g)	5.9	103.9	103.5	212.0	5.8		106.3
	Percent Moisture	10.7	16.7	16.8	19.6		16.0	
1058	Ra-226 (pCi/g)	87.7	139.6	142.4	179.1	40.0		137.2
	Percent Moisture	12.7	16.3	18.1	25.2		18.1	
1057	Ra-226 (pCi/g)	123.3	130.2	141.3	125.3	16.3		130.0
	Percent Moisture	14.9	13.1	17.9	17.0		15.7	
1059	Ra-226 (pCi/g)	176.8	97.4	143.1	307.3	42.4		181.2
	Percent Moisture	22.7	15.3	15.4	31.3		21.2	
1060	Ra-226 (pCi/g)	168.1	127.7	104.8	319.0	37.5		179.9
	Percent Moisture	26.5	20.7	17.0	27.7		23.0	
1062	Ra-226 (pCi/g)	86.0	179.5	137.9	327.1	31.4		182.6
	Percent Moisture	5.5	25.0	14.0	20.8		16.3	
1063	Ra-226 (pCi/g)	90.7	116.6	177.3	400.6	47.8		196.3
	Percent Moisture	10.6	12.5	29.5	43.5		24.0	
1061	Ra-226 (pCi/g)	73.9	198.2	98.3	202.3	30.4		143.2
	Percent Moisture	7.6	18.4	11.2	24.5		15.4	
	Average Ra-226	38.7	50.8	63.9	134.8			72.0
	Average Moisture	13.2	15.3	18.9	23.8		17.8	
	Average Flux					14.4		

Table 3-4

ARCO Bluewater Mill Main Tailings Pile
Slimes Area

Location I. D. No.		Depth of Sample (ft) 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226
1064	Ra-226 (pCi/g)	14.2	19.1	15.7	3.8	1.3		13.2
	Percent Moisture	14.4	10.4	16.6	16.1		14.4	
1093	Ra-226 (pCi/g)	5.1	7.1	17.3	4.4	9.0		8.5
	Percent Moisture	19.0	17.7	24.7	19.0		20.1	
1092	Ra-226 (pCi/g)	14.6	4.9	10.4	16.4	7.5		11.6
	Percent Moisture	13.0	13.8	20.2	22.4		17.4	
1091	Ra-226 (pCi/g)	14.4	7.7	10.3	15.6	3.5		12.0
	Percent Moisture	13.6	11.8	21.2	21.8		17.1	
1089	Ra-226 (pCi/g)	22.5	13.3	6.9	8.4	13.3		12.8
	Percent Moisture	12.2	8.4	12.8	18.6		13.0	
1090	Ra-226 (pCi/g)	4.2	10.2	13.7	18.7	10.5		11.7
	Percent Moisture	11.8	11.0	17.9	24.7		16.4	
1088	Ra-226 (pCi/g)	12.4	10.3	3.3	11.0	8.2		9.3
	Percent Moisture	16.4	17.4	23.2	27.9		21.2	
1087	Ra-226 (pCi/g)	10.2	4.2	4.0	12.7	4.7		7.8
	Percent Moisture	10.5	12.3	20.4	25.0		17.1	
1086	Ra-226 (pCi/g)	3.4	1.9	3.6	7.6	1.5		4.1
	Percent Moisture	7.9	11.9	12.2	20.5		13.1	

Table 3-4

ARCO Bluewater Mill Main Tailings Pile
Slimes Area

Location I. D. No.		Depth of Sample (ft) 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226
1085	Ra-226 (pCi/g)	7.8	5.1	9.5	3.2	3.9		6.4
	Percent Moisture	15.6	17.6	19.8	26.4		19.9	
1084	Ra-226 (pCi/g)	5.8	6.9	6.4	7.0	1.8		6.5
	Percent Moisture	16.5	12.7	14.5	17.4		15.3	
1083	Ra-226 (pCi/g)	69.3	25.4	7.4	25.8	31.6		32.0
	Percent Moisture	19.5	15.1	23.1	35.5		23.3	
1082	Ra-226 (pCi/g)	54.1	5.8	2.3	13.6	18.2		19.0
	Percent Moisture	20.9	26.0	26.1	30.3		25.8	
1081	Ra-226 (pCi/g)	25.1	19.7	10.1	8.2	9.3		15.8
	Percent Moisture	11.7	16.3	21.4	22.9		18.1	
1080	Ra-226 (pCi/g)	20.5	28.5	11.5	8.9	11.2		17.4
	Percent Moisture	11.4	8.6	15.7	25.5		15.3	
1077	Ra-226 (pCi/g)	17.6	9.3	2.9	18.8	6.3		12.2
	Percent Moisture	21.4	10.5	23.0	24.7		19.9	
1076	Ra-226 (pCi/g)	7.5	11.6	14.0	4.2	7.5		9.3
	Percent Moisture	14.5	19.8	20.2	21.2		18.9	
1075	Ra-226 (pCi/g)	26.1	33.8	5.8	6.7	59.6		18.1
	Percent Moisture	17.2	17.7	18.5	19.1		18.1	
1074	Ra-226 (pCi/g)	3.1	9.4	4.5	6.2	2.0		5.8
	Percent Moisture	12.7	24.4	17.8	24.9		20.0	

Table 3-4

ARCO Bluewater Mill Main Tailings Pile
Slimes Area

Location I. D. No.		Depth of Sample (ft) 0'-2'	2'-4'	4'-6'	6'-8'	Exit Flux (pCi/m2s)	Avg Moisture	Avg Ra-226
1073	Ra-226 (pCi/g)	10.0	11.5	15.5	6.8	3.7		11.0
	Percent Moisture	18.6	15.5	22.1	23.6		20.0	
1072	Ra-226 (pCi/g)	4.1	3.0	4.4	12.7	4.5		6.1
	Percent Moisture	11.9	9.1	20.5	26.4		17.0	
1079	Ra-226 (pCi/g)	3.1	10.7	16.2	6.4	1.2		9.1
	Percent Moisture	6.9	11.1	21.4	11.1		12.6	
1078	Ra-226 (pCi/g)	5.5	11.2	8.2	5.5	27.9		7.6
	Percent Moisture	11.1	13.5	15.3	18.1		14.5	
1071	Ra-226 (pCi/g)	14.9	11.4	9.4	0.9	10.6		9.2
	Percent Moisture	9.9	5.2	28.6	10.1		13.5	
1070	Ra-226 (pCi/g)	19.6	79.9	5.1	1.4	5.3		26.5
	Percent Moisture	17.8	15.6	17.7	20.5		17.9	
1069	Ra-226 (pCi/g)	2.8	9.8	16.4	11.6	12.0		10.2
	Percent Moisture	13.4	17.8	18.5	24.4		18.5	
1068	Ra-226 (pCi/g)	37.5	21.5	9.9	4.6	5.8		18.4
	Percent Moisture	15.9	23.0	24.8	27.2		22.7	
1067	Ra-226 (pCi/g)	13.8	5.2	8.9	2.1	3.0		7.5
	Percent Moisture	30.2	14.2	16.3	10.8		17.9	
1066	Ra-226 (pCi/g)	23.8	7.1	12.5	26.5	5.8		17.5
	Percent Moisture	8.6	7.0	15.3	13.6		11.1	
1065	Ra-226 (pCi/g)	9.0	6.0	10.5	12.8	2.1		9.6
	Percent Moisture	12.3	10.3	16.7	26.1		16.4	
	Average Ra-226	16.1	13.7	9.2	9.8			12.2
	Average Moisture	14.6	14.2	19.6	21.9		17.5	
	Average Flux					9.7		

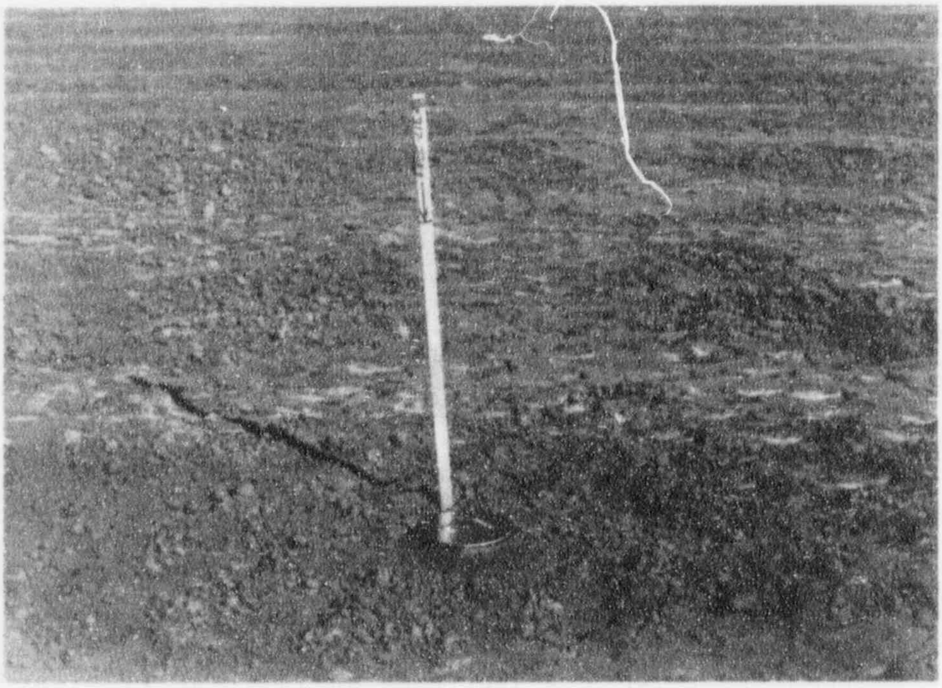

Figure 3.3 Radon Flux Canister Placed on Top of Radon Barrier

Figure 3-4 Radon Flux Canister Placed on Top of Bare Tailings Sands

at the site beginning 24 hours prior to placement of the canisters or during the measurements. Daily minimum temperatures did not go below 32 degrees during the flux measurement periods. Daily site meteorological station barometric pressure, rainfall, and maximum temperatures for the month of September are provided in Appendix E. The radon flux measurement periods were September 8-9, September 23-24, and September 29-30. The rainfall during September occurred on September 6 (0.03 in.), September 12 (0.02 in.), and September 13 (0.32 in.).

3.2 Ra-226 Measurements

As part of the calibration of the RAECOM Model and radon barrier design requirements, the Ra-226 concentration in the upper eight feet of the pile was measured. Continuous 2-feet long core samples were taken to a depth of eight feet at each of the 93 sampling points where the flux measurements were made. The sampling locations are shown in Figure 3-1. In the Slimes and Mixed Area, the first sample was obtained beginning at the surface to a 24-inch depth; in the sands area, the first sample was taken beginning at the radon barrier-tailings interface. The samples were placed in bags and sent to the on-site laboratories for analysis for Ra-226 and moisture content.

Figure 3-5 shows the drill rig at one of the 93 sampling locations on the MTP. Holes were augered to a depth of 8 feet while continuously driving a split-spoon sampler (Figure 3-6). Four 24-inch samples were bagged (Figure 3-7) at each location and sent to the sample storage room (Figure 3-8) for splitting and analysis for moisture and Ra-226.

The samples for Ra-226 assay were prepared and placed in plastic containers for gamma spectral analysis. The size of the container was dependent on the sample activity. Higher activity samples were placed in 350 gram capacity beakers while lower activity samples were placed in 1200 gram beakers. This provided higher analytical sensitivity for the lower activity samples for a reasonable counting time.

Some of the activities and facilities associated with the Ra-226 analysis are shown in Figures 3-9

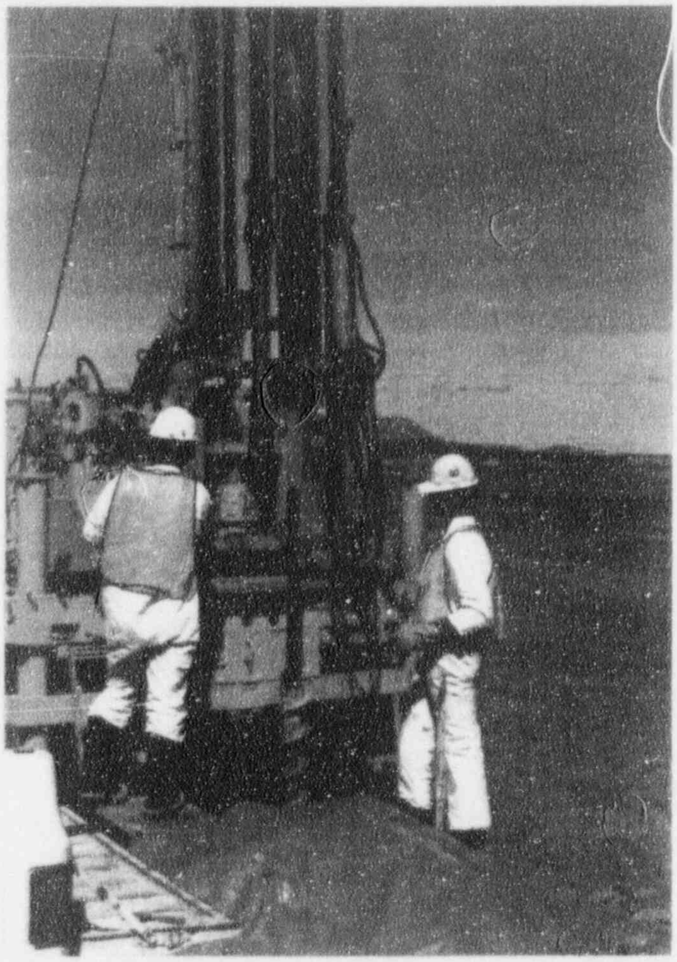

Figure 3-5 Drill Rig on Top of Main Tailings Pile

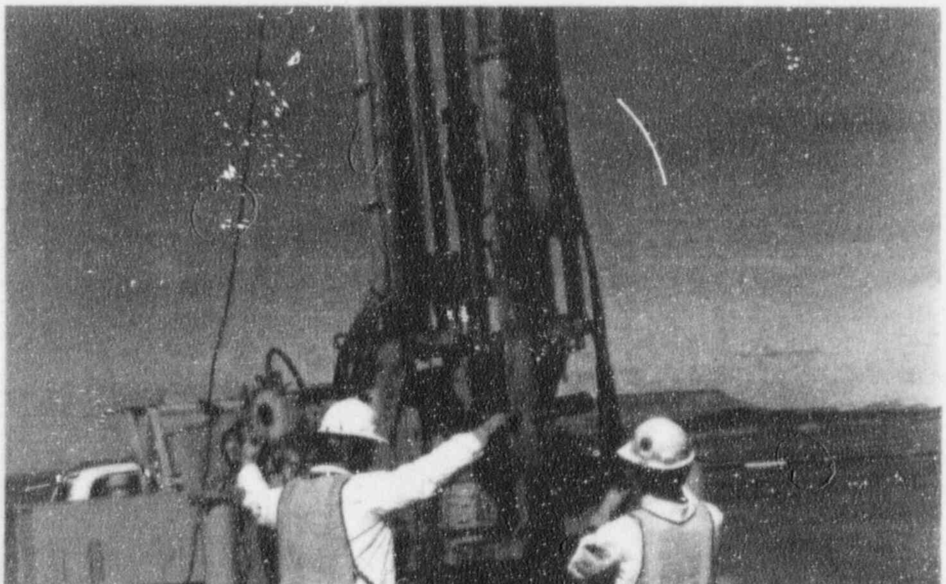

Figure 3-6 Drillers Driving Split-Spoon Sampler

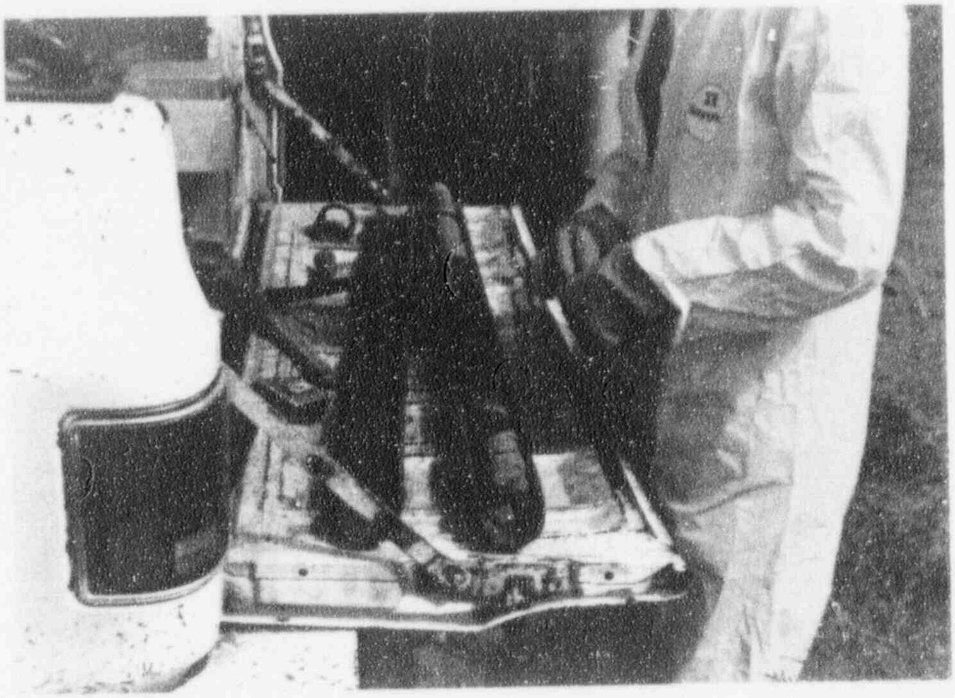
Figure 3-7 Split Spoon and Sample

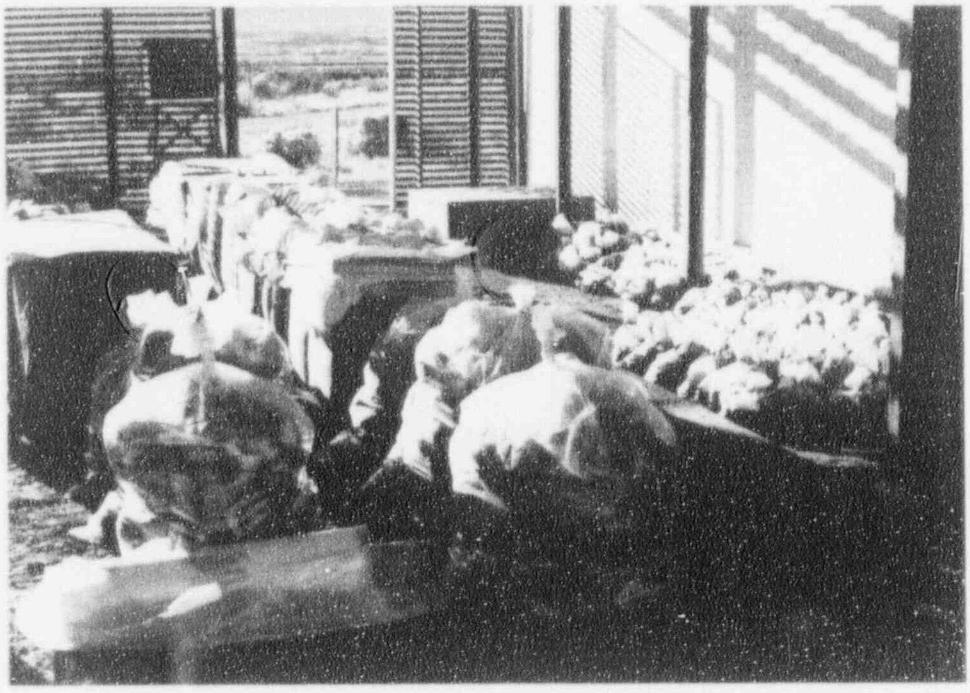
Figure 3-8 Sample Storage Room

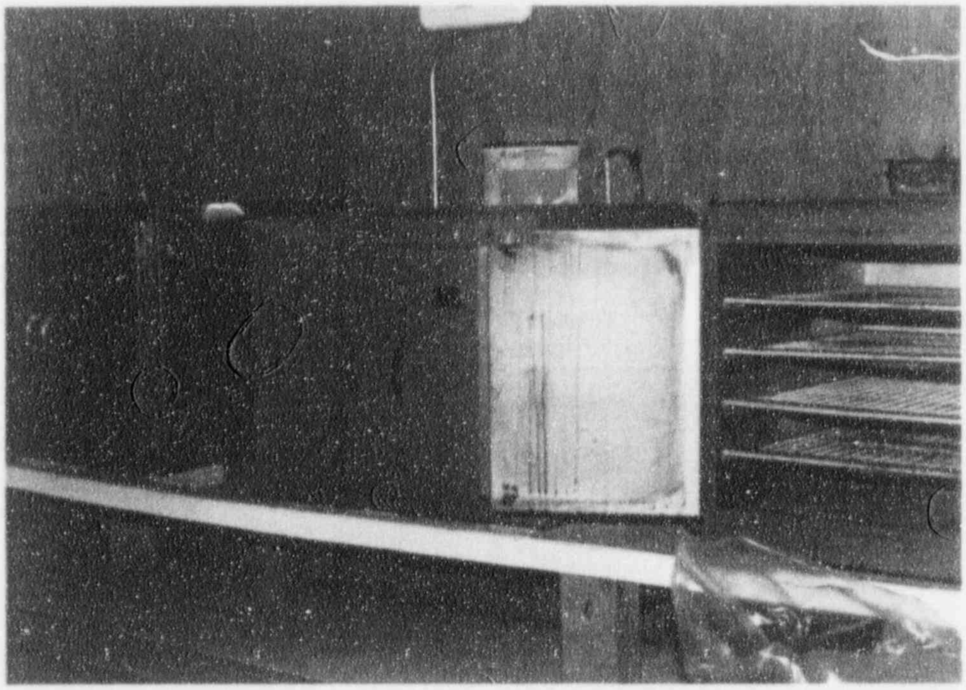

Figure 3-9 Ovens for Drying Soil and Tailings Samples

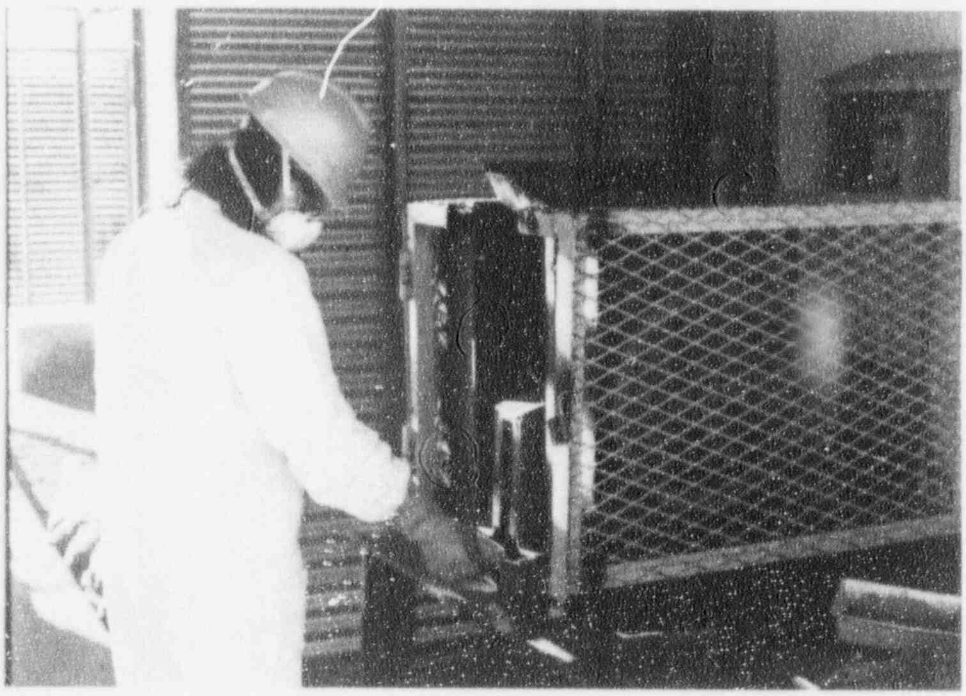

Figure 3-10 Technician Crushing Sample Prior to Ra-226 Analysis

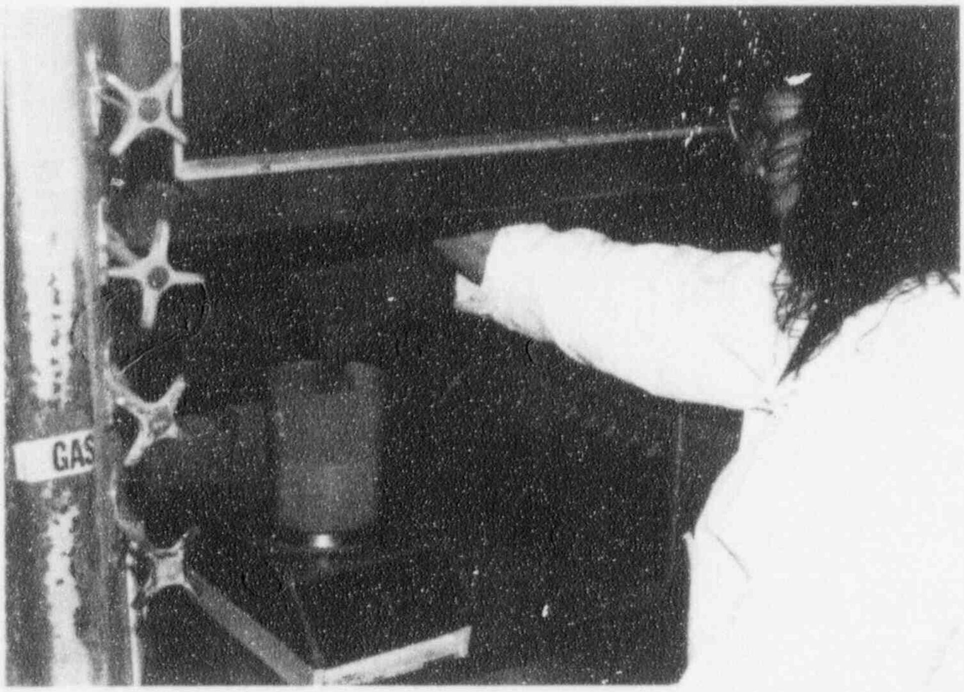

Figure 3-11 Technician Filling Sample Container

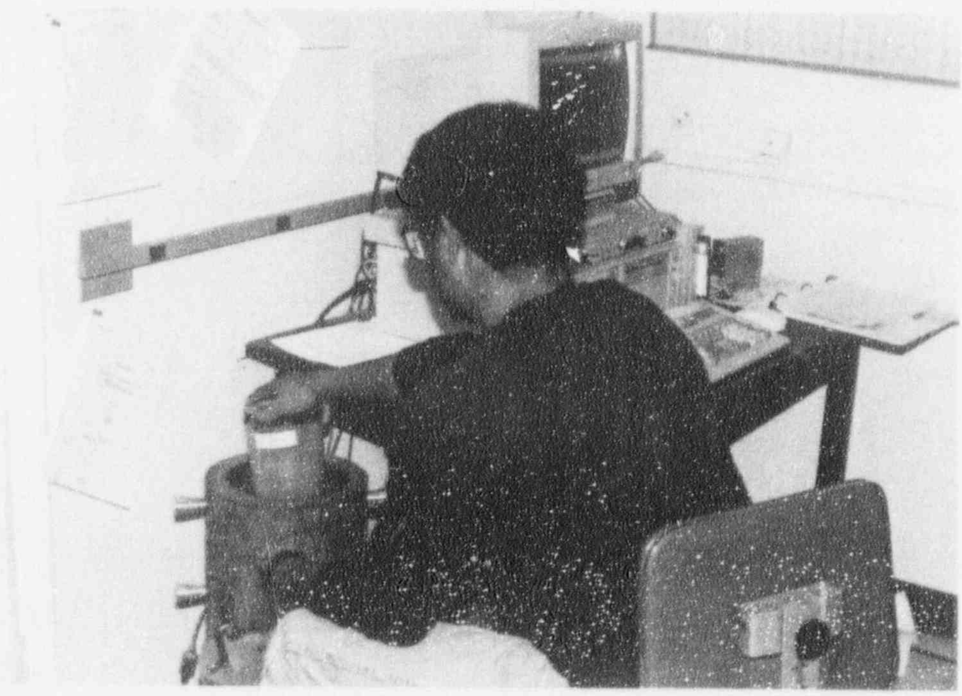

Figure 3-12 Loading Sample into Gamma-Ray Spectrometer

to 3-12. The sample is first placed in a metal pan and dried for approximately 12 hours in one of the ovens shown in Figure 3-9. The sample is then crushed (Figure 3-10), mixed, split, and placed in the sample counting beaker (Figure 3-11). After the sample beaker has been sealed for a minimum period of 28 days, the sample is counted on the gamma-ray spectrometer (Figure 3-12).

All of the 372 samples were analyzed on-site using gamma-ray spectrometers with 3-inch by 3-inch NaI(Tl) detectors. ARCO's spectrometer that has been operating to support the remediation since 1991 was used for analysis. Five percent of the samples are routinely sent to an outside vendor, Acculabs Research Laboratory, Inc. for an independent analysis as part of the QA requirements. ARCO's Standard Operating Procedures for Gamma-Ray Spectroscopy Analyses are provided in Appendix F. The results of the Ra-226 analyses for the 372 samples are also provided in Appendix F.

The QA data comparing the on-site gamma-ray spectral analyses to the off-site laboratory analyses is included as Appendix G. The good agreement between the analyses indicates that the accuracy of the Ra-226 data is acceptable.

3.3 Measurements of the Moisture Content

All of the samples collected for Ra-226 analysis were split for moisture analysis at the on-site laboratory by Sergent, Hauskins, and Beckwith personnel, an ARCO contractor employed to perform geotechnical testing. While removing the radon barrier at the 20 locations shown in Figure 3-2, samples were taken at 0.5, 1.0, and 1.5 feet (when available) beneath the top surface of the radon barrier. Where the radon barrier was less than 1.5 feet thick, fewer than 3 samples were obtained. While drilling through the radon barrier, a single representative sample was obtained and analyzed. All samples were analyzed for moisture using the ASTM D 2216 procedure. Results are presented as a percent of the dry weight. Appendix H consists of the laboratory reports for the moisture determinations.

The results of the moisture measurements are presented in Table 3-1, Table 3-2, Table 3-3, and Table 3-4. In Table 3-2, the average of the samples taken at 6-inch intervals is given. As indicated by the data, the recently placed radon barrier still retains the high moistures similar to that at which it was placed. Radon barrier moistures in the 20 locations averaged 12.5 percent of dry weight, with the individual samples ranging from 7.1 to 18.0 percent. An average of 11.3 percent moisture for the other 13 locations on the Sands Area is based on the analysis of one representative sample per location. Averaging the moistures for the 33 locations results in an average radon barrier moisture of 12.1 percent. As indicated in Table 3-2, a few of the samples taken near the radon barrier/tailings interface had low moisture contents. This may have resulted from the sample being a mixture of the radon barrier and the underlying fill or tailings.

3.4 Density Measurements

Dry density measurements were made on materials during the placement of material on the MTP as part of the contractor's extensive data base and QA/QC program. Since these data were available, there was no need to obtain additional data. Densities were measured by the sand-cone method where sections of compacted material were extracted. The volume was determined using calibrated sand, and running the standard dry density test (ASTM D 1556) in the on-site geotechnical laboratory. Standard proctor tests were done on a subset of the samples using the ASTM D 698 method in which the maximum dry density was measured. Several hundred tests were performed for each of the material types to assure that the construction technical specifications were attained. Table 3-5 presents the mean maximum dry density and mean as-placed dry density along with the respective standard deviation of the measurements for the dike sands, evaporation pond material, windblown material, and radon barrier material.

The data in Table 3-5 indicate that the average compaction for all materials was very high (> 94% of standard proctor). The data also indicates that the average dry density of the as-built windblown material is greater than the average maximum dry density. This apparent anomaly can be attributed to sampling error since only a subset of the samples were analyzed for maximum dry density. Scatter plots of the measured values for the as-placed dry density and

Table 3–5 **ARCO Bluewater Mill Main Tailings Pile Material Densities**

Material	Maximum Dry Density*	As–Placed Dry Density*
	g/cc	g/cc
Dike Sands	1.67 ± 0.14	1.57 ± 0.14
Evaporation Pond	1.62 ± 0.08	1.60 ± 0.08
Windblown	1.79 ± 0.13	1.81 ± 0.13
Radon Barrier	1.90 ± 0.03	1.85 ± 0.06

* errors reported as 1 standard deviation

maximum dry density are included as Appendix I for the four different types of material.

3.5 Radon Barrier Diffusion Coefficient

The Reclamation Plan design for the radon barrier was based on measured parameters of samples taken from the radon barrier borrow area. Tests on the material showed that the maximum dry density was approximately 1.87 g/cc. The design called for the radon cover to be compacted to a dry density of 1.78 g/cc, which was 95 percent of maximum dry density.

Samples taken from the radon cover material as it was placed on the Sands Area (See Table 3-5) indicate that the as-placed material has a dry density of 1.85 ± 0.06 g/cc. Standard proctor tests indicated a maximum dry density for the material of 1.90 ± 0.03 g/cc, indicating an average compaction of 97 percent of standard proctor. While the measured average maximum dry density for the Reclamation Plan agrees well with the average maximum dry density for the existing radon cover material, the average compaction is 97 percent rather than 95 percent as specified in the Reclamation Plan.

The radon diffusion coefficient is highly dependent on two parameters, the dry density and the moisture fraction (fractional void space filled with water). The cover design is based on a long-term moisture of 9.5 percent. Therefore it was decided that in order to calculate the required cover thickness for the MTP, a new radon diffusion measurement would be made at 9.5 percent moisture and a compaction near 1.85 g/cc. Table 3-6 shows that the new value for the diffusion coefficient is 0.0086 cm^2/s. This can be compared to 0.0139 cm^2/s that was used in the Reclamation Plan.

In order to calibrate the model to the ARCO MTP, radon barrier diffusion coefficients for the cover material were also measured at the current moistures. After reviewing the moisture data for the as-placed cover, measurements were made over a range of values (11.2, 14.0, and 15.6 percent) so that interpolations may be made at the specific moistures at the test locations. The results are given in Table 3-6.

Table 3–6 ARCO Bluewater Mill Main Tailings Pile Measured Diffusion Coefficients

Moisture dry wt. %	D (SQ.CM/S)	Density (g/cc)	Saturation (%)
9.5	0.0086	1.83	54
11.2	0.0021	1.84	65
14	0.00021	1.84	81
15.6	0.00028	1.84	90

4.0 MAIN TAILINGS PILE COVER DESIGN

The radon barrier design data presented in Section 3 of this report differ significantly from that used in the Reclamation Plan. As suspected, the results of the Ra-226 analyses show that the Ra-226 concentrations in the upper layers of the MTP are much lower than originally estimated. Table 4-1 compares the average Ra-226 concentrations in the Reclamation Plan to the results from this study. As can be seen from the data, the top layer of the Sands Area shows a significant reduction in the Ra-226 concentration. This probably can be explained by the mixing of the temporary cover and berm material with the top layer during the grading of the Sands Area. Similar reductions in Ra-226 concentrations are evident for the other layers. A portion of the difference may arise from the sampling error in the initial characterization. The initial characterization in the Reclamation Plan was based on only 20 samples taken from the top 8 feet layer of the Sands Area. This compares with 132 samples taken at uniformly spaced locations and uniform 24-inch depth intervals that have been used for this final design.

The concentration profile in Table 4-1 for the Mixed Area indicates that the additional low activity off-pile contaminated material has reduced the average layer Ra-226 concentrations to approximately 25 percent of that presented in the Reclamation Plan. The samples for the Slimes Area reflect the concentration of the off-pile material that was placed on the slimes tailings. As indicated by the data, the average concentration for this off-pile material is less 13 pCi/g. This compares with assumed average concentrations in the Reclamation Plan of 34 pCi/g for the windblown material, 71 pCi/g for the evaporation pond material, and 157 pCi/g for the berm sand.

As indicated previously, the current compaction of the off-pile materials and the radon barrier is higher than the design specifications, leading to the measurement of a radon diffusion coefficient that is approximately 60 percent of that which was used for the design in the Reclamation Plan. This along with the reduced Ra-226 concentrations of the uppermost layers of the pile significantly reduce the required radon barrier thickness.

Table 4-1

ARCO Bluewater Mill Main Tailings Pile
Ra-226 Source Term

Depth(ft)	Sands Area		Mixed Area		Slimes Area	
	Plan Data	As-Built Data	Plan Data	As-Built Data	Plan Data	As-Built Data
0-2	103	56	180	39	38	16
2-4	126	79	220	51	71	14
4-6	143	117	304	64	73	9
6-8	213	132	347	135	103	10

The data collection effort for this study was focussed on the top eight feet of the pile, since only a very small fraction of the radon generated below eight feet reaches the surface prior to decay. A conservative estimate was made (RAE,1993) of the impact of ignoring all material deeper than eight feet from the surface of the Sands Area. The calculation revealed that the calculated flux was only six percent lower than that obtained by including the data for the deeper layers. Nevertheless, data reported in the Reclamation Plan (ARCO,1990) for layers more than 8 feet from the surface were used for all calculations in this study.

The data discussed in this report were provided to V. C. Rogers of Rogers & Associates Engineering Corporation for analysis and interpretation. The material that follows is based on the report, "Evaluation of the Radon Barrier Thickness for the Main Tailings Pile at the Bluewater Mill Site". The report has been included as Appendix K.

4.1 Calibration of the RAECOM Model

The RAECOM model was calibrated to the MTP by modeling the as-built pile under current moisture conditions. The radon flux predictions from the model were compared to the actual measured flux. The source diffusion coefficient (D) was determined by using the measured source D from ARCO, 1990 and correcting it to the measured layer moisture and density. The RAECOM model was then run to compare the output to the measured flux. Repeated runs were made with the source D adjusted until the predicted flux matched the measured flux. The factor used to adjust the source D for each layer is referred to as the calibration factor. A calibration factor for each of three areas of the MTP was determined.

For the Sands Area, the twenty locations on the bare Sands Area were used. The data in Table 3-2 indicate that the average flux from the area was 29.4 pCi/m^2s. The previously-measured D was corrected to the current layer moisture, Ra-226 concentration, and compaction. The model predicted a flux of 49.6 pCi/m^2. In order to match the predicted flux with the measured flux, a calibration factor of 0.468 was required.

The Mixed and Slimes Areas have off-pile material but no radon barrier cover. Attempts at using source Ds corrected to the current site conditions again overpredicted the flux. The flux for the Mixed Area and Slimes Area was overpredicted by 81 percent and 30 percent, respectively. In order to match the calculations with the measured flux, calibration factors of 0.27 and 0.79 were required for the Mixed and Slimes Areas, respectively.

Using all 33 test locations for the Sands Area, the average flux was measured to be 1.3 pCi/m^2s. Using the adjusted D for the tailings at the current moisture conditions, a cover thickness of 51 cm, and a D for the cover corresponding to the current moisture resulted in a calculated flux of 2.3 pCi/m^2s.

The results of these calibrating efforts show that RAECOM is conservative for predicting the flux from the bare MTP pile in that it consistently overestimates the flux from the pile. However, if the source D is reduced by 21-63 percent, the predictions can be made to match the measured values.

The data for the same 20 test areas where the flux was measured above the radon barrier was then examined for the Sands Area. The average radon flux from the cover was measured to be 1.6 pCi/m^2s. Using the tailings Ds that had been adjusted to match the bare tailings flux and a cover D that had been measured at the current moisture, RAECOM predicted a flux of 2.0 pCi/m^2s. The cover D was estimated by interpolating between the measured values of D near the average moisture of 12.5 percent. The prediction was again conservative with the difference of 25 percent in fairly good agreement. This indicates that the RAECOM code can be calibrated to the MTP by using a slightly lower D for the radon barrier material.

4.2 Final Radon Barrier Cover Thickness for the Main Tailings Pile

The calibrated RAECOM model has been demonstrated to provide an accurate prediction of the flux from the MTP. Characterization data on which RAECOM calibrations were made consists of hundreds of measurements to define the current pile configuration with high precision and accuracy. A discussion of the parameters that were used in the final design follows.

The long-term moisture design parameters for the MTP approved in the Reclamation Plan (ARCO, 1992) are 9.5 percent for the radon cover, 8 percent for the tailings sands, 15 percent for the mixed tailings, and 30 percent for the slimes tailings. The off-pile materials, which are primarily native soil, were assumed to retain a long-term average moisture of 9.5 percent, with the exception of the dike sands which was eight percent. During excavation of the dikes, it was discovered that the dike materials more closely resembled the native soil than tailings sand. This observation along with the facts that there were relatively small quantities involved, and that they were primarily placed directly on the very wet slimes tailings led to a decision to consider all off-pile materials to have a long-term moisture of 9.5 percent.

The very precisely determined average Ra-226 concentrations for the top four layers (See Table 4-1) were used. For layers deeper than eight feet, data from ARCO, 1990 were used. The accuracy of these data is of less importance since radon sources lying deeper than eight feet from the surface have little influence on the flux as discussed in Section 4.0.

A new measurement of the diffusion coefficient for the radon cover material at the current compaction and long-term moisture provides data appropriate for the final design. Because of the changes during construction, the previous cover D measurements used in the Reclamation Plan are no longer appropriate. A final small correction to the cover D was made during the model calibration to correct for the overprediction of RACOM from the covered portion of the MTP.

The as-built compaction data was also a significant element in the redesign of the cover thickness since the diffusion coefficient is highly sensitive to the compaction. The hundreds of measurements on the cover material as it was being placed provide assurance that the mean compaction is accurately known. A measure of compaction uniformity is revealed by the small standard deviation (see Table 3-5) resulting in a coefficient of variation of only 1.6 percent. These data provide confidence that the placement of material has been done with a very high degree of uniformity at a high dry density.

Tailings emanating fractions based on ARCO, 1990 were used for all calculations.
RAECOM was used to calculate the radon barrier thickness requirements using parameters for the long-term moisture conditions. The cover thickness requirements to meet the 20 pCi/m^2s standard for the Sands, Mixed, and Slimes Areas are summarized in Table 4-2. The thickness for the Sands, Mixed, and Slimes Areas are 39 cm, 27 cm, and 0 cm, respectively.

Additional radon barrier cover has recently been placed on the Sands Area to a uniform thickness of 73 cm. Since this exceeds the design thickness of 39 cm, no additional cover is required. A one-foot thick final radon barrier cover will be placed on the mixed area. The Reclamation Plan (ARCO,1990) requires a 6-inch thick erosion protection layer above the radon barrier. In order to apply this erosion protection layer, a 6-inch thick radon barrier cover will be applied to act as a working surface over the Slimes Area to prevent mixing of the off-pile material with the erosion protection layer.

Using the long-term design parameters for the three areas, and the thicknesses of the final radon barrier as discussed above, the long-term projected flux for the Sands Area is 10.4 pCi/m^2s; for the Mixed Area, the long-term projected flux is 18.6 pCi/m^2s; and for the Slimes Area, the long-term projected flux is 7.3 pCi/m^2s. This results in an area-weighted average flux of 11.6 pCi/m^2s as shown in Table 4-2. This shows that the average projected flux for the MTP is conservative in that it is only 58 percent of the flux criterion of 20 pCi/m^2s. This provides ARCO additional assurance that the pile will comply with the flux standard.

Table 4-2 **ARCO Bluewater Mill Main Tailings Pile Final Radon Barrier Design**

Area	Surface Area Acres	Required Cover (cm)	Proposed Cover (cm)	Projected Flux (pCi/sq m/s)
Sands Area	101.9	39	73	10.4
Mixed Area	67.5	27	30.5	18.6
Slimes Area	79.5	0	15	7.3
			Area-Weighted Average	11.6

5.0 DESIGN OF OTHER TAILINGS AREAS AT THE BLUEWATER MILL SITE

In addition to the MTP, tailings areas at the Bluewater Mill Site include the Carbonate Tailings Pile and the Acid Tailings Pile. These areas are shown in Figure 5-1.

The 23-acre Acid Tailings Pile will remain open for contaminated material disposal until all materials have been consolidated. ARCO has retained one evaporation pond, IIIA, for continued use for receiving run-off from the MTP and water from the decontamination of construction equipment. This pond will be decommissioned after all contaminated materials have been consolidated on the Acid Tailings Pile and a lift of material has been placed on the MTP. The evaporation pond debris and contaminated soil will be placed on the Acid Tailings Pile. The Acid Tailings Pile will then be graded to its final configuration. Only at that time can an accurate determination be made of the radiological source term.

The Carbonate Tailings Pile has been covered with radon barrier to a depth of 8 to 12 feet according to the Reclamation Plan. One design change was to cover a 4-acre tailings area that extended beyond the original boundary at the northwest corner of the pile. This was done rather than to attempt to consolidate the tailings. Cleanup of the tailings to near background levels would have been impractical since the tailings were interspersed with lava rock.

The schedule in the current ARCO NRC license for the site calls for the completion of the radon barrier placement by the end of December 28, 1994. Since the radiological source term will not be available until the final configuration of the Acid Tailings Pile has been determined, the thickness of the final radon barrier cannot be calculated. The schedule for completion of the evaporation pond decommissioning is midsummer 1994. The sampling and analysis of the Acid Tails will take approximately 6-8 weeks. Considering the additional time to do the engineering and contract modifications, there will be no time for regulatory review and approval.

In order to meet the very tight schedule for the completion of this work, ARCO seeks NRC approval to proceed with the completion of the radon barrier for the Acid Tailings Pile and the

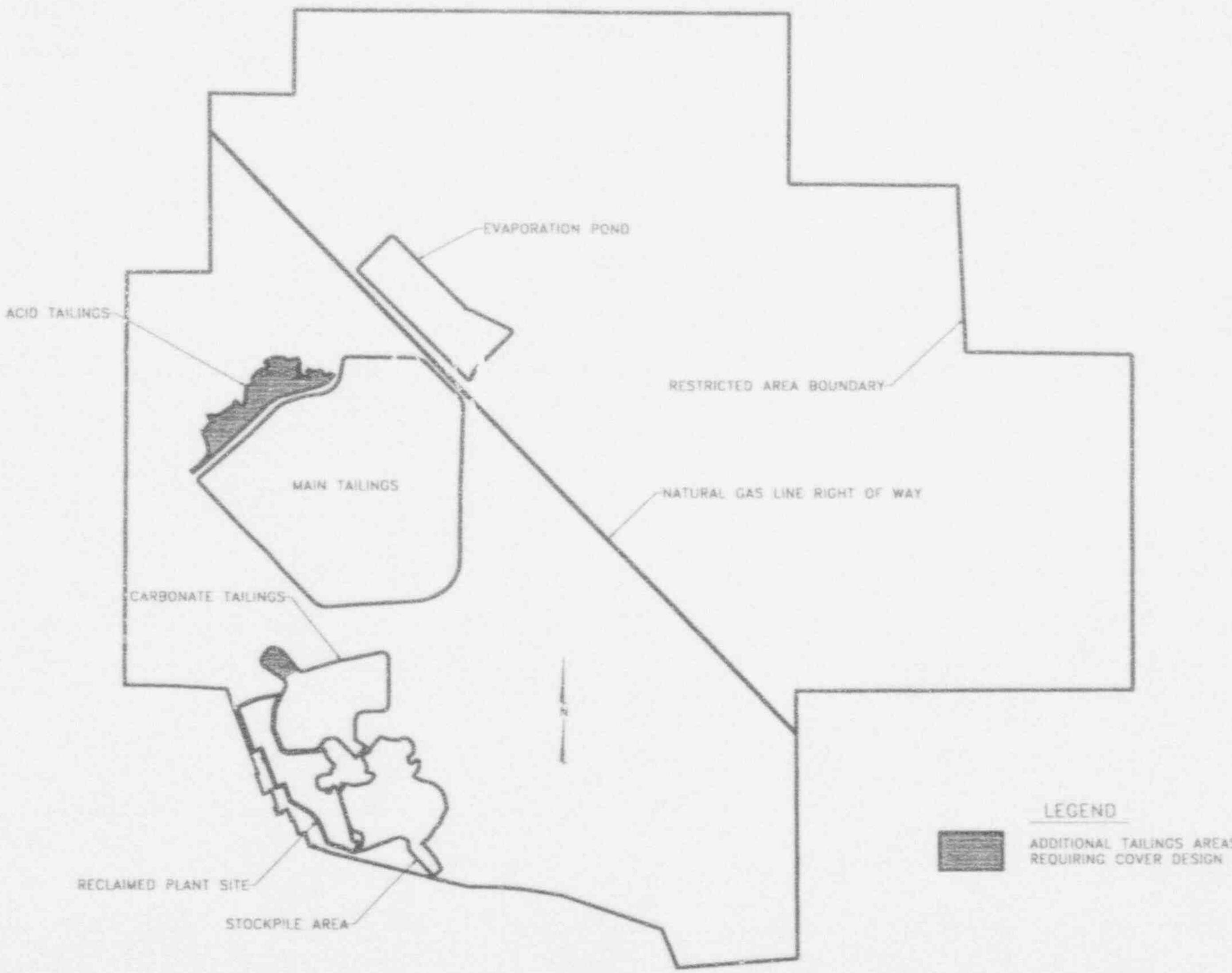

FIGURE 5-1
ADDITIONAL TAILINGS AREAS
REQUIRING RADON COVER DESIGN

ANDERSON ENGINEERING CO., INC.
CIVIL ENGINEERS CONSTRUCTION MANAGERS

ATLANTIC RICHFIELD COMPANY

DATE: 12/07/93
HORIZ. SCALE: NOT TO SCALE

Carbonate Tailings Pile extension using a design based on the protocol as outlined below. The protocol is consistent with that used for the MTP.

1. ARCO will characterize the Ra-226 profile within 8 feet of the surface on which the radon barrier is placed. For the 22-acre Acid Tailings Pile, continuous 24-inch core samples will be taken at 10 locations. For the 4-acre extension to the Carbonate Tailings Pile, the core samples will be taken at 3 locations. All samples will be analyzed for Ra-226 content.

2. The RAECOM model will be run using measured Ra-226 concentrations for the tailings. Tailings diffusion coefficients and other characteristics will be based on measured as-built parameters or other site characterization data, RAECOM model calibration data presented in Section 4 and Appendix K, and radon barrier cover diffusion coefficients measured at the long-term moisture and as-built dry densities.

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APPENDIX A

Work Plan for Characterizing Main Tailings Pile

Work Plan for Characterizing Main Tailings Pile

1.0 Sands Area

1. Identify 30 locations evenly distributed over the sands of the Main Tailings Pile. Survey these locations.

2. Make 24-hour flux measurements at these 30 locations using EPA Method 115 or equivalent.

3. At 20 of the 30 locations, make moisture determinations beginning at a depth of six inches and at six-inch intervals through the radon barrier. At these locations, remove the radon barrier from around the flux measurement point to a distance of 10 feet or more. Determine the radon barrier thickness at the flux measurement point by survey data. Wait approximately 2 weeks and then make 24-hour flux measurements at these 20 locations using EPA Method 115 or the equivalent.

4. Take a continuous sample through eight feet of material beneath the radon barrier at the 30 locations identified in Number 1 above. (Note: approximately 10 locations will require penetrating the radon barrier prior to taking the continuous eight-feet sample). For those 10 locations, take a representative sample of the cover material for moisture measurements. Bag each 24-inch section beginning with the radon barrier/subbarrier material interface. Do not use radon barrier for the sample.

5. Make moisture determinations and Ra-226 concentration measurements on the 120 samples obtained in 4 above. For the 10 locations where the radon barrier was penetrated, make a moisture determination on the representative sample.

6. Restore areas by removing all excavated material, restore with clean radon barrier, and compact to original specifications.

2.0 Mixed Sands/Slimes Area

1. Identify 30 locations evenly distributed over the mixed area of the Main Tailings Pile.

2. Make flux measurements at these 30 locations. Survey the location of the 30 points.

3. Take a continuous sample through eight feet of material, beginning at the surface, at each of the 30 locations identified in Number 1 above. Bag each 24-inch segment beginning with the top segment.

4. Make moisture determinations and Ra-226 concentration measurements on the 120 samples obtained in Number 3 above.

5. Restore the areas by placing clean fill in the drill holes as directed by the ARCO engineering group.

3.0 Slimes Area

1. Identify 30 locations evenly distributed over the slimes area of the Main Tailings Pile.

2. Make flux measurements at these 30 locations. Survey the location of the 30 points.

3. Take a continuous sample through eight feet of material, beginning at the surface, at each of the 30 locations identified in Number 1 above. Bag each 24-inch segment beginning with the top segment.

4. Make moisture determinations and Ra-226 concentration measurements on the 120 samples obtained in Number 3 above.

5. Restore the areas by placing clean fill material in the drill holes as directed by the ARCO engineering group.

4.0 Radon Diffusion Coefficient Measurements

1. Collect a representative sample of radon barrier from the top of the Main Tailings Pile. Measure the radon diffusion coefficient at the long-term design moisture of 9.5 percent. Also measure the radon diffusion coefficient at three additional moistures spanning the moisture range of 11-16 percent, corresponding to the current sands radon barrier moisture range.

APPENDIX B

ERG Radon Flux Canister and Measurement Procedures

Measurement of Radon-222 Flux Using the ERG Canister and Associated Procedures

August 1993

Prepared by

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ERG Radon Flux Canister and Measurement Procedures

1.0 Introduction

In developing the National Source and Hazardous Air Pollutant Standards (40 CFR Part 61), the U. S. Environmental Protection Agency requires that radon flux measurements be made according to 40 CFR Part 61, Appendix B, Monitoring for Radon Emissions (Method 115). Method 115 cites the canister design and associated procedures in publication EPA 520/5-85-029, "Radon Flux Measurements on Gardinier and Royster Phosphogypsum Piles Near Tampa and Mulberry, Florida," as the basic procedure to follow. Other procedures may be used but must be approved by the EPA prior to making the measurements.

The large-area activated charcoal canister (LAACC) design described in Method 115 consists of a 10-in diameter PVC pipe cap, fiberglass screen, plastic grid, and scrubber pads. Activated charcoal is placed in the plastic grid which is sandwiched between the 0.5 inch thick scrubber pads. A one-inch scrubber pad is placed in the very end of the cap for use as a spacer, then the charcoal sandwiched between the 0.5 inch scrubber pads is placed into the cap, all of which is held in place by a retaining spring. A 0.25 inch hole is drilled into the end of the cap to eliminate pressure differentials.

The LAACC uses approximately 170 grams of activated charcoal which is loaded into the canister prior to deployment. At the end of the exposure period, the charcoal is removed and placed in a cottage cheese container, sealed, and counted on a gamma-ray spectrometer.

The dimensions of the LAACC canister were important parameters in that the canisters should be 10 inches in diameter and the distance between the charcoal layer and the ground surface should be 0.75 to 1 inch.

The purpose of this report is to demonstrate that the ERG Canister is comparable in design to the LAACC canister and that the canister and associated procedures meet all requirements of EPA Method 115.

2.0 ERG Radon Flux Canister Design

The ERG Canister was designed to be comparable to the specifications of EPA Method 115, while avoiding handling difficulties associated with the LAACC. The primary difficulties in using the LAACC were associated with handling the charcoal at the job site, quite often at a remote area. The charcoal fines create a dusty environment during the loading and unloading of the canisters. Performing these operations indoors is not advisable unless a vented hood is available. Also, the time required to load or unload the canisters may be several hours, depending upon the number of canisters and number of field personnel available. In addition, the unloading of the canisters creates an opportunity for the radon to escape from the pore space between charcoal particles as well as loss from the fines that are released to the atmosphere.

The ERG Canister was designed using a two-inch deep polished aluminum (32 mil thickness) cake pan as the basic collector. A handle was riveted to the top for ease of handling. The hollow rivets provide an air path to eliminate any pressure differential between the collector and the outside air. The exterior of the ERG Canister is shown in Figure 1.

A hole was drilled in the center of the canister for a bolt. Aluminum spacers made from 32 mil flat stock were designed to create eight equal-sized sectors within the canister as shown in Figure 2. Approximately 380 grams of activated charcoal is placed within the sectors (see Figure 3). Two very fine aluminum screens rotated at 45 degrees from one another were stapled together and placed over the sector spacers and a wire supporting mesh is added last to provide additional support. A washer and nut is added to the central bolt to secure the wire supporting mesh. The screens and mesh are fastened to the canister side walls by adding a thin bead of DP-190 Epoxy Adhesive, manufactured by 3-M Corporation. This adhesive was selected due to its low outgassing properties. Lastly, a small amount of epoxy is added to the nut and bolt to secure the nut to the bolt. The assembled canister without charcoal is shown in Figure 4.

The dimensions of the ERG Canister are similar to that of the LAACC, both being 10 inches in diameter. The distance between the charcoal layer and the ground surface is 1 inch, similar to the LAACC. The ERG Canister contains approximately twice as much charcoal as the LAACC.

Desorption of radon from the activated charcoal is known to occur at elevated temperatures. The polished aluminum surface provides a good heat reflecting surface and is superior to the white PVC material used in the LAACC design.

All materials used to construct the ERG Canister were chosen to allow the canister to be baked out at elevated temperatures without emitting gaseous products that may impair the function of the activated charcoal.

3.0 Standard Canister Design

Since the activated charcoal is permanently contained in the ERG Canister, a sealed standard consisting of Ra-226 in equilibrium with its daughters is required which has the same geometrical configuration as the canisters. This was accomplished as shown in Figures 5 and 6. A thin (18 mil) aluminum disk was used to contain the Ra-226 spiked charcoal rather than the wire screen and supporting mesh. A thin aluminum band was inserted on the side wall and epoxy applied as a sealant between the band and the side wall, between the band and the disk, and around the bolt and rivets. For information on the preparation of the spiked activated charcoal, see Section 5 of Standard Operating Procedure ERG.011 which is attached.

4.0 Counting System

The standards and canisters are counted on a computer based gamma-ray spectrometer consisting of a 3-inch by 3-inch NaI(Tl) detector, placed in a lead shield. Inserts for the canisters and standards were prepared from low density insulation board manufactured by Dow Chemical Company as shown in Figure 7 and 8. The insert fits within the canisters and standards and is properly sized to fit onto an upward looking detector housing. This ensures reproducible geometry during the counting of the standards and canisters.

5.0 Canister Handling and Flux Calculations

The canisters and activated charcoal are baked at 110 degrees Celsius for 24 hours, allowed to cool for 10 minutes at ambient temperature, and sealed in a zip-lock plastic bag. The plastic bag is large enough to allow the insert to be placed in the canister for counting with the bag in place. Therefore as much air must be displaced from the bag as practical during the sealing of the bag.

The canisters are transported in specially constructed boxes having spacers designed to protect the canisters and plastic bags from excessive agitation and friction. Upon deployment, the canisters are removed from the bags and placed on the area to be characterized for approximately 24 hours. The canisters are then retrieved and placed in bags and immediately returned to the counting laboratory. After a minimum of four hours, the canister inserts are placed in the canisters (still within the plastic bags) for analysis using gamma-ray spectroscopy. After all counting is complete, the canisters are baked out to drive off the remaining radon and then bagged.

A Lotus 123 spreadsheet is used to input all data needed to calculate the flux as defined in EPA Method 115. These data and details of the handling and counting of the canisters are provided in Standard Operating Procedures ERG.010 and ERG.011 which are attached.

Average radon flux for the area is determined using the area-weighting procedure specified in Method 115.

6.0 Canister and Standards Testing

The 609 keV photopeak from Bi-214 was used to determine the Radon-222 content of the canister. Calculations show that the attenuation of this gamma ray due to the aluminum disk in the standard is approximately 1.5 percent. An estimate of the effective thickness of the aluminum screen and wire support for the canisters gives a similar attenuation. Therefore the analytical error due to standard and canister design is considered less than 1 percent.

Measurements were made at a uranium mill tailings pile to validate the procedures. Samples placed on areas with fluxes ranging from less than 7 pCi/m^2s to over 100 pCi/m^2s were counted several times during the time interval of 4 hours to 65 hours after retrieval. Calculated fluxes for all counting times were consistent and within the errors calculated for the measurements. Field blanks and other tests on unexposed canisters were analyzed to ensure that the plastic bags provide a proper seal.

7.0 Summary

The ERG Canister was designed to meet the requirements in EPA Method 115 while avoiding the charcoal handling difficulties associated with the LAACC canister. The canister design and handling procedures reduce the probability of loss of activity from the activated charcoal and minimize the probability of human error since no transfer of charcoal and relabeling is required.

The ERG Canister and associated procedures (attached) is not considered an alternative method to EPA Method 115. However it is believed to have certain advantages as discussed above.

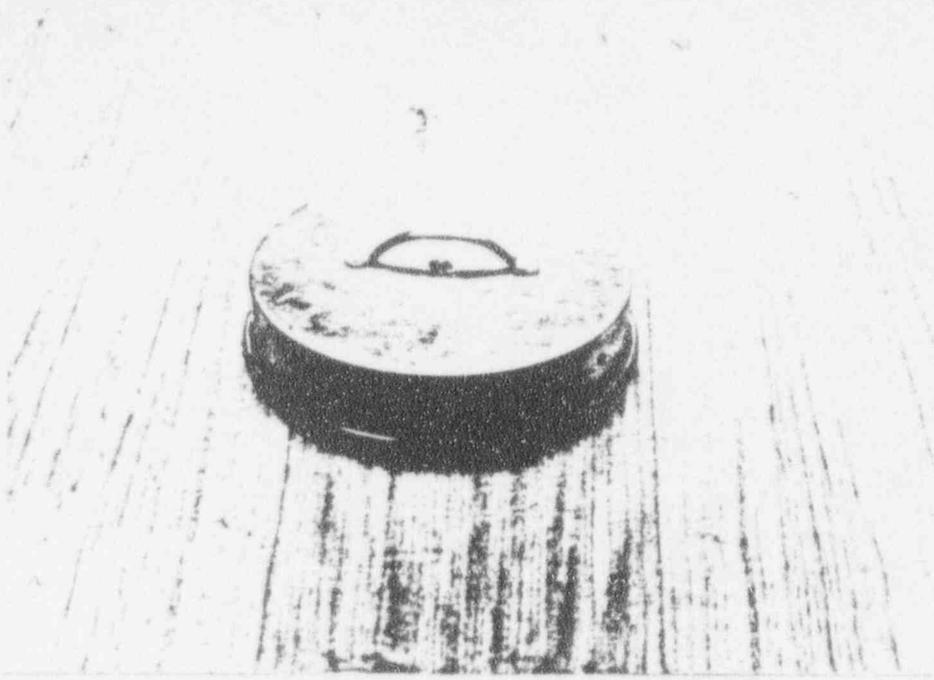

Figure 1.   ERG Radon Flux Canister

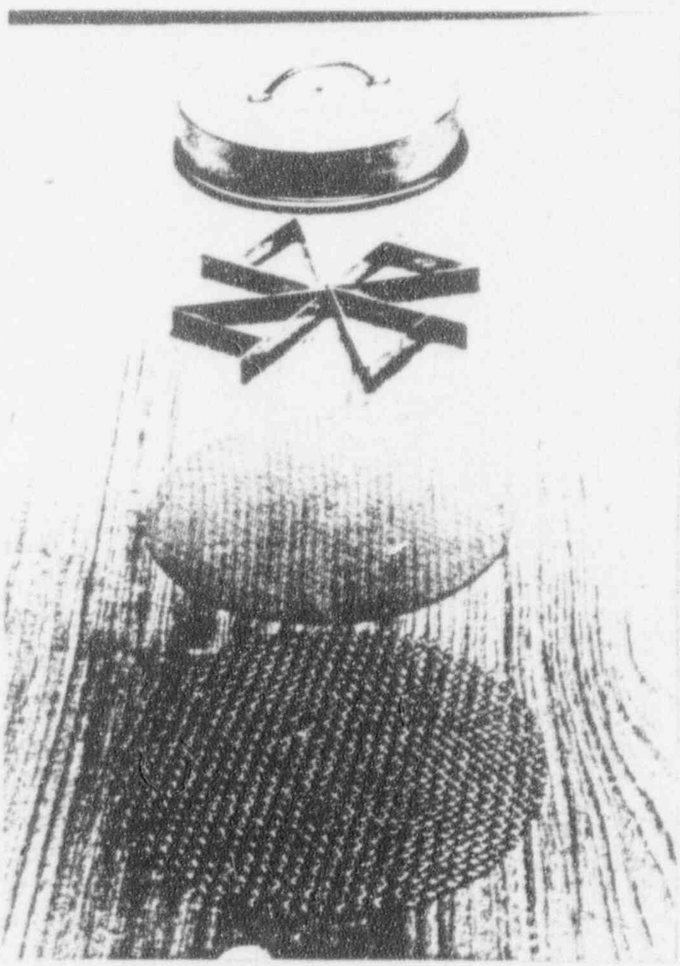

Figure 2. ERG Canister Internal Components

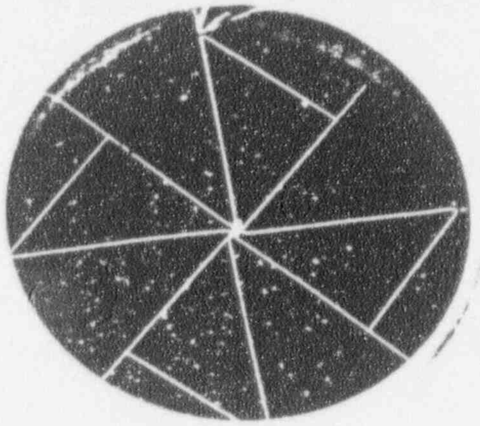

Figure 3.   ERG Canister with Activated Charcoal

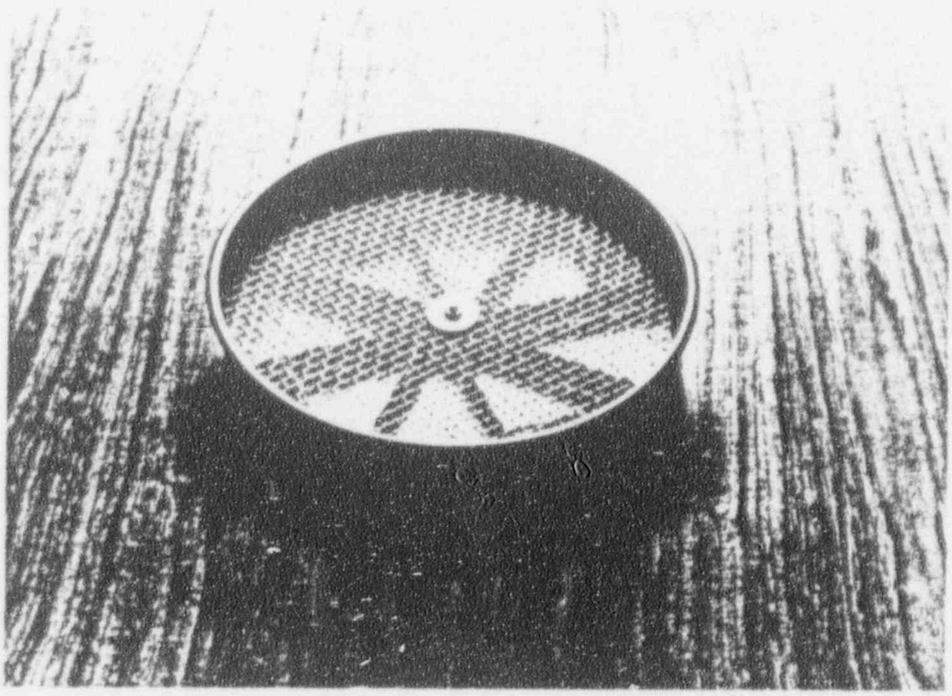

Figure 4.   ERG Assembled Canister without Activated Charcoal

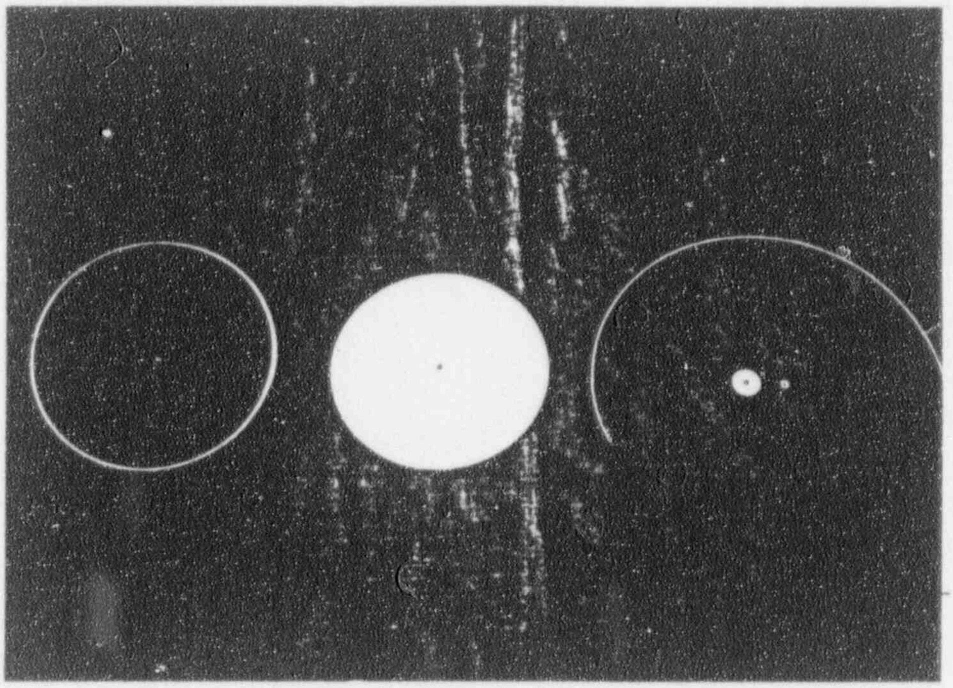

Figure 5. Calibration Standard with Spiked Charcoal and Components

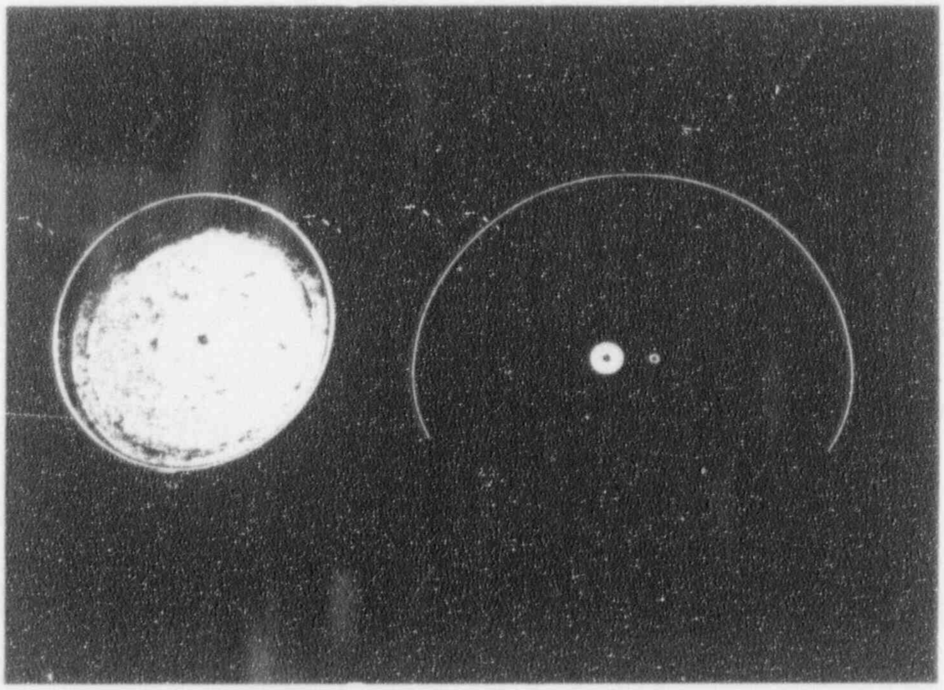

Figure 6. Calibration Standard Partially Assembled

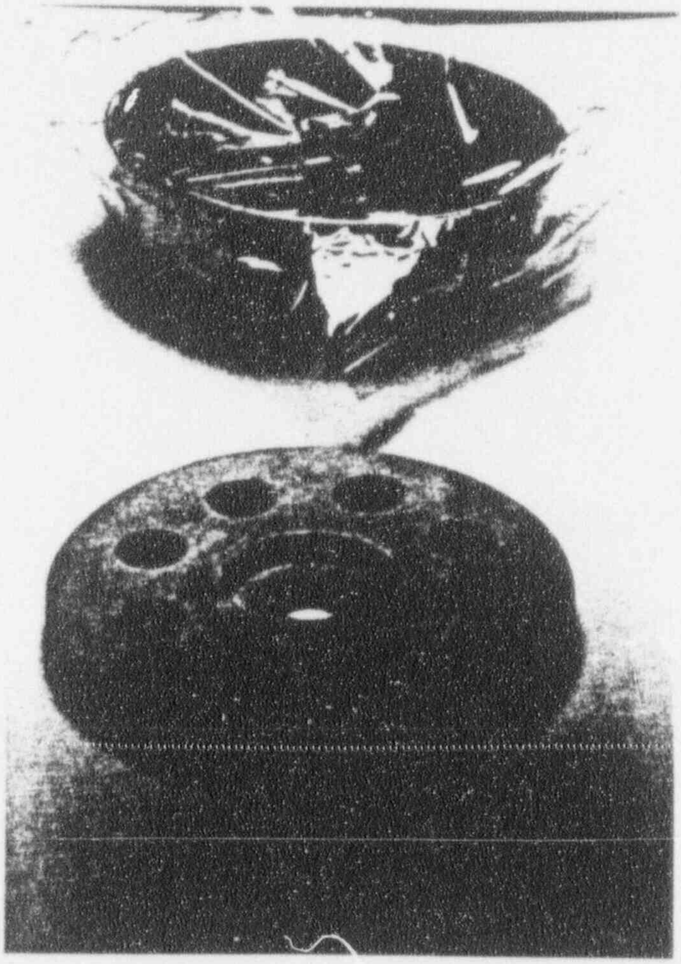

Figure 7. ERG Canister and Insert for Counting

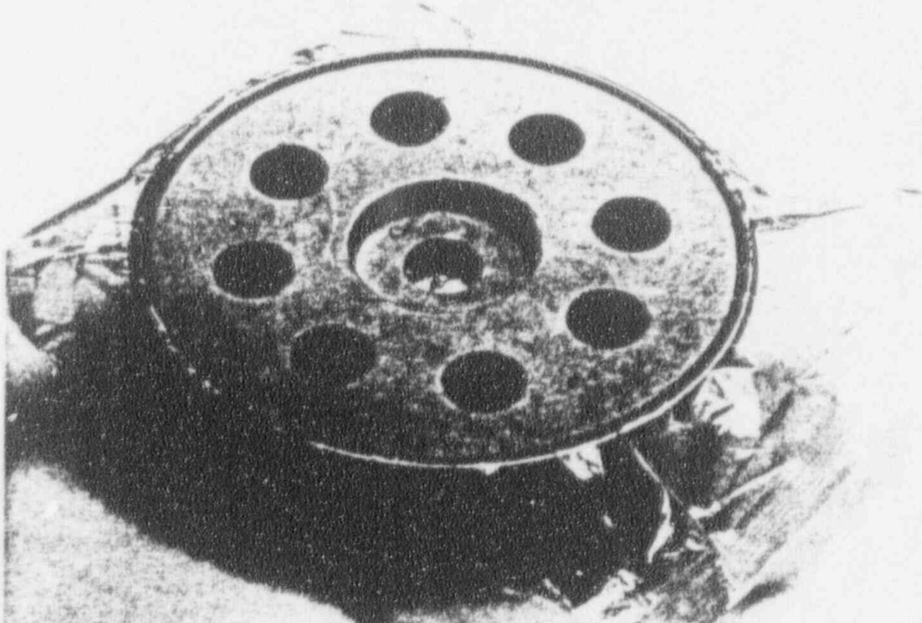

Figure 8. Assembled Insert and ERG Canister

U. S. Department of Energy
New Brunswick Laboratory

New Brunswick Laboratory Certified Reference Materials Certificate of Analysis

CRM 3-B

Low Grade Pitchblende

U_3O_8 content of the material dried at 110°C to constant weight - 3.90%

This material was made from a pitchblende ore diluted with dunite and was prepared to test procedures for chemical analysis. Analyses on the pitchblende ore from which this sample was made show that the ratio of grams of radium to grams of uranium is 3.38×10^{-7}.

June 1969
New Brunswick, New Jersey

Clement J. Rodden
Area Manager

U. S. Department of Commerce
John T. Connor, Secretary
National Bureau of Standards
A. V. Astin, Director

Certificate

Standard Reference Material 4964-B

Gamma-Ray Standard

Radium-226

This standard consists of radium-226 in approximately 5.2 grams of carrier solution in a flame-sealed glass ampoule. The carrier solution is 0.2%, by weight, $BaCl_2 \cdot 2H_2O$ in a 5.8%, by weight, solution of HCl.

The weight, in grams, of radium-226 contained in the ampoule as of June, 1965, was

$\cdot 1013_3 \times 10^{-6} \pm 0.50\% \cdot$

This standard was calibrated by comparing its gamma-ray emission rate with those of a series of standards prepared from material that was compared, in the National Bureau of Standards radiation balance, with the national radium standards. The gamma-ray emission rates were compared in the National Bureau of Standards $4\pi\gamma$ ionization chamber.

The estimated overall uncertainty, 0.50 percent, is the sum of 0.38 percent, which is three times the standard error, and of 0.12 percent, which is the linear sum of the estimated limits of the systematic errors.

This standard was prepared and calibrated in the Radiation Physics Division by members of the Radioactivity Section, W. B. Mann, Chief.

WASHINGTON, D. C. 20234
December 31, 1965
4964-B-156

W. Wayne Meinke, Chief,
Office of Standard Reference Materials.

Appendix ERG.011A

Radon Flux Analysis Data Sheet

Radon Flux Measurements

Site____________________

Canister Number	Lab Date	Start Count Time	Deploy Date	Deploy Time	Retrieve Date	Retrieve Time	Collection Time (sec)	Count Time (sec)	Peak Counts	Percent Error	Bkg counts	Percent Error	Detector Efficiency	Canister Activity(nCi)	Flux pCi/m2s	Flux Error 1.00 S.D.	LLD pCi/m2s	Remarks

Standard Operating Procedure ERG.010

Deployment of Radon-222 Flux Canisters

1.0 Purpose

Provide instructions for measuring Rn-222 flux from ground or tailings surfaces.

2.0 Discussion

Radon-222 is an inert radioactive gas with a half life of 3.8 days. Radon flux from soils is a measure of the potential buildup of radon in structures that may be placed on the soil. For remediated uranium mill tailings piles, regulations (10 CFR Part 40, Appendix A and 40 CFR Part 192) limit the radon flux to 20 pCi/m2 s. Additional potential applicable regulations include the National Source and Hazardous Air Pollutant Standards(40 CFR Part 61). The NESHAPS regulations (40 CFR Part 61) specify that Method 115, "Radon 222 Emissions from Uranium Mill Tailings Piles" or an equivalent method shall be used to demonstrate compliance with 40 CFR 61. This procedure has been written to comply with all requirements in Method 115.

The ERG charcoal canister consists of a ten inch diameter right circular cylinder open on one end and a vent hole and handle on the other end. The cylinder is filled with approximately 0.75 inches of activated charcoal (380 grams) divided into eight equal volume compartments and held in place with a metal screen and support. Measurements are made by placing the open end of the canister on the area to be characterized and allowing the collected radon to adsorb onto the charcoal. Upon retrieval, the entire canister is sealed in a plastic bag and transported to the laboratory for gamma spectral analysis.

A NaI gamma-ray spectrometer is used to measure the amount of Rn-222 adsorbed to the charcoal by measuring the 609 keV gamma ray from the Bi-214 daughter. A minimum of 4 hours between the end of the collection period is necessary to allow the Bi-214 to come into equilibrium.

The calculations convert the activity on the charcoal to an average flux, considering the parameters, canister area, collection time, time from end of collection to the beginning of counting, and the counting time. The bag is not opened or removed from the canister until after the count is made to assure that any desorbed radon will be collected and counted along with that on the charcoal.

3.0 Equipment and Supplies Checklist

____________ Charcoal canisters sealed in plastic bags

____________Extra plastic bags

____________Waterproof ink pen

____________Rn-222 Canister Chain of Custody Record (Appendix ERG.010A)

____________Watch

____________hand trowel

____________uncontaminated soil

____________cloth or paper towells

4.0 Procedure

4.1 Prior to shipment of canisters, bake the canisters at 100 degrees Celsius for 24 hours or longer. Place and seal in plastic bags for shipment. Use the specially designed shipping cartons.

4.2 Review the Data Acceptance Criteria (Section 5.0) before deploying the canisters. Upon arrival at the place of deployment, carefully open the shipping cartons being careful not to destroy the cartons or spacers since they are necessary for returning the canister to the laboratory. Remove the ERG numbered canisters from the shipping boxes. Document any evidence that a bag may have been punctured in shipping. Do not use this canister. Protect the boxes from mud and moisture.

4.3 Remove the plastic bags as the canisters are deployed. The canisters should be deployed over the area to be characterized using an evenly spaced grid pattern. The canister shall be placed on a fairly level flat surface. Place uncontaminated soil (not tailings) around the outside of the canister for a proper seal. A small hand trowel shall be used to assist in this task. One hundred points for each area should normally be selected. Record the canister number, location, and deployment time and date on the Rn-222 Canister Chain of Custody Record (Appendix ERG.010A) using a waterproof ink pen.

4.4 Select 5 canisters for each 100 measurements to be used as field blanks. These field blanks shall accompany the field deployment crew but shall remain sealed in their plastic bags. During the radon collection period, store the field blanks in a low radon background area such as an outside drafty building. Protect the plastic bags from direct exposure to the sun, harsh chemicals, or intense heat.

4.5 Review the data to ensure that the data for each canister is complete. If location coordinates are not provided, carefully construct a map using natural bench marks as reference points and give each location a unique identifier. Indicate approximate site dimensions and canister locations on the map. Use the canister number that is stamped on the top of each canister. Assign a similarly sounding, but fictitious location identifier number to each canister used as a field blank.

4.6 Review the Data Acceptance Criteria (Section 5) before retrieving canisters. As canisters are retrieved, record the retrieval time and date on the Rn-222 Canister Chain of Custody Record (Appendix ERG.010A). Also record under "comments" those canisters that do not meet the acceptance criteria.

4.7 Remove the canisters after a minimum of 24 hours and maximum of 28 hours, recording on the Radon-222 Canister Chain of Custody Record (Appendix ERG.010A) the time and date at which each canister is removed. Remove all soil and tailings from each canister by wiping the canister with a clean cloth or paper towell. Place the canister in a plastic bag, removing as much air as practical and carefully seal. Also record under "Comments" those canisters that do not meet the acceptance criteria and the reason for not doing so.

4.8 Place all canisters (including the field blanks) in the specially designed shipping cartons, tape the cartons, and ship for overnight delivery to ERG. Call ERG at 505-298-4224 and advise that the shipment has been made and the anticipated arrival time.

5.0 Data Acceptance Criteria (From EPA Method 115)

5.1 At least 85 percent of the measurements must yield useable results. Otherwise all measurements must be repeated.

5.2 Measurements may not be initiated within 24 hours of a rainfall.

5.3 If a rainfall occurs during the 24 hour measurement period, the measurement is invalid if the seal around the lip of the collector has washed away or if the collector is surrounded by water.

5.4 Measurements shall not be performed if the ambient temperature is below 35 degrees F or if the ground is frozen.

5.5 Allow the canisters to collect radon for approximately 24 hours.

Appendix ERG.010A

Radon-222 Canister Chain of Custody Record

Radon – 222 Canister Chain of Custody Record

Facility ____________________
Pile or Stack Name ____________________
Area of Pile or Stack ____________________
Field Representative ____________________

	Deployment	Retrival
Date		
Rel. Humid.		
Bar. Press		
Temp. (F)		

Deployment/Retrieval Record

Item	Location ID or Description	Coordinates		Canister Number	Deployment		Retrieval		Comments
		North	East		Time	By	Time	By	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Radon – 222 Canister Chain of Custody Record

Facility ______________________
Pile or Stack Name ______________________
Area of Pile or Stack ______________________
Field Representative ______________________

	Deployment	Retrival
Date		
Rel. Humid.		
Bar. Press		
Temp. (F)		

Deployment/Retrieval Record

Item	Location ID or Description	Coordinates		Canister Number	Deployment		Retrieval		Comments
		North	East		Time	By	Time	By	
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									
36									
37									
38									
39									
40									

Radon – 222 Canister Chain of Custody Record

Facility ______________________

Pile or Stack Name ______________________

Area of Pile or Stack ______________________

Field Representative ______________________

	Deployment	Retrival
Date		
Rel. Humid.		
Bar. Press		
Temp. (F)		

Deployment/Retrieval Record

Item	Location ID or Description	Coordinates North	Coordinates East	Canister Number	Deployment Time	Deployment By	Retrieval Time	Retrieval By	Comments
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									

Radon – 222 Canister Chain of Custody Record

Facility ____________________
Pile or Stack Name ____________________
Area of Pile or Stack ____________________
Field Representative ____________________

	Deployment	Retrival
Date		
Rel. Humid.		
Bar. Press		
Temp. (F)		

Deployment/Retrieval Record

Item	Location ID or Description	Coordinates		Canister Number	Deployment		Retrieval		Comments
		North	East		Time	By	Time	By	
61									
62									
63									
64									
65									
66									
67									
68									
69									
70									
71									
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73									
74									
75									
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78									
79									
80									

Standard Operating Procedure ERG.011

Analysis of Radon-222 Flux Canisters

1.0 Purpose

This procedure is used to determine the quantity of radon adsorbed onto the activated charcoal within the ERG radon flux canisters and to calculate the radon flux. It consists of procedures for handling and counting the samples using gamma-ray spectroscopy along with the QA/QC requirements in EPA Method 115 and references cited therein (see 40 CFR Part 61).

2.0 Discussion

This procedure is used in conjunction with Standard Operating Procedure ERG.010 to measure the radon-222 flux from uranium mill tailings piles and phosphate stacks.

ERG radon flux canisters were designed to provide the equivalent measurement capability to that specified in EPA Method 115 without having to handle the charcoal. This was accomplished by designing an all-metal canister that can be baked out with the charcoal in place. The entire canister is placed in a plastic bag at the time of retrieval in the field and remains in the bag throughout the counting process. After counting, the bag is removed and the entire canister is placed in the oven for 24 hours at 110 degrees C to drive off the residual radon. The canister is then sealed in a plastic bag for storage.

Data from the gamma-spectral analyses along with field data recorded on the Radon-222 Canister Chain of Custody Record (SOP ERG.010, Appendix ERG.010A) are used in a Lotus 123 spreadsheet to calculate the average flux for each canister.

3.0 Equipment and Supplies Checklist

_____Radon-222 Canister Chain of Custody Record (Appendix ERG.010A)

_____Exposed ERG Canisters sealed in plastic bags

_____Canberra Accuspec Gamma-ray spectrometer with lead shielding, computer and printer

_____Detector centering inserts for standards and canisters

_____Two standard Ra-226 charcoal sources traceable to NIST or another reference laboratory.

_____One sealed blank canister consisting of unexposed charcoal. The charcoal must be from the same batch as the canisters.

_____LOTUS software with spreadsheet master file FLUXMAST.WK3

4.0 Procedure

4.1 Place detector centering insert into ERG Standard No. 1 and place on detector. Count for 1200 s. Establish Region of Interest (ROI) for 603 keV photopeak of Bi-214. Record Area and % Error for the 603 photopeak.

4.2 Place ERG Standard No. 3 on detector and count for 1200 s. Check ROI established in 4.1 to assure that it is appropriate. If not, readjust the ROI and repeat 4.1 until ROI has been adjusted properly. Record Area and % Error on Radon Flux Analysis Data Sheet (Appendix ERG.011A)

4.3 Place the detector centering insert in blank canister (leave plastic bag on) and place on detector. Count for 1200 s and record total area and % Error. This is the background run and should be used until a new background run is made.

4.4 Enter data from 4.1-4.3 in LOTUS Spreadsheet master file FLUXMAST.WK3. The spreadsheet will calculate the efficiency for the two standards and the average. The average will be used in the flux calculations. In order to assure that the 10 percent accuracy requirement has been met (EPA Method 115 requirement), the spreadsheet will check to determine if the average is within 5 % of the two individual determinations. If it is not, a "recount" will be recorded in the spreadsheet for the flux indicating to the operator that the canisters must be recounted.

4.5 Enter the background area and % error in the appropriate columns of the spreadsheet. This background should be used for a period of five hours or until one-half of the canisters from a single batch have been analyzed, whichever is the least. At that point, repeat 4.3 and use the newly determined background for the next five hours or for the duration of the counting, whichever is less. Repeat until all counting is complete.

4.6 Every 10th canister will be rerun as a QC sample. The results of these samples will not be used in the calculation of the site flux but will, however, be included in the data report as a QC sample. Record the sample as Canister XX-QC, where XX is the canister number as stamped on the top of the canister.

4.7 Wait for a minimum of 4 hours after retrieval, count all samples for 200 s or more, depending upon the activity and the length of time that the canisters have been retrieved. Leave all canisters sealed in the plastic bag until all counting is complete and the canisters are ready to be placed in the oven for baking out.

The spreadsheet will check to assure that, for all calculated fluxes above 1 pCi/m^2s, the precision (standard deviation/calculated flux) is better than 10 percent. If this requirement is not met, the value will be recorded but a "recount" will appear in the Remarks column. For these canisters, count for a longer counting time.

4.8 At the end of each counting day, repeat 4.1-4.4 and compare the results with the initial efficiency determination. The efficiency should agree within 10 percent of the previously determined efficiency. If not, the entire batch of canisters should be rerun using the latest determined efficiency.

5.0 Preparation of Standards

ERG Standard No. 1 was prepared from reference material obtained from the U. S. Department of Commerce, National Bureau of Standards. The standard reference material was diluted is a weak HCl acid solution. Each of the eight compartments in the ERG canisters were filled with charcoal. Ten nanoCi of Ra-226 solution (approximately 10 drops) was distributed evenly in the charcoal of each compartment. The charcoal was allowed to dry for a few minutes before a solid 18 mil aluminum disk was placed on top of the charcoal. A thin retainer band was added to the inside wall of the collector to provide support. This retainer band was fixed with a low outgassing epoxy to assure that the disk would remain in place. All potential gas leak paths were coated with the epoxy. Care was taken to assure that the temperature change was minimal during the drying time for the epoxy to minimize gas transport through the epoxy. The distribution of Ra-226 within each of the eight compartments was further enhanced by shaking the standard after the canister had been sealed. The standard solution was known to an accuracy of 0.5 percent. A copy of the certification of the standard solution is attached to this SOP.

ERG Standard No. 3 was prepared from Certified Reference Material from the Department of Energy's New Brunswick Laboratory. Finely divided pitchblende ore (10,980 pCi/g) was weighed on a Mettler H5 electronic balance, SN 05531, on June 22, 1993. The canister was filled with charcoal and then emptied into an appropriately sized jar. The finely divided ore (7.1789 grams) was added and the mixture shaken until the charcoal was coated uniformly with the ore. The mixture was then placed into the canister and sealed in a similar manner as was described for ERG Standard No. 1. The activity in ERG Standard No. 3 was calculated to be 78.83 nCi Ra-226. A copy of the reference material certificate is attached to this SOP.

On July 18, 1993, both standard sources were counted on the gamma-ray spectrometer for 1200 seconds and the efficiency determined to be as follows:

Canister	Efficiency
Standard #3	0.00837 (0.00007)
Standard #1	0.00867 (0.00007)

where the 1 standard deviation error is presented in parentheses.

The best value to use, since the errors are similar, is the mean of the two values. The mean value of 0.00852 is a point at which the two numbers overlap within approximately 2 standard deviations, where the standard deviations reported above do not include the error in the reference material. This indicates very good agreement between the two standards.

If one defines the accuracy as the mean value minus the individual values divided by the mean value plus the linear addition of the uncertainty of the reference material, then the accuracy of the efficiency is approximately 2.3 percent using the stated uncertainty of the reference material in Standard #1. This indicates that the efficiency is known to within 3.0 percent and is certainly within the 10 percent requirement specified in EPA Method 115.

The uncertainty of the material in Standard #3 is not given other than the percent uranium is given to within 3 significant figures, indicating a 0.3 percent or better uncertainty. The quoted mass ratio of radium to uranium indicates that the radium is within 2 percent of being in equilibrium with the uranium. Adding these uncertainties linearly, the uncertainty of the radium content is considered to be 2.3 percent. Again defining the accuracy as in the preceding paragraph, the accuracy of the reported efficiency (0.00846) is less than 4.1 percent. This is again within the 10 percent accuracy requirement specified in Method 115.

Standard Operating Procedure ERG.010

Deployment of Radon-222 Flux Canisters

1.0 Purpose

Provide instructions for measuring Rn-222 flux from ground or tailings surfaces.

2.0 Discussion

Radon-222 is an inert radioactive gas with a half life of 3.8 days. Radon flux from soils is a measure of the potential buildup of radon in structures that may be placed on the soil. For remediated uranium mill tailings piles, regulations (10 CFR Part 40, Appendix A and 40 CFR Part 192) limit the radon flux to 20 pCi/m2 s. Additional potential applicable regulations include the National Source and Hazardous Air Pollutant Standards(40 CFR Part 61). The NESHAPS regulations (40 CFR Part 61) specify that Method 115, "Radon 222 Emissions from Uranium Mill Tailings Piles" or an equivalent method shall be used to demonstrate compliance with 40 CFR 61. This procedure has been written to comply with all requirements in Method 115.

The ERG charcoal canister consists of a ten inch diameter right circular cylinder open on one end and a vent hole and handle on the other end. The cylinder is filled with approximately 0.75 inches of activated charcoal (380 grams) divided into eight equal volume compartments and held in place with a metal screen and support. Measurements are made by placing the open end of the canister on the area to be characterized and allowing the collected radon to adsorb onto the charcoal. Upon retrieval, the entire canister is sealed in a plastic bag and transported to the laboratory for gamma spectral analysis.

A NaI gamma-ray spectrometer is used to measure the amount of Rn-222 adsorbed to the charcoal by measuring the 609 keV gamma ray from the Bi-214 daughter. A minimum of 4 hours between the end of the collection period is necessary to allow the Bi-214 to come into equilibrium.

The calculations convert the activity on the charcoal to an average flux, considering the parameters, canister area, collection time, time from end of collection to the beginning of counting, and the counting time. The bag is not opened or removed from the canister until after the count is made to assure that any desorbed radon will be collected and counted along with that on the charcoal.

3.0 Equipment and Supplies Checklist

____________Charcoal canisters sealed in plastic bags

____________Extra plastic bags

____________Waterproof ink pen

____________Rn-222 Canister Chain of Custody Record (Appendix ERG.010A)

____________Watch

____________hand trowel

4.0 Procedure

4.1 Prior to shipment of canisters, bake the canisters at 100 degrees Celsius for 24 hours or longer. Place and seal in plastic bags for shipment. Use the specially designed shipping cartons.

4.2 Review the Data Acceptance Criteria (Section 5.0) before deploying the canisters. Upon arrival at the place of deployment, carefully open the shipping cartons being careful not to destroy the cartons or spacers since they are necessary for returning the canister to the laboratory. Remove the ERG numbered canisters from the shipping boxes. Document any evidence that a bag may have been punctured in shipping. Do not use this canister. Protect the boxes from mud and moisture.

4.3 Remove the plastic bags as the canisters are deployed. The canisters should be deployed over the area to be characterized using an evenly spaced grid pattern. The canister shall be placed on a fairly level flat surface. Place soil or tailings around the outside of the canister for a proper seal. A small hand trowel shall be used to assist in this task. One hundred points for each area should normally be selected. Record the canister number, location, and deployment time and date on the Rn-222 Canister Chain of Custody Record (Appendix ERG.010A) using a waterproof ink pen.

4.4 Select 5 canisters for each 100 measurements to be used as field blanks. These field blanks shall accompany the field deployment crew but shall remain sealed in their plastic bags. During the radon collection period, store the field blanks in a low radon background area such as an outside drafty building. Protect the plastic bags from direct exposure to the sun, harsh chemicals, or intense heat.

4.5 Review the data to ensure that the data for each canister is complete. If location coordinates are not provided, carefully construct a map using natural bench marks as reference points and give each location a unique identifier. Indicate approximate site dimensions and canister locations on the map. Use the canister number that is stamped on the top of each canister. Assign a similarly sounding, but fictitious location identifier number to each canister used as a field blank.

4.6 Review the Data Acceptance Criteria (Section 5) before retrieving canisters. As canisters are retrieved, record the retrieval time and date on the Rn-222 Canister Chain of Custody Record (Appendix ERG.010A). Also record under "comments" those canisters that do not meet the acceptance criteria.

4.7 Remove the canisters after a minimum of 24 hours and maximum of 28 hours, recording on the Radon-222 Canister Chain of Custody Record (Appendix ERG.010A) the time and date at which each canister is removed. Place the canister in a plastic bag, removing as much air as practical and carefully seal. Also record under "Comments" those canisters that do not meet the acceptance criteria and the reason for not doing so.

4.8 Place all canisters (including the field blanks) in the specially designed shipping cartons, tape the cartons, and ship for overnight delivery to ERG. Call ERG at 505-298-4224 and advise that the shipment has been made and the anticipated arrival time.

5.0 Data Acceptance Criteria (From EPA Method 115)

5.1 At least 85 percent of the measurements must yield useable results. Otherwise all measurements must be repeated.

5.2 Measurements may not be initiated within 24 hours of a rainfall.

5.3 If a rainfall occurs during the 24 hour measurement period, the measurement is invalid if the seal around the lip of the collector has washed away or if the collector is surrounded by water.

5.4 Measurements shall not be performed if the ambient temperature is below 35 degrees F or if the ground is frozen.

5.5 Allow the canisters to collect radon for approximately 24 hours.

APPENDIX C

Radon Flux Data Reports for Main Tailings Pile

Radon Flux Measurements

Site : ARCO Bluewater Mill – Covered Sands

Canister Number	Lab Date	Start Count Time	Deploy Date	Deploy Time	Retrieve Date	Retrieve Time	Collection Time (sec)	Count Time (sec)	Peak Counts	Percent Error	Bkg counts	Percent Error	Detector Efficiency	Canister Activity(pCi)	Flux pCi/m2s	Flux Error 1.00 S.D.	LLD pCi/m2s	Remarks
72	09/10/93	01:26	09/08	12:51	09/09	12:48	86220	1200	491	3.18E+01	197	80.3	8.67E-03	9.17E+02	0.21	0.08	0.27	OK
107	09/10/93	01:47	09/08	12:45	09/09	12:53	86880	1200	286	5.62E+01	197	80.3	8.67E-03	2.78E+02	0.06	0.06	0.27	OK
95	09/10/93	02:08	09/08	12:49	09/09	12:52	86580	1200	333	5.01E+01	197	80.3	8.67E-03	4.24E+02	0.10	0.08	0.27	OK
63	09/10/93	02:30	09/08	12:54	09/09	12:47	85980	1200	470	3.38E+01	197	80.3	3.67E-03	8.51E+02	0.20	0.08	0.27	OK
201	09/10/93	02:51	09/08	12:42	09/09	12:41	86340	1200	359	[illegible]	197	80.3	8.67E-03	5.05E+02	0.12	0.08	0.27	OK
99	09/10/93	03:13	09/08	12:30	09/09	12:45	87300	1200	271	5.98E+01	197	80.3	8.67E-03	2.31E+02	0.05	0.08	0.27	OK
200	09/10/93	03:35	09/08	12:25	09/09	12:44	87540	1200	531	3.07E+01	197	80.3	6.67E-03	1.04E+03	0.24	0.08	0.27	OK
59	09/10/93	03:55	09/08	12:39	09/09	12:35	86160	1200	843	1.80E+01	197	80.3	8.67E-03	2.01E+03	0.47	0.08	0.28	OK
41	09/10/93	04:23	09/08	12:33	09/09	12:30	86220	1200	923	1.64E+01	197	80.3	8.67E-03	2.26E+03	0.53	0.08	0.28	OK
202	09/10/93	04:45	09/08	[illegible]	09/09	12:33	86280	1200	143	1.14E+02	197	80.3	8.67E-03	-1.68E+02	-0.04	0.09	0.28	OK
203	09/10/93	05:12	09/08	12:37	09/09	[illegible]	86580	1200	1197	1.54E+01	197	80.3	8.67E-03	3.12E+03	0.73	0.09	0.28	OK
75	09/10/93	05:34	09/08	14:01	[illegible]	13:43	85320	1200	1547	1.12E+01	197	80.3	8.67E-03	4.21E+03	1.00	0.09	0.28	OK
31	09/10/93	05:57	09/08	13:58	09/09	13:42	85440	1200	603	2.69E+01	197	80.3	8.67E-03	1.27E+03	0.30	0.09	0.28	OK
39	09/10/93	06:30	09/08	14:15	00:00	13:40	84300	1200	628	24.4	197	80.3	8.67E-03	1.34E+03	0.33	0.08	0.28	OK
80	09/10/93	07:12	09/08	14:13	09/09	13:35	84120	1200	565	2.79E+01	197	80.3	8.67E-03	1.15E+03	0.28	0.09	0.29	OK
29	09/10/93	07:32	09/08	13:52	09/09	13:55	86580	1200	728	2.31E+01	197	80.3	8.67E-03	1.66E+03	0.39	0.09	0.28	OK
43	09/10/93	07:56	09/08	13:55	09/09	13:40	85500	1200	2201	8.20E+00	197	80.3	8.67E-03	6.25E+03	1.51	0.09	0.28	OK
28	09/10/93	08:19	09/08	13:48	09/09	14:00	87120	1200	515	3.09E+01	197	80.3	8.67E-03	9.92E+02	0.24	0.08	0.28	OK
26	09/10/93	08:43	09/08	14:05	09/09	13:45	85200	1200	1755	1.04E+01	197	80.3	8.67E-03	4.86E+03	1.18	0.09	0.29	OK
TB 78	09/10/93	09:05	09/08	14:18	09/09	13:43	84300	1200	5	3.21E+03	197	80.3	8.67E-03	-5.99E+02	-0.15	0.09	0.29	OK
TB 93	09/10/93	09:30	09/08	14:24	09/09	13:49	84300	1200	86	1.93E+02	197	80.3	8.67E-03	-3.46E+02	-0.09	0.09	0.29	OK
TB 11	09/10/93	09:52	09/08	14:27	09/09	15:51	91440	1200	405	3.72E+01	197	80.3	8.67E-03	6.49E+02	0.15	0.08	0.27	OK
TB 109	09/10/93	10:13	09/08	14:21	09/09	13:47	84360	1200	389	3.94E+01	197	80.3	8.67E-03	5.99E+02	0.15	0.09	0.29	OK

Radon Flux Measurements

Site : ARCO Bluewater Mill – Covered Sands

Canister Number	Lab Date	Start Count Time	Deploy Date	Deploy Time	Retrieve Date	Retrieve Time	Collection Time (sec)	Count Time (sec)	Peak Counts	Percent Error	Bkg counts	Percent Error	Detector Efficiency	Canister Activity(nCi)	Flux pCi/m2s	Flux Error 1.00 S.D.	LLD pCi/m2s	Remarks
106	09/09/93	16:45	09/08	13:30	09/09	13:25	86100	1200	696	2.50E+01	411	39.6	8.67E-03	8.89E+02	0.19	0.08	0.26	OK
35	09/09/93	19:11	09/08	13:44	09/09	13:32	85680	1200	17030	2.00E+00	411	39.6	8.67E-03	5.18E+04	11.36	0.13	0.26	OK
30	09/09/93	19:32	09/06	13:35	09/09	13:29	86040	1200	14670	2.30E+00	411	39.6	8.67E-03	4.45E+04	9.74	0.13	0.26	OK
85	09/09/93	19:54	09/08	14:13	09/09	13:35	84120	1200	720	2.20E+01	411	39.6	8.67E-03	9.64E+02	0.22	0.08	0.27	OK
62	09/09/93	20:15	09/06	13:15	09/09	13:17	86520	1200	937	1.59E+01	411	39.6	8.67E-03	1.64E+03	0.36	0.08	0.26	OK
23	09/09/93	20:38	09/08	13:24	09/09	13:13	85740	1200	3357	6.40E+00	411	39.6	8.67E-03	9.19E+03	2.04	0.10	0.27	OK
94	09/09/93	21:00	09/08	13:27	09/09	13:22	86100	1200	2294	8.00E+00	411	39.6	8.67E-03	5.87E+03	1.30	0.09	0.27	OK
74	09/09/93	21:22	09/06	13:18	09/09	13:15	86220	1200	8844	3.00E+00	411	39.6	8.67E-03	2.63E+04	5.84	0.11	0.27	OK
27	09/09/93	21:44	09/08	13:24	09/09	13:13	85740	1200	7672	3.20E+00	411	39.6	8.67E-03	2.26E+04	5.07	0.10	0.27	OK
40	09/09/93	22:10	09/08	13:03	09/09	13:10	86820	1200	1112	1.55E+01	411	39.6	8.67E-03	2.19E+03	0.49	0.08	0.27	OK
103	09/09/93	22:31	09/08	13:42	09/09	13:08	84360	1200	713	2.18E+01	411	39.6	8.67E-03	9.42E+02	0.22	0.08	0.28	OK
37	09/09/93	22:53	09/08	12:55	09/09	13:04	86940	1200	593	2.83E+01	411	39.6	8.67E-03	5.68E+02	0.13	0.08	0.27	OK
108	09/09/93	23:15	09/08	13:00	09/09	13:00	86400	1200	678	2.43E+01	411	39.6	6.67E-03	8.33E+02	0.19	0.08	0.27	OK
110	09/09/93	23:38	09/08	13:00	09/09	13:00	86400	1200	961	1.65E+01	411	39.6	8.67E-03	1.72E+03	0.39	0.08	0.27	OK
102	09/09/93	23:58	09/08	13:07	09/09	12:59	85920	1200	1597	1.16E+01	411	39.6	8.67E-03	3.70E+03	0.84	0.09	0.27	OK
22	09/10/93	00:42	09/05	13:10	09/09	12:57	85620	1200	308	5.51E+01	197	80.3	8.67E-03	3.46E+02	0.08	0.08	0.27	OK
38	09/10/93	01:05	09/08	13:13	09/09	12:55	85320	1200	349	4.65E+01	197	80.3	8.67E-03	4.74E+02	0.11	0.08	0.27	OK

Radon Flux Measurements

Site: ARCO Bluewater Mill – Bare Sands

Bkg counts are for 1200 seconds

Canister Number	Lab Date	Start Count Time	Deploy Date	Deploy Time	Retrieve Date	Retrieve Time	Collection Time (sec)	Count Time (sec)	Peak Counts	Percent Error	Bkg counts	Percent Error	Detector Efficiency	Canister Activity (pCi)	Flux pCi/m2s	Flux Error 1.00 S.D.	LLD pCi/m2s	Remarks
76TB	10/01	08:47	09/29	15:40	09/30	16:12	88320	1200	359	43.60	375	41.70	0.008574	−5.04E+01	−0.01	0.08	0.27	OK
58TB	10/01	09:10	09/29	15:40	09/30	16:12	88320	1200	319	49.50	375	41.70	0.008574	−1.77E+02	−0.04	0.08	0.27	OK
89	10/01	09:30	09/29	15:40	09/30	16:12	88320	600	14064	2.19	375	41.70	0.008574	4.32E+04	20.35	0.24	0.27	OK
82	10/01	09:42	09/29	15:35	09/30	16:08	88380	1200	2428	8.69	375	41.70	0.008574	6.47E+03	1.51	0.10	0.27	OK
77	10/01	10:15	09/29	15:27	09/30	15:50	87780	600	47672	1.10	375	41.70	0.008574	1.49E+05	70.61	0.40	0.28	OK
81	10/01	10:47	09/29	15:14	09/30	15:34	87600	600	20268	1.80	375	41.70	0.008574	6.27E+04	30.10	0.29	0.28	OK
87	10/01	11:13	09/29	15:31	09/30	16:01	88200	600	8136	2.85	375	41.70	0.008574	2.45E+04	11.84	0.19	0.28	OK
66	10/01	11:40	09/29	15:22	09/30	15:40	87480	600	36231	1.27	375	41.70	0.008574	1.13E+05	54.41	0.36	0.28	OK
96	10/01	11:50	09/29	15:07	09/30	15:29	87720	600	18043	1.95	375	41.70	0.008574	5.57E+04	26.96	0.28	0.28	OK
3	10/01	12:06	09/29	14:48	09/30	15:18	88200	600	2756	6.23	375	41.70	0.008574	7.31E+03	3.87	0.15	0.28	OK
3	10/01	12:16	09/29	14:48	09/30	15:18	88200	600	3183	5.18	375	41.70	0.008574	8.85E+03	4.52	0.14	0.28	OK
98	10/01	12:34	09/29	14:54	09/30	15:21	88020	600	6143	3.45	375	41.70	0.008574	1.82E+04	9.0[illegible]	0.17	0.28	OK
100	10/01	12:45	09/29	14:59	09/30	15:24	87900	600	28862	1.46	375	41.70	0.008574	8.98E+04	43.54	0.33	0.28	OK
33	10/01	13:04	09/29	14:29	09/30	15:03	88440	600	14818	2.03	375	41.70	0.008574	4.55E+04	22.20	0.24	0.28	OK
92	10/01	13:18	09/29	14:34	09/30	15:06	88320	600	20594	1.68	375	41.70	0.008574	6.37E+04	31.05	0.28	0.28	OK
79	10/01	13:32	09/29	14:38	09/30	15:09	88260	600	17804	1.83	375	41.70	0.008574	5.49E+04	26.86	0.26	0.28	OK
97	10/01	13:50	09/29	14:43	09/30	15:14	88260	600	11917	2.32	375	41.70	0.008574	3.64E+04	17.91	0.22	0.28	OK
86	10/01	14:00	09/29	14:14	09/30	14:51	88620	600	175[illegible]	1.83	375	41.70	0.008574	5.43E+04	26.58	0.26	0.28	OK
69	10/01	14:22	09/29	14:09	09/30	14:48	88740	500	50720	1.06	375	41.70	0.008574	1.59E+05	77.36	0.42	0.28	OK
54	10/01	14:35	09/29	14:19	09/30	14:56	88620	600	16447	1.94	375	41.70	0.008574	5.07E+04	24.94	0.26	0.29	OK
15	10/01	14:47	09/29	14:25	09/30	14:59	88440	600	13056	2.22	375	41.70	0.008574	4.00E+04	19.80	0.24	0.29	OK
15	10/01	15:00	09/29	14:25	09/30	14:59	88440	600	13044	2.23	375	41.70	0.008574	3.99E+04	19.81	0.24	0.29	OK
2	10/01	15:17	09/29	14:02	09/30	14:44	88920	600	22635	1.64	375	41.70	0.008574	7.02E+04	34.56	0.30	0.29	OK
70	10/01	15:32	09/29	13:43	09/30	14:39	89760	600	22594	1.62	375	41.70	0.008574	7.00E+04	34.29	0.29	0.28	OK

Radon – 222 Canister Chain of Custody Record

Facility: ARCO Bluewater Mill
Pile or Stack Name: Main Tailing Pile
Area of Pile or Stack: Sand
Field Representative: N Patel, Blia Paese

	Deployment	Retrival
Date	09/29/93	09/30/93
Rel. Humid.	18	17
Bar. Press	23.52	23.50
Temp. (F)	76	77

Minimum Temp during 24hr Period - 36°

Deployment/Retrieval Record

Item	Location ID or Description	Coordinates North	Coordinates East	Canister Number	Deployment Time	Deployment By	Retrieval Time	Retrieval By	Comments
1	1002	31800	24700	70 ✓	1:43 pm	BR/NP	2:39 pm	NP/BR	OK
2	1001	32200	24800	02 ✓	2:02 pm	BR/NP	2:44 pm	NP/BR	OK
3	1007	32200	24200	69	2:09 pm	BR/NP	2:48 pm	NP/BR	OK
4	1008	31800	24200	86	2:14 pm	BR/NP	2:51 pm	NP/BR	Double Bagged OK T
5	1009	31500	24000	54	2:19 pm	BR/NP	2:56 pm	NP/BR	OK
6	1018	31800	23400	15	2:25 pm	BR/NP	2:59 pm	NP/BR	OK M
7	1017	32200	23400	33	2:29 pm	BR/NP	3:03 pm	NP/BR	OK T
8	1016	32300	23600	92	2:34 pm	BR/NP	3:06 pm	NP/BR	OK T
9	1015	32500	23400	79	2:38 pm	BR/NP	3:09 pm	NP/BR	OK T
10	1013	32900	23700	97 ✓	2:43 pm	BR/NP	3:14 PM	NP/BR	OK T
11	1014	32900	23200	03	2:48 pm	BR/NP	3:18 pm	NP/BR	OK T
12	1025	32900	22600	98	2:54	BR/NP	3:21 pm	NP/BR	OK T
13	1026	32500	22600	100 kb	2:59	BR/NP	3:24 pm	NP/BR	OK Number 100 T
14	1024	32500	23000	96 ✓	3:07 pm	BR/NP	3:29 PM	NP/BR	OK T
15	1022	32000	23000	81 ✓	3:14 PM	BR/NP	3:34 PM	NP/BR	OK T
16	1020	31500	23100	66	3:22 pm	BR/NP	3:40 pm	NP/BR	OK T ←
17	1028	31700	22600	77	3:27 pm	BR/NP	3:50 pm	NP/BR	OK T
18	1029	32300	22300	87	3:31 pm	BR/NP	4:01 PM	NP/BR	OK T
19	1031	32500	21900	82 ✓	3:35 pm	BR/NP	4:06 pm	NP/BR	OK M
20	1033	32900	21900	89	3:40 pm	BR/NP	4:12 PM	NP/BR	OK M

Canister # 58 & # 76, still in the Bag are Trip Blanks.

[signature]

Radon Flux Measurements

Site: ARCO Bluewater Mill

Mixed-Slimes MTP

Bkg counts are for 1200 seconds

Canister Number	Lab Date	Start Count Time	Deploy Date	Deploy Time	Retrieve Date	Retrieve Time	Collection Time (sec)	Count Time (sec	Peak Counts	Percent Error	Bkg counts	Percent Error	Detector Efficiency	Canister Activity(pCi)	Flux pCi/m2s	Flux Error 1.00 S.D.	LLD pCi/m2s	Remarks
37	09/24	20:10	09/23	17:20	09/24	14:53	77580	600	9315	2.95	242	63.00	0.008707	2.82E+04	13.65	0.22	0.27	OK
30	09/24	20:22	09/23	17:25	09/24	14:53	77280	600	8269	2.97	242	63.00	0.008707	2.49E+04	12.16	0.20	0.27	OK
27	09/24	20:35	09/23	17:14	09/24	14:57	78180	600	35605	1.26	242	63.00	0.008707	1.10E+05	52.46	0.34	0.27	OK
16	09/24	20:47	09/23	14:03	09/24	15:26	91380	600	5973	3.44	242	63.00	0.008707	1.78E+04	7.49	0.14	0.23	OK
26	09/24	21:02	09/23	16:35	09/24	15:06	81060	600	3809	4.74	242	63.00	0.008707	1.11E+04	5.29	0.14	0.26	OK
35	09/24	21:13	09/23	16:30	09/24	15:04	81240	1200	1731	10.15	242	63.00	0.008707	4.62E+03	1.07	0.09	0.26	OK
62	09/24	21:35	09/23	16:38	09/24	15:08	81000	600	3127	5.57	242	63.00	0.008707	8.96E+03	4.33	0.14	0.26	OK
43	09/24	21:45	09/23	17:31	09/24	15:01	77400	600	6458	3.58	242	63.00	0.008707	1.93E+04	9.53	0.19	0.27	OK
95	09/24	22:00	09/23	14:57	09/24	14:30	84780	600	13168	2.24	242	63.00	0.008707	4.01E+04	18.16	0.22	0.25	OK
57	09/24	22:10	09/23	13:57	09/24	14:28	88260	600	4548	4.59	242	63.00	0.008707	1.34E+04	5.95	0.15	0.24	OK
57	09/24	22:21	09/23	13:57	09/24	14:28	88260	600	5071	3.82	242	63.00	0.008707	1.50E+04	6.66	0.14	0.24	OK
8TB	09/25	08:12	09/23	13:57	09/24	14:28	88260	1200	99	165.00	242	63.00	0.008707	−4.44E+02	−0.10	0.08	0.26	OK
104TB	09/25	08:45	09/23	13:57	09/24	14:28	88260	600	194	55.00	242	63.00	0.008707	−1.49E+02	0.11	0.10	0.26	OK
94	09/25	09:00	09/23	17:10	09/24	15:10	79200	600	3834	4.36	242	63.00	0.008707	1.11E+04	5.95	0.15	0.29	OK
31	09/25	09:28	09/23	15:18	09/24	14:34	83760	600	2395	6.04	242	63.00	0.008707	6.68E+03	3.49	0.13	0.28	OK
41	09/25	09:37	09/23	14:52	09/24	14:43	85860	600	1328	11.60	242	63.00	0.008707	3.37E+03	1.81	0.13	0.27	OK
19	09/25	09:48	09/23	13:45	09/24	14:21	88560	600	1495	9.92	242	63.00	0.008707	3.89E+03	2.01	0.12	0.27	OK
74	09/25	10:13	09/23	15:23	09/24	14:32	83340	600	8689	2.90	242	63.00	0.008707	2.62E+04	13.28	0.21	0.28	OK
19	09/25	10:28	09/23	13:45	09/24	14:21	88560	600	1649	8.71	242	63.00	0.008707	4.37E+03	2.25	0.12	0.27	OK
38	09/25	10:43	09/23	15:31	09/24	14:40	83340	600	3110	5.28	242	63.00	0.008707	8.90E+03	4.65	0.14	0.28	OK
203	09/25	10:53	09/23	15:03	09/24	14:10	83220	600	7194	3.22	242	63.00	0.008707	2.16E+04	11.06	0.19	0.28	OK
203	09/25	11:04	09/23	15:03	09/24	14:10	83220	600	7349	3.08	242	63.00	0.008707	2.21E+04	11.32	0.19	0.28	OK
202	09/25	11:15	09/23	16:20	09/24	14:14	78840	600	6472	3.49	242	63.00	0.008707	1.93E+04	10.46	0.20	0.30	OK
44	09/25	11:31	09/23	13:23	09/24	14:15	89520	600	11377	2.37	242	63.00	0.008707	3.46E+04	16.54	0.21	0.27	OK

Radon Flux Measurements

Site: ARCO Bluewater Mill

Mixed–Slimes MTP

Bkg counts are for 1200 seconds

Canister Number	Lab Date	Start Count Time	Deploy Date	Deploy Time	Retrieve Date	Retrieve Time	Collection Time (sec)	Count Time (sec)	Peak Counts	Percent Error	Bkg counts	Percent Error	Detector Efficiency	Canister Activity(pCi)	Flux pCi/m2s	Flux Error 1.00 S.D.	LLD pCi/m2s	Remarks
18	09/25	11:47	09/23	13:55	09/24	14:18	87780	600	18748	1.88	242	63.00	0.008707	5.74E+04	27.91	0.28	0.27	OK
102	09/25	12:00	09/23	14:58	09/24	14:16	83880	600	6055	3.47	242	63.00	0.008707	1.80E+04	9.29	0.18	0.28	OK
56	09/25	12:12	09/23	13:47	09/24	14:06	87540	600	863	15.35	242	63.00	0.008707	1.93E+03	1.12	0.12	0.27	Recount
25	09/25	12:25	09/23	13:50	09/24	14:08	87480	600	875	15.91	242	63.00	0.008707	1.96E+03	1.14	0.12	0.27	Recount
47	09/25	12:38	09/23	13:25	09/24	14:18	89580	600	3156	5.62	242	63.00	0.008707	9.05E+03	4.49	0.15	0.27	OK
53	09/25	12:50	09/23	13:20	09/24	14:12	89520	600	3776	4.84	242	63.00	0.008707	1.10E+04	5.43	0.15	0.27	OK
52	09/25	13:05	09/23	13:15	09/24	14:08	89580	600	960	14.00	242	63.00	0.008707	2.23E+03	1.25	0.12	0.27	OK
101	09/25	13:17	09/23	13:19	09/24	14:11	89520	600	933	12.50	242	63.00	0.008707	2.14E+03	1.21	0.11	0.27	OK
53	09/25	13:30	09/23	13:20	09/24	14:12	89520	600	3745	4.82	242	63.00	0.008707	1.09E+04	5.41	0.15	0.27	OK
101	09/25	13:42	09/23	13:19	09/24	14:11	89520	600	673	20.10	242	63.00	0.008707	1.34E+03	0.83	0.12	0.27	OK
56	09/25	14:15	09/23	13:47	09/24	14:06	87540	1200	1929	9.47	242	63.00	0.008707	5.24E+03	1.29	0.09	0.28	OK
101	09/25	14:38	09/23	14:38	09/24	14:11	84780	1200	1119	16.60	242	63.00	0.008707	2.72E+03	0.69	0.10	0.29	OK
25	09/25	15:00	09/23	15:00	09/24	14:08	83280	1200	1762	10.70	242	63.00	0.008707	4.72E+03	1.23	0.10	0.29	OK
64	09/25	15:21	09/23	15:21	09/24	13:57	81360	1200	1457	11.70	242	63.00	0.008707	3.77E+03	1.01	0.10	0.30	OK
5	09/25	15:43	09/23	15:43	09/24	14:08	80700	600	3756	4.70	242	63.00	0.008707	1.09E+04	6.07	0.16	0.30	OK
91	09/25	15:53	09/23	13:04	09/24	13:50	89160	1200	1114	15.50	242	63.00	0.008707	2.71E+03	0.67	0.09	0.28	OK
55	09/25	16:25	09/23	13:06	09/24	13:56	89400	600	3209	5.36	242	63.00	0.008707	9.21E+03	4.73	0.15	0.28	OK
10	09/25	16:40	09/23	13:00	09/24	13:50	89400	600	1929	7.27	242	63.00	0.008707	5.24E+03	2.77	0.12	0.28	OK
201	09/25	16:50	09/23	15:58	09/24	14:48	82200	600	2827	6.05	242	63.00	0.008707	8.02E+03	4.46	0.16	0.30	OK
93	09/25	17:02	09/23	15:15	09/24	14:28	83580	600	4732	4.00	242	63.00	0.008707	1.39E+04	7.51	0.17	0.30	OK
22	09/25	17:15	09/23	15:55	09/24	14:44	82140	600	2325	6.92	242	63.00	0.008707	6.47E+03	3.65	0.15	0.30	OK
59	09/25	17:28	09/23	15:40	09/24	14:46	83160	600	3336	4.83	242	63.00	0.008707	9.60E+03	5.27	0.15	0.30	OK
110	09/25	17:40	09/23	16:08	09/24	14:51	81780	600	6510	3.24	242	63.00	0.008707	1.95E+04	10.63	0.19	0.30	OK
29	09/25	17:52	09/23	15:04	09/24	14:30	84360	600	5634	3.55	242	63.00	0.008707	1.67E+04	8.96	0.18	0.29	OK

Radon Flux Measurements

Site: ARCO Bluewater Mill

Mixed – Slimes MTP

Bkg counts are for 1200 seconds

Canister Number	Lab Date	Start Count Time	Deploy Date	Deploy Time	Retrieve Date	Retrieve Time	Collection Time (sec)	Count Time (sec)	Peak Counts	Percent Error	Bkg counts	Percent Error	Detector Efficiency	Canister Activity(pCi)	Flux pCi/m2s	Flux Error 1.00 S.D.	LLD pCi/m2s	Remarks
78	09/25	18:05	09/23	14:50	09/24	14:35	85500	600	2467	6.65	242	63.00	0.008707	6.91E+03	3.77	0.15	0.29	OK
78	09/25	18:15	09/23	14:50	09/24	14:35	85500	600	2614	5.87	242	63.00	0.008707	7.36E+03	4.01	0.14	0.29	OK
71	09/25	18:30	09/23	14:05	09/24	14:38	88380	600	38246	1.25	242	63.00	0.008707	1.18E+05	59.58	0.39	0.28	OK
99	09/25	18:42	09/23	15:27	09/24	14:30	82980	600	5050	3.73	242	63.00	0.008707	1.49E+04	8.18	0.17	0.30	OK
107	09/25	18:53	09/23	14:55	09/24	14:29	84840	600	19504	1.73	242	63.00	0.008707	5.98E+04	31.57	0.29	0.30	OK
13	09/25	19:07	09/23	13:30	09/24	14:24	89640	600	4869	3.97	242	63.00	0.008707	1.44E+04	7.37	0.16	0.28	OK
6	09/25	19:42	09/23	13:41	09/24	14:26	89100	600	3792	4.63	242	63.00	0.008707	1.10E+04	5.76	0.15	0.28	OK
200	09/25	20:00	09/23	15:40	09/24	14:42	82920	600	1295	10.40	242	63.00	0.008707	3.27E+03	1.97	0.13	0.30	OK
42	09/25	20:10	09/23	13:35	09/24	14:33	89880	600	3852	4.68	242	63.00	0.008707	1.12E+04	5.82	0.16	0.28	OK
23	09/25	20:20	09/23	15:47	09/24	14:45	82680	600	7244	2.91	242	63.00	0.008707	2.17E+04	11.99	0.19	0.30	OK
63	09/25	20:30	09/23	15:35	09/24	14:40	83100	1200	2022	9.00	242	63.00	0.008707	5.53E+03	1.49	0.10	0.30	OK
49	09/25	20:50	09/23	13:34	09/24	14:35	90060	616	7518	2.97	242	63.00	0.008707	2.26E+04	11.27	0.18	0.28	OK
49	09/25	21:05	09/23	13:34	09/24	14:35	90060	600	7531	2.90	242	63.00	0.008707	2.26E+04	11.61	0.18	0.28	OK
67	09/25	21:18	09/23	11:47	09/24	14:05	94680	600	20991	1.61	242	63.00	0.008707	6.44E+04	31.43	0.27	0.27	OK
46	09/25	21:43	09/23	11:50	09/24	14:05	94500	600	31700	1.34	242	63.00	0.008707	9.76E+04	47.78	0.33	0.27	OK
34	09/25	21:55	09/23	13:38	09/24	14:30	89520	600	1979	7.80	242	63.00	0.008707	5.39E+03	2.95	0.14	0.29	OK
65	09/25	22:10	09/23	11:39	09/24	13:55	94560	600	28056	1.43	242	63.00	0.008707	8.63E+04	42.44	0.32	0.28	OK
60	09/25	22:18	09/23	11:36	09/24	13:55	94740	600	26432	1.48	242	63.00	0.008707	8.13E+04	39.95	0.31	0.28	OK
36	09/25	22:30	09/23	11:45	09/24	14:00	94500	600	20081	1.69	242	63.00	0.008707	6.16E+04	30.40	0.27	0.28	OK
51	09/25	22:43	09/23	11:44	09/24	14:00	94560	600	24739	1.58	242	63.00	0.008707	7.60E+04	37.54	0.31	0.28	OK
83	09/25	22:53	09/23	11:33	09/24	13:53	94800	300	5102	3.93	242	63.00	0.008707	1.51E+04	15.37	0.32	0.28	OK
83	09/25	23:04	09/23	11:33	09/24	13:53	94800	300	5708	3.24	242	63.00	0.008707	1.70E+04	17.24	0.29	0.28	OK
12	09/25	23:10	09/23	11:27	09/24	13:45	94680	300	2164	6.30	242	63.00	0.008707	5.97E+03	6.44	0.22	0.28	OK
48	09/25	23:15	09/23	11:25	09/24	13:40	94500	300	2285	5.55	242	63.00	0.008707	6.34E+03	6.83	0.21	0.28	OK
84	09/25	23:23	09/23	11:30	09/24	13:50	94800	600	3890	5.10	242	63.00	0.008707	1.13E+04	5.77	0.17	0.28	OK

Radon – 222 Canister Chain of Custody Record

Facility: ARCO
Pile or Stack Name: MTP MIXED/SLIMES
Area of Pile or Stack: BLUEWATER
Field Representative: KB/TS

	Deployment	Retrival
Date	9-23-93	9-24-93
Rel. Humid.		
Bar. Press		~~28~~ KB 23.4 @ 1301
Temp. (F)		

Deployment/Retrieval Record

Item	Location ID or Description	Coordinates North	Coordinates East	Canister Number	Deployment Time	Deployment By	Retrieval Time	Retrieval By	Comments
1	1054			48	1125	KB/TS	1340	KB/TS/BR	
2	1055			12	1127	KB/TS	1345	BR	Moved 20' due East (water)
3	1056			84	1130	KB/TS	1350	KB	
4	1057			83	1133	KB/TS	1353	KB	
5	1058			60	1136	KB/TS	1355	BR	
6	1059			65	1139	KB/TS	1355	KB	
7	1060			51	1144	KB/TS	1400	BR	Moved 20 ft WEST
8	1061			36	1145	KB/TS	1400	KB	
9	1062			67	1147	KB/TS	1405	BR	
10	1063			46	1150	KB/TS	1405	KB	
11	1034			10	1300	KB/TS	1350	TS	
12	1035			91	1304	KB/TS	1350	RR	
13	1037			55	1306	KB/TS	1356	RR	
14	1036			64	1309	KB/TS	1357	RR	Only · may have been watered
15	1039			52	1315	KB/TS	1408	RR	30' from haul Road
16	1038			5	1317	KB/TS	1408	RR	
17	1040			101	1319	KB/TS	1411	RR	30' from haul Road
18	1041			53	1320	KB/TS	1412	RR	
19	1042			44	1323	KB/TS	1415	RR	
20	1045			47	1325	KB/TS	1418	RR	

APPENDIX D

Land Survey Data for the Main Tailings Pile

ATLANTIC RICHFIELD COMPANY
BLUEWATER MILL RECLAMATION

MAIN TAILINGS IMPOUNDMENT
RADON CANISTER LOCATIONS - MIXED AREA

Point Number	Northing Y	Easting X	Radon Barrier Elevation	Subgrade Elevation	Depth of Cover (ft)
1034	32702.74	24750.19		6626.9	
1035	32907.91	24755.43		6627.1	
1036	33405.27	24741.89		6627.7	
1037	33167.94	24550.16		6628.1	
1038	33229.19	24247.86		6627.5	
1039	33460.93	24336.24		6626.5	
1040	33552.74	23947.91		6625.1	
1041	33268.06	23929.20		6627.0	
1042	33266.48	23615.27		6627.2	
1043	33602.67	23588.40		6625.6	
1044	33764.06	23411.98		6623.9	
1045	33413.58	23494.20		6626.3	
1046	33374.83	22162.10		6625.2	
1047	33697.38	22152.60		6624.3	
1048	33636.91	21905.72		6625.0	
1049	33296.02	21840.74		6626.3	
1050	33298.00	21522.19		6627.3	
1051	33730.89	21607.65		6625.4	
1052	33489.83	21327.28		6626.3	
1053	33262.59	21090.09		6628.1	
1054	33002.13	21306.53		6626.3	
1055	33043.50	21728.95		6626.1	
1056	33061.84	22136.70		6628.7	
1057	33134.12	22510.93		6628.7	
1058	33083.79	22903.71		6631.0	
1059	33181.23	23198.03		6628.0	
1060	33072.74	23467.99		6630.8	
1061	33034.98	23857.33		6630.2	
1062	32949.56	24151.76		6628.4	
1063	32835.43	24394.28		6628.0	

ATLANTIC RICHFIELD COMPANY
BLUEWATER MILL RECLAMATION

MAIN TAILINGS IMPOUNDMENT
RADON CANISTER LOCATIONS - SLIMES AREA

Point Number	Northing Y	Easting X	Radon Barrier Elevation	Subgrade Elevation	Depth of Cover (ft)
1064	33737.07	24560.23		6624.1	
1065	33804.00	24190.14		6623.0	
1066	33880.79	23843.95		6622.6	
1067	33974.75	23467.09		6622.1	
1068	34022.74	23145.53		6621.9	
1069	34071.24	22802.67		6621.5	
1070	34050.77	22405.38		6621.4	
1071	33975.23	21985.23		6623.6	
1072	34278.28	22127.00		6621.6	
1073	34343.90	22517.55		6620.5	
1074	34371.31	22927.84		6620.5	
1075	34313.86	23277.59		6620.2	
1076	34219.67	23694.75		6620.9	
1077	34164.41	24076.40		6621.4	
1078	34078.56	24427.64		6623.2	
1079	33974.32	24739.72		6624.3	
1080	34325.74	24749.66		6623.2	
1081	34355.43	24514.04		6622.2	
1082	34410.37	24196.56		6620.5	
1083	34458.64	23885.70		6620.3	
1084	34516.48	23516.12		6619.9	
1085	34562.00	23174.04		6620.0	
1086	34810.11	23116.39		6619.6	
1087	34847.83	23439.33		6618.5	
1088	34750.74	23798.00		6619.7	
1089	34714.53	24190.25		6619.4	
1090	34677.67	24551.25		6620.9	
1091	34952.00	24265.45		6618.7	
1092	34971.30	23876.26		6618.3	
1093	35018.62	23344.32		6618.6	

ATLANTIC RICHFIELD COMPANY
BLUEWATER MILL RECLAMATION

MAIN TAILINGS IMPOUNDMENT
RADON CANISTER LOCATIONS - SANDS AREA

Point Number	Northing Y	Easting X	Radon Barrier Elevation	Subgrade Elevation	Depth of Cover (ft)
1001	32200.00	24801.16	6644.5	6642.2	2.3
1002	31798.90	24700.96	6657.6	6655.6	2.0
1003	31599.77	24400.60	6668.4	6666.1	2.2
1004	31799.55	24398.69	6662.7	6660.2	2.5
1005	32303.92	24601.70	6644.5	6642.4	2.1
1006	32497.32	24095.78	6646.6	6644.6	1.9
1007	32200.77	24199.80	6653.3	6652.0	1.4
1008	31800.06	24202.17	6665.0	6663.4	1.5
1009	31499.60	24002.88	6676.9	6675.9	1.1
1010	31796.56	23801.39	6672.3	6670.4	1.9
1011	32199.01	23798.44	6660.7	6658.5	2.2
1012	32499.81	23696.87	6652.7	6651.0	1.7
1013	32900.49	23699.05	6637.6	6636.5	1.1
1014	32899.83	23200.99	6640.2	6638.5	1.7
1015	32499.98	23399.58	6655.1	6653.5	1.7
1016	32299.60	23597.97	6660.6	6658.8	1.8
1017	32197.95	23398.69	6667.3	6665.2	2.1
1018	31801.44	23401.73	6678.9	6676.4	2.5
1019	31500.89	23502.82	6681.6	6680.4	1.3
1020	31499.62	23097.84	6681.6	6680.5	1.1
1021	31802.02	22897.98	6676.1	6673.4	2.7
1022	31998.54	23004.65	6672.2	6669.8	2.4
1023	32200.39	22899.81	6664.0	6661.6	2.4
1024	32501.95	22999.33	6654.6	6652.7	1.9
1025	32901.95	22600.10	6636.6	6635.7	0.9
1026	32498.96	22598.81	6646.1	6644.6	1.5
1027	32100.90	22597.31	6659.7	6658.1	1.7
1028	31691.54	22598.23	6671.5	6670.3	1.2
1029	32301.65	22293.92	6648.8	6647.4	1.4
←1030	32498.69	22296.10	6642.3	6640.9	1.5
1031	32499.03	21893.56	6644.0	6643.7	0.3
1032	32700.68	21689.21	6639.5	6638.6	0.9
1033	32902.33	21894.84	6634.6	6634.1	0.6

APPENDIX E

Meteorological Data for Radon Flux Measurement Periods

ARCO Bluewater Mill
Meterological Data
September, 1993

Date	Temperature High	Temperature Low	Relative Humidity High	Relative Humidity Low	Precipitation (inches)
1	79	52	95	39	
2	80	48	96	60	
3	82	45	99	25	
4	82	44	95	11	
5	82	46	98	9	
6	76	48	90	39	0.03
7	70	46	100	47	
8	78	42	93	9	
9	78	40	94	9	
10	78	48	85	26	
11	84	48	99	12	
12	73	50	82	36	0.02
13	70	48	98	42	0.32
14	68	33	99	19	
15	70	36	98	28	
16	76	40	97	14	
17	74	42	91	11	
18	69	36	96	13	
19	72	34	96	14	
20	78	34	96	13	
21	84	38	91	18	
22	84	44	86	23	
23	82	46	86	15	
24	77	50	80	15	
25	74	33	78	14	
26	79	32	84	10	
27	81	32	85	10	
28	82	31	88	10	
29	77	32	89	13	
30	77	36	79	17	

APPENDIX F

Ra-226 Concentration Data for Main Tailings Pile

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-3152S	Source Term #1001 0-2'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	311	30	7.2	2.9	3.94	PJN
93-3153S	Source Term #1001 2-4'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	881	16	22.0	4.0	3.94	PJN
93-3154S	Source Term #1001 4-6'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	696	18	17.2	3.7	3.94	PJN
93-3155S	Source Term #1001 6-8'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	871	19	21.8	4.5	3.94	PJN
93-3206S	Source Term #1010 0-2'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	1862	9	48.1	4.8	4.23	PJN
93-3207S	Source Term #1010 2-4'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	5011	5	129.8	7.2	4.23	PJN
93-3208S	Source Term #1010 4-6'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4032	6	104.4	6.7	4.23	PJN
93-3209S	Source Term #1010 6-8'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	5394	5	139.6	7.7	4.23	PJN
93-3210S	Source Term #1012 0-2'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4316	6	111.8	6.6	4.23	PJN
93-3211S	Source Term #1012 2-4'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	2388	8	61.7	5.3	4.23	PJN
93-3212S	Source Term #1012 4-6'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4815	5	124.7	7.0	4.23	PJN
93-3213S	Source Term #1012 6-8'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	5329	5	138.1	7.0	4.23	PJN
93-3214S	Source Term #1030 0-2'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	3222	7	83.4	6.2	4.23	PJN
93-3215S	Source Term #1030 2-4'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4277	6	110.6	6.9	4.23	PJN
93-3216S	Source Term #1030 4-6'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	5755	5	149.1	7.9	4.23	PJN
93-3217S	Source Term #1030 6-8'	10-13-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	9863	4	255.6	10.2	4.23	PJN
93-3218S	Source Term #1025 0-2'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	3697	6	95.7	6.4	4.23	PJN
93-3219S	Source Term #1025 2-4'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	6036	5	156.4	8.1	4.23	PJN
93-3220S	Source Term #1025 4-6'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	7453	4	193.2	8.8	4.23	PJN
93-3221S	Source Term #1025 6-8'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	6332	5	164.1	8.4	4.23	PJN
93-3222S	Source Term #1031 0-2'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	110	90	2.6	3.1	4.23	PJN
93-3223S	Source Term #1031 2-4'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	309	23	7.8	2.6	4.23	PJN
93-3224S	Source Term #1031 4-6'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	3202	7	82.9	6.0	4.23	PJN
93-3225S	Source Term #1031 6-8'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4125	6	106.6	6.6	4.23	PJN

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-3126S	Source Term #1021 0-2'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	1357	12	34.4	4.6	3.94	JS
93-3127S	Source Term #1021 2-4	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	733	19	18.2	4.0	3.94	JS
93-3128S	Source Term #1021 4-6'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4418	6	114.1	7.5	3.94	JS
93-3129S	Source Term #1021 6-8'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4811	6	124.4	7.8	3.94	JS
93-3130S	Source Term #1027 0-2'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4892	6	126.5	7.7	3.94	JS
93-3131S	Source Term #1027 2-4'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4698	6	121.4	7.6	3.94	JS
93-3132S	Source Term #1027 4-6'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4298	7	111.0	7.5	3.94	JS
93-3133S	Source Term #1027 6-8'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	5369	5	138.9	7.8	3.94	PJN
93-3134S	Source Term #1023 0-2'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	1108	14	27.9	4.3	3.94	PJN
93-3135S	Source Term #1023 2-4'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4977	6	128.7	7.7	3.94	PJN
93-3136S	Source Term #1023 4-6'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	2525	9	64.8	6.1	3.94	JS
93-3137S	Source Term #1023 6-8'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4035	7	104.2	7.7	3.94	PJN
93-3138S	Source Term #1011 0-2'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	2791	9	71.8	6.5	3.94	PJN
93-3139S	Source Term #1011 2-4'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4268	6	110.2	7.0	3.94	PJN
93-3140S	Source Term #1011 4-6'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4494	6	116.1	7.5	3.94	PJN
93-3141S	Source Term #1011 6-8'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4542	6	117.4	7.5	3.94	PJN
93-3144S	Source Term #1003 0-2'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	366	29	8.6	3.3	3.94	PJN
93-3145S	Source Term #1003 2-4'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	3804	7	98.2	6.7	3.94	PJN
93-3146S	Source Term #1003 4-6'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	2685	8	69.0	5.8	3.94	PJN
93-3147S	Source Term #1003 6-8'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	3465	7	89.3	6.4	3.94	PJN
93-3148S	Source Term #1004 0-2'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	697	21	17.2	4.2	3.94	PJN
93-3149S	Source Term #1004 2-4'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	1067	14	26.9	4.3	3.94	PJN
93-3150S	Source Term #1004 4-6'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	4915	6	127.1	7.5	3.94	PJN
93-3151S	Source Term #1004 6-8'	10-13-93	JM	10-15-93	350	350	11-12-93	5.00	5.00	36.00	177	3898.00	100.6	2847	8	73.2	6.3	3.94	PJN

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-3226S	Source Term #1026 0-2'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	3738	6	96.8	6.5	4.23	PJN
93-3227S	Source Term #1026 2-4'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	3698	6	95.7	6.4	4.23	PJN
93-3228S	Source Term #1026 4-6'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	7175	5	186.0	8.6	4.23	PJN
93-3229S	Source Term #1026 6-8'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	5880	5	152.4	7.7	4.23	PJN
93-3230S	Source Term #1006 0-2'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	70	114	1.6	2.7	4.23	PJN
93-3231S	Source Term #1006 2-4'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	252	38	6.3	3.1	4.23	PJN
93-3232S	Source Term #1006 4-6'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	3844	6	99.5	6.4	4.23	PJN
93-3233S	Source Term #1006 6-8'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	6226	5	161.4	7.8	4.23	PJN
93-3234S	Source Term #1002 0-2'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.5	482	22	12.3	3.3	4.23	PJN
93-3235S	Source Term #1002 2-4'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	247	40	6.2	3.1	4.23	PJN
93-3236S	Source Term #1002 4-6'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3835.00	100.6	4418	6	114.4	6.7	4.23	PJN
93-3237S	Source Term #1002 6-8'	10-15-93	JM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	5758	5	149.2	7.7	4.23	PJN
93-3238S	Source Term #1033 0-2'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	912	15	23.4	4.1	4.23	PJN
93-3239S	Source Term #1033 2-4'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	841	14	21.8	3.6	4.23	PJN
93-3240S	Source Term #1033 4-6'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	234	38	5.8	2.9	4.23	PJN
93-3241S	Source Term #1033 6-8'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4617	5	119.6	6.7	4.23	PJN
93-3242S	Source Term 1024 0-2'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	3311	7	85.7	6.0	4.23	PJN
93-3243S	Source Term 1024 2-4'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4737	5	122.7	6.9	4.23	PJN
93-3244S	Source Term 1024 4-6'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	5493	5	142.3	7.4	4.23	PJN
93-3245S	Source Term 1024 6-8'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	6822	5	176.8	8.3	4.23	PJN
93-3246S	Source Term #1007 0-2'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	2177	9	56.3	5.3	4.23	PJN
93-3247S	Source Term #1007 2-4'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	3301	7	85.4	6.3	4.23	PJN
93-3248S	Source Term #1007 4-6'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	6239	5	161.7	8.1	4.23	PJN
93-3249S	Source Term #1007 6-8'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4338	6	112.4	6.9	4.23	PJN

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	BKG. COUNTS %Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	SAMPLE COUNTS %Error	Ra226 (pCi/gm) Conc.	Ra226 (pCi/gm) Error*	LLD	Lab Tech
93-3250S	Source Term #1013 0-2'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	1126	12	29.0	3.9	4.23	PJN
93-3251S	Source Term #1013 2-4'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	1083	11	27.9	3.7	4.23	PJN
93-3252S	Source Term #1013 4-6'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	9283	4	240.7	9.3	4.23	PJN
93-3253S	Source Term #1013 6-8'	10-15-93	JSM	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4247	6	110.0	6.9	4.23	PJN
93-3254S	Source Term #1032 0-2'	10-15-93	MD	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	1607	9	41.5	4.2	4.23	PJN
93-3255S	Source Term #1032 2-4'	10-15-93	MD	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	5643	5	146.2	7.7	4.23	PJN
93-3256S	Source Term #1032 4-6'	10-15-93	MD	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4044	6	104.7	6.9	4.23	PJN
93-3257S	Source Term #1032 6-8'	10-15-93	MD	10-16-93	350	350	11-22-93	5.00	5.00	9.00	762	3885.00	100.6	4986	5	129.2	7.2	4.23	PJN
93-3278S	Source Term #1008 0-2'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	2130	9	54.8	5.4	4.49	PJN
93-3279S	Source Term #1008 2-4'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	3100	7	79.9	6.2	4.49	PJN
93-3280S	Source Term #1008 4-6'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	3913	7	100.9	7.1	4.49	PJN
93-3281S	Source Term #1008 6-8'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	3878	7	100.0	7.1	4.49	PJN
93-3282S	Source Term #1014 0-2'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	1039	15	26.5	4.5	4.49	PJN
93-3283S	Source Term #1014 2-4'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	5147	6	132.9	8.0	4.49	PJN
93-3284S	Source Term #1014 4-6'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	6780	5	175.2	9.5	4.49	PJN
93-3285S	Source Term #1014 6-8'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	5960	6	154.0	8.8	4.49	PJN
93-3286S	Source Term #1005 0-2'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	177	57	4.2	3.2	4.49	PJN
93-3287S	Source Term #1005 2-4'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	1120	12	28.6	4.0	4.49	PJN
93-3288S	Source Term #1005 4-6'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	425	24	10.6	3.2	4.49	PJN
93-3289S	Source Term #1005 6-8'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	2672	8	68.8	5.9	4.49	PJN
93-3290S	Source Term #1015 0-2'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	3499	7	90.2	6.5	4.49	PJN
93-3291S	Source Term #1015 2-4'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	2956	8	76.1	6.1	4.49	PJN
93-3292S	Source Term #1015 4-6'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	4962	6	128.1	8.0	4.49	PJN
93-3293S	Source Term #1015 6-8'	10-14-93		10-17-93	350	350	11-14-93	5.00	5.00	16.00	456	3900.00	100.6	5643	5	145.7	7.9	4.49	PJN

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	BKG. COUNTS %Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	SAMPLE COUNTS %Error	Ra226 (pCi/gm) Conc.	Ra226 (pCi/gm) Error*	Ra226 (pCi/gm) LLD	Lab Tech.
93-3294S	Source Term #1022 0-2'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	2428	8	61.5	5.4	4.07	RR
93-3295S	Source Term #1022 2-4'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	4219	6	107.8	6.5	4.07	RR
93-3296S	Source Term #1022 4-6'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	5406	5	138.5	7.1	4.07	RR
93-3297S	Source Term #1022 6-8'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	4355	6	111.3	6.7	4.07	RR
93-3298S	Source Term #1029 0-2'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	2989	7	76.0	5.3	4.07	RR
93-3299S	Source Term #1029 2-4'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	3357	7	85.5	5.9	4.07	RR
93-3300S	Source Term #1029 4-6'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	3765	6	96.1	6.2	4.07	RR
93-3301S	Source Term #1029 6-8'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	6061	5	155.4	7.7	4.07	RR
93-3302S	Source Term #1016 0-2'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	4511	5	115.3	6.4	4.07	RR
93-3303S	Source Term #1016 2-4'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	7768	4	199.5	8.9	4.07	RR
93-3304S	Source Term #1016 4-6'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	4102	6	104.8	6.5	4.07	RR
93-3305S	Source Term #1016 6-8'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	3227	7	82.2	5.9	4.07	RR
93-3306S	Source Term #1009 0-2'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	2260	8	57.2	5.0	4.07	RR
93-3307S	Source Term #1009 2-4'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	1683	9	42.3	4.4	4.07	RR
93-3308S	Source Term #1009 4-6'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	4816	5	123.2	7.0	4.07	RR
93-3309S	Source Term #1009 6-8'			10-18-93	350	350	11-14-93	5.00	5.00	45.00	147	3940.00	100.6	6428	5	164.9	8.2	4.07	RR
93-3314S	Source Term #1020 0-2'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	2699	8	68.5	5.9	4.07	RR
93-3315S	Source Term #1020 2-4'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	1970	9	49.7	5.1	4.07	RR
93-3316S	Source Term #1020 4-6'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	4401	5	112.5	6.4	4.07	RR
93-3317S	Source Term #1020 6-8'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	6899		177.0	1.7	4.07	RR
93-3318S	Source Term #1028 0-2'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	4939	5	126.4	6.8	4.07	RR
93-3319S	Source Term #1028 2-4'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	3611	6	92.1	6.2	4.07	RR
93-3320S	Source Term #1028 4-6'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	4942	5	126.5	7.2	4.07	RR
93-3321S	Source Term #1028 6-8'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	7475	4	191.9	8.5	4.07	RR

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI #1, Bi-214 609 kev BKG. COUNTS Area	BKG. COUNTS %Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	SAMPLE COUNTS %Error	Ra226 (pCi/gm) Conc.	Ra226 (pCi/gm) Error*	Ra226 (pCi/gm) LLD	Lab Tech
93-3322S	Source Term #1018 0-2'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	1259	11	31.4	4.1	4.07	RR
93-3323S	Source Term #1018 2-4'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	1455	10	36.4	4.3	4.07	RR
93-3324S	Source Term #1018 4-6'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	7306	4	187.5	8.2	4.07	RR
93-3325S	Source Term #1018 6-8'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	7767	4	199.4	8.6	4.07	RR
93-3326S	Source Term #1017 0-2'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	2489	8	63.1	5.6	4.07	RR
93-3327S	Source Term #1017 2-4'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	4669	5	119.4	6.7	4.07	RR
93-3328S	Source Term #1017 4-6'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	4517	6	115.5	7.1	4.07	RR
93-3329S	Source Term #1017 6-8'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	4867	5	124.5	7.0	4.07	RR
93-3330S	Source Term #1019 0-2'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	3270	7	83.3	6.0	4.07	RR
93-3331S	Source Term #1019 2-4'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	1536	11	38.5	4.8	4.07	RR
93-3332S	Source Term #1019 4-6'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	4328	5	110.6	6.2	4.07	RR
93-3333S	Source Term #1019 6-8'			10-18-93	350	350	11-15-93	5.00	5.00	45.00	147	3940.00	100.6	3613	6	92.2	6.0	4.07	RR

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ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp Count Time	ROI #1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-2925S	Source Term #1046 0-2'	10-1-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	1793	10	47.1	5.2	4.01	PJN
93-2926S	Source Term #1046 2-4'	10-1-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	810	14	20.7	3.4	4.01	PJN
93-2927S	Source Term #1046 4-6'	10-1-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	1950	8	51.3	4.6	4.01	PJN
93-2928S	Source Term #1046 6-8'	10-1-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	9533	4	255.1	9.9	4.01	PJN
93-2929S	Source Term #1049 0-2'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	2410	8	63.7	5.6	4.01	PJN
93-2930S	Source Term #1049 2-4'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	3104	7	82.4	6.0	4.01	PJN
93-2931S	Source Term #1049 4-6'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	2771	8	73.4	5.9	4.01	PJN
93-2932S	Source Term #1049 6-8'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	4874	6	129.9	7.5	4.01	PJN
93-2933S	Source Term #1051 0-2'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	719	18	18.3	3.9	4.01	PJN
93-2934S	Source Term #1051 2-4'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	[illegible]	161	3783	100.6	533	22	13.3	3.5	4.01	PJN
93-2935S	Source Term #1051 4-6'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	1257	12	32.7	4.4	4.01	PJN
93-2936S	Source Term #1051 6-8'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	676	18	17.1	3.6	4.01	PJN
93-2937S	Source Term #1053 0-2'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	743	14	18.9	3.3	4.01	PJN
93-2938S	Source Term #1053 2-4'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	371	22	8.9	2.8	4.01	PJN
93-2939S	Source Term #1053 4-6'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	289	34	6.7	3.2	4.01	PJN
93-2940S	Source Term #1053 6-8'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	3315	6	88.0	5.8	4.01	PJN
93-2941S	Source Term #1052 0-2'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	148	58	2.9	2.9	4.01	PJN
93-2942S	Source Term #1052 2-4'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	323	31	7.6	3.2	4.01	PJN
93-2943S	Source Term #1052 4-6'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	533	22	13.3	3.5	4.01	PJN
93-2944S	Source Term #1052 6-8'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	278	40	6.4	3.4	4.01	PJN
93-2945S	Source Term #1050 0-2'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	290	33	6.7	3.1	4.01	PJN
93-2946S	Source Term #1050 2-4'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	650	18	16.4	3.5	4.01	PJN
93-2947S	Source Term #1050 4-6'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	1034	14	26.7	4.3	4.01	PJN
93-2948S	Source Term #1050 6-8'	9-30-93	JM	10-10-93	350	350	11-18-93	5	5	39	161	3783	100.6	1107	14	28.7	4.4	4.01	PJN

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ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-3041S	Source Term #1048 0-2'	10-8-93	JM	10-12-93	350	350	11-10-93	5	5	102	55	3908	100.6	85	90	-0.4	2.5	3.54	RR
93-3042S	Source Term #1048 2-4'	10-8-93	JM	10-12-93	350	350	11-10-93	5	5	102	55	3908	100.6	451	22	9.2	3.0	3.54	RR
93-3043S	Source Term #1048 4-6'	10-8-93	JM	10-12-93	350	350	11-10-93	5	5	102	55	3908	100.6	397	27	7.8	3.2	3.54	RR
93-3044S	Source Term #1048 6-8'	10-8-93	JM	10-12-93	350	350	11-10-93	5	5	102	55	3908	100.6	932	16	21.9	4.1	3.54	RR
93-3045S	Source Term #1047 0-2'	10-8-93	JM	10-12-93	350	350	11-10-93	5	5	102	55	3908	100.6	804	18	18.6	4.1	3.54	RR
93-3046S	Source Term #1047 2-4'	10-8-93	JM	10-12-93	350	350	11-10-93	5	5	102	55	3908	100.6	136	63	0.9	2.7	3.54	RR
93-3047S	Source Term #1047 4-6'	10-8-93	JM	10-12-93	350	350	11-10-93	5	5	102	55	3908	100.6	929	15	21.9	4.0	3.54	RR
93-3048S	Source Term #1047 6-8'	10-8-93	JM	10-12-93	350	350	11-10-93	20	20	102	55	3908	100.6	1277	11	31.1	4.1	3.54	RR
93-3063S	Source Term #1044 0-2'	10-11-93	JM	10-13-93	350	350	11-10-93	5	5	102	55	3908	100.6	698	19	15.8	3.8	3.54	RR
93-3064S	Source Term #1044 2-4'	10-11-93	JM	10-13-93	350	350	11-10-93	5	5	102	55	3908	100.6	487	24	9.6	3.3	3.54	RR
93-3065S	Source Term #1044 4-6'	10-11-93	JM	10-13-93	350	350	11-10-93	5	5	102	55	3908	100.6	641	16	14.2	3.1	3.54	RR
93-3066S	Source Term #1044 6-8'	10-11-93	JM	10-13-93	350	350	11-10-93	5	5	102	55	3908	100.6	685	17	15.4	3.5	3.54	RR
93-3078S	Source Term #1043 0-2'	10-11-93	JM	10-13-93	350	350	11-10-93	5	5	102	55	3908	100.6	566	21	12.3	3.5	3.54	RR
93-3079S	Source Term #1043 2-4'	10-11-93	JM	10-13-93	350	350	11-10-93	5	5	102	55	3908	100.6	235	34	3.5	2.6	3.54	RR
93-3080S	Source Term #1043 4-6'	10-11-93	JM	10-13-93	350	350	11-10-93	5	5	102	55	3908	100.6	599	19	13.1	3.3	3.54	RR
93-3081S	Source Term #1043 6-8'	10-11-93	JM	10-13-93	350	350	11-10-93	5	5	102	55	3908	100.6	702	18	15.9	3.6	3.54	RR
93-3082S	Source Term #1040 0-2'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	798	14	20.4	3.4	4.10	RR
93-3083S	Source Term #1040 2-4'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	313	31	7.9	3.1	4.10	RR
93-3084S	Source Term #1040 4-6'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	398	27	10.1	3.2	4.10	RR
93-3085S	Source Term #1040 6-8'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	282	34	7.1	3.0	4.10	RR
93-3086S	Source Term #1039 0-2'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	600	31	15.3	5.2	4.10	RR
93-3087S	Source Term #1039 2-4'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	552	19	14.1	3.2	4.10	RR
93-3088S	Source Term #1039 4-6'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	1109	13	2d.5	4.0	4.10	RR
93-3089S	Source Term #1039 6-8'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	709	19	18.1	4.0	4.10	RR

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ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-3090S	Source Term #1036 0-2'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	606	20	15.5	3.5	4.10	RR
93-3091S	Source Term #1036 2-4'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	465	22	11.8	3.2	4.10	RR
93-3092S	Source Term #1036 4-6'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	448	20	11.4	2.9	4.10	RR
93-3093S	Source Term #1036 6-8'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	551	17	14.0	3.0	4.10	RR
93-3094S	Source Term #1035 0-2'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	147	50	3.6	2.6	4.10	RR
93-3095S	Source Term #1035 2-4'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3886	100.6	126	65	3.0	2.7	4.10	RR
93-3096S	Source Term #1035 4-6'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	176	52	4.3	2.9	4.10	RR
93-3097S	Source Term #1035 6-8'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	2251	8	58.1	5.1	4.10	RR
93-3098S	Source Term #1034 0-2'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	565	21	14.4	3.5	4.10	RR
93-3099S	Source Term #1034 2-4'	10-12-93	JM	10-14-93	350	350	11-11-93	5	5	10	665	3888	100.6	445	22	11.3	3.1	4.10	RR
93-3100S	Source Term #1034 4-6'	10-12-93	JM	10-14-93	350	350	11-12-93	5	5	36	177	3898	100.6	394	31	9.3	3.6	3.94	PJN
93-3101S	Source Term #1034 6-8'	10-12-93	JM	10-14-93	350	350	11-12-93	5	5	36	177	3898	100.6	4089	6	105.6	7.0	3.94	PJN
93-3102S	Source Term #1054 0-2'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	453	97	10.9	11.6	3.94	JS
93-3103S	Source Term #1054 2-4'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	2829	7	72.8	5.6	3.94	PJN
93-3104S	Source Term #1054 4-6'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	5770	5	149.4	7.8	3.94	PJN
93-3105S	Source Term #1054 6-8'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	11123	4	288.8	11.0	3.94	PJN
93-3106S	Source Term #1045 0-2'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	274	36	6.2	3.1	3.94	PJN
93-3107S	Source Term #1045 2-4'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	379	21	8.9	2.7	3.94	PJN
93-3108S	Source Term #1045 4-6'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	541	20	13.2	3.3	3.94	PJN
93-3109S	Source Term #1045 6-8'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	7735	4	200.5	8.5	3.94	PJN
93-3110S	Source Term #1042 0-2'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	439	27	10.5	3.5	3.94	PJN
93-3111S	Source Term #1042 2-4'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	722	17	17.9	3.6	3.94	PJN
93-3112S	Source Term #1042 4-6'	10-12-93	JM	10-15-93	350	350	11-17-93	5	5	36	177	3898	100.6	5796	5	150.0	7.5	3.94	PJN
93-3113S	Source Term #1042 6-8'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	10574	4	274.5	10.6	3.94	PJN

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	BKG. COUNTS %Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	SAMPLE COUNTS %Error	Ra226 (pCi/gm) Conc.	Ra226 (pCi/gm) Error*	LLD	Lab Tech
93-3114S	Source Term #1041 0-2'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	267	37	6.0	3.1	3.94	PJN
93-3115S	Source Term #1041 2-4'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	746	15	18.5	3.4	3.94	PJN
93-3116S	Source Term #1041 4-6'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	199	50	4.2	3.1	3.94	PJN
93-3117S	Source Term #1041 6-8'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	3381	6	87.1	6.0	3.94	PJN
93-3118S	Source Term #1038 0-2'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	264	33	5.9	2.8	3.94	PJN
93-3119S	Source Term #1038 2-4'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	97	104	1.6	3.1	3.94	PJN
93-3120S	Source Term #1038 4-6'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	524	19	12.7	3.1	3.94	PJN
93-3121S	Source Term #1038 6-8'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	1231	12	31.1	4.3	3.94	PJN
93-3122S	Source Term #1037 0-2'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	587	21	14.4	3.7	3.94	PJN
93-3123S	Source Term #1037 2-4'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	163	60	3.3	3.1	3.94	PJN
93-3124S	Source Term #1037 4-6'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	410	25	9.7	3.1	3.94	PJN
93-3125S	Source Term #1037 6-8'	10-12-93	JM	10-15-93	350	350	11-12-93	5	5	36	177	3898	100.6	781	16	19.4	3.6	3.94	PJN
93-3258S	Source Term #1055 0-2'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	893	17	22.7	4.3	4.49	PJN
93-3259S	Source Term #1055 6-8'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	10003	4	258.7	11.0	4.49	PJN
93-3260S	Source Term #1055 4-6'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	7853	5	203.0	9.9	4.49	PJN
93-3261S	Source Term #1056 0-2'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	244	40	5.9	3.1	4.49	PJN
93-3262S	Source Term #1056 2-4'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	4028	7	103.9	7.3	4.49	PJN
93-3263S	Source Term #1056 4-6'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	4013	7	103.5	7.4	4.49	PJN
93-3264S	Source Term #1056 6-8'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	8202	5	212.0	9.8	4.49	PJN
93-3265S	Source Term #1055 2-4'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	3342	8	86.1	7.2	4.49	PJN
93-3266S	Source Term #1058 0-2'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	3403	8	87.7	7.1	4.49	PJN
93-3267S	Source Term #1058 2-4'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	5405	5	139.6	7.9	4.49	PJN
93-3268S	Source Term #1058 4-6'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	5515	6	142.4	8.3	4.49	PJN
93-3269S	Source Term #1058 6-8'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	6932	5	179.1	9.6	4.49	PJN

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-3270S	Source Term #1057 0-2'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	4775	6	123.3	7.6	4.49	PJN
93-3271S	Source Term #1057 0-2'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	5044	6	130.2	7.9	4.49	PJN
93-3272S	Source Term #1057 4-6'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	5470	5	141.3	7.7	4.49	PJN
93-3273S	Source Term #1057 6-8'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	4852	6	125.3	7.2	4.49	PJN
93-3274S	Source Term #1059 0-2'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	6843	5	176.8	9.4	4.49	PJN
93-3275S	Source Term #1059 2-4'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	3777	7	97.4	7.0	4.49	PJN
93-3276S	Source Term #1059 4-6'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	5540	5	143.1	7.9	4.49	PJN
93-3277S	Source Term #1059 6-8'	10-13-93	JM/JA	10-17-93	350	350	11-14-93	5	5	16	456	3900	100.6	11879	4	307.3	11.7	4.49	PJN
93-3310S	Source Term #1060 0-2'	10-15-93	JA	10-18-93	350	350	11-14-93	5	5	45	147	3940	100.6	6552	5	168.1	8.3	4.07	RR
93-3311S	Source Term #1060 2-4'	10-15-93	JA	10-18-93	350	350	11-14-93	5	5	45	147	3940	100.6	4989	5	127.7	6.9	4.07	RR
93-3312S	Source Term #1060 4-6'	10-15-93	JA	10-18-93	350	350	11-14-93	5	5	45	147	3940	100.6	4104	6	104.8	6.9	4.07	RR
93-3313S	Source Term #1060 6-8'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	12395	3	319.0	10.9	4.07	RR
93-3334S	Source Term #1062 0-2'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	3376	7	86.0	6.4	4.07	RR
93-3335S	Source Term #1062 2-4'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	6995	4	179.5	8.2	4.07	RR
93-3336S	Source Term #1062 4-6'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	5384	5	137.9	7.4	4.07	PJN
93-3337S	Source Term #1062 6-8'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	12710	3	327.1	11.2	4.07	PJN
93-3338S	Source Term #1063 0-2'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	3556	6	90.7	6.1	4.07	PJN
93-3339S	Source Term #1063 2-4'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	4561	6	116.6	6.9	4.07	PJN
93-3340S	Source Term #1063 4-6'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	6908	4	177.3	8.2	4.07	PJN
93-3341S	Source Term #1063 6-8'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	15554	3	400.6	12.2	4.07	PJN
93-3342S	Source Term #1061 0-2'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	2907	7	73.9	5.7	4.07	PJN
93-3343S	Source Term #1061 2-4'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	7720	4	198.2	8.8	4.07	PJN
93-3344S	Source Term #1061 4-6'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	3852	6	98.3	6.3	4.07	PJN
93-3345S	Source Term #1061 6-8'	10-15-93	JA	10-18-93	350	350	11-15-93	5	5	45	147	3940	100.6	7877	4	202.3	8.4	4.07	PJN

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-2829S	Source Term #1093 0-2'	10-1-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	4685	8	5.1	0.6	0.97	JS@
93-2830S	Source Term #1093 2-4'	10-1-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	5583	6	7.1	0.5	0.43	JS
93-2831S	Source Term #1093 4-6'	10-1-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	15801	3	17.3	0.7	0.97	JS@
93-2832S	Source Term #1093 6-8'	10-1-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	3472	8	4.4	0.4	0.43	JS
93-2833S	Source Term #1092 0-2'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	13371	4	14.6	0.7	0.97	JS@
93-2834S	Source Term #1092 2-4'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	3837	7	4.9	0.4	0.43	JS
93-2835S	Source Term #1092 4-6'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	9533	5	10.4	0.6	0.97	JS@
93-2836S	Source Term #1092 6-8'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	12663	3	16.4	0.6	0.43	JS
93-2837S	Source Term #1091 0-2'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	12820	4	14.0	0.7	0.97	JS@
93-2838S	Source Term #1091 2-4'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	5987	6	7.7	0.5	0.43	JS
93-2839S	Source Term #1091 4-6'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	9463	5	10.3	0.6	0.97	JS@
93-2840S	Source Term #1091 6-8'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	12077	4	15.6	0.6	0.43	JS
93-2841S	Source Term #1090 0-2'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	3892	8	4.2	0.5	0.97	JS@
93-2842S	Source Term #1090 2-4'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	7900	5	10.2	0.5	0.43	JS
93-2843S	Source Term #1090 4-6'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	12551	4	13.7	0.7	0.97	JS@
93-2844S	Source Term #1090 6-8'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	14443	3	18.7	0.7	0.43	JS
93-2845S	Source Term #1088 0-2'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	11324	4	12.4	0.7	0.97	JS@
93-2846S	Source Term #1088 2-4'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	7980	5	10.3	0.5	0.43	JS
93-2847S	Source Term #1088 4-6'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	68	545	90950	100.0	3078	3	3.3	0.4	0.97	JS@
93-2848S	Source Term #1088 6-8'	10-4-93	JM	10-8-93	1200	1200	11-5-93	20	20	126	110	76657	100.0	8511	4	11.0	0.5	0.43	JS
93-2849S	Source Term #1087 0-2'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	8009	5	10.2	0.5	0.47	RL
93-2850S	Source Term #1087 2-4'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	3363	9	4.2	0.4	0.47	RL
93-2851S	Source Term #1087 4-6'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	3930	8	4.0	0.4	0.50	RL
93-2852S	Source Term #1087 6-8'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	11776	4	12.7	0.6	0.50	RL

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-2853S	Source Term #1086 0-2'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	2801	9	3.4	0.4	0.47	RL
93-2854S	Source Term #1086 2-4'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	2029	15	1.9	0.4	0.50	RL@
93-2855S	Source Term #1086 4-6'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	2931	9	3.6	0.4	0.47	RL
93-2856S	Source Term #1086 6-8'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	7180	5	7.6	0.5	0.50	RL@
93-2857S	Source Term #1085 0-2'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	6135	6	7.8	0.5	0.47	RL
93-2858S	Source Term #1085 2-4'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	4856	7	5.1	0.4	0.50	RL@
93-2859S	Source Term #1085 4-6'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	7462	5	9.5	0.5	0.47	RL
93-2860S	Source Term #1085 6-8'	10-1-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	3181	9	3.2	0.4	0.50	RL@
93-2861S	Source Term #1084 0-2'	10-4-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	5528	7	5.8	0.5	0.50	RL@
93-2862S	Source Term #1084 2-4'	10-4-93	JM	10-9-93	1200	1200	11-23-93	20	20	12	1173	76128	100.0	5241	6	6.9	0.5	0.44	RL
93-2863S	Source Term #1084 4-6'	10-4-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	6041	6	6.4	0.5	0.50	RL@
93-2864S	Source Term #1084 6-8'	10-4-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	5534	6	7.0	0.5	0.47	RL
93-2865S	Source Term #1083 0-2'	10-4-93	JM	10-9-93	1200	1200	11-29-93	20	20	12	1173	76128	100.0	52794	2	69.3	1.2	0.44	RL
93-2866S	Source Term #1083 2-4'	10-4-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	19696	3	25.4	0.7	0.47	RL
93-2867S	Source Term #1083 4-6'	10-4-93	JM	10-9-93	1200	1200	11-29-93	20	20	12	1173	76198	100.0	5616	6	7.4	0.4	0.44	RL
93-2868S	Source Term #1083 6-8'	10-4-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	23612	3	25.8	0.7	0.50	RL@
93-2869S	Source Term #1082 0-2'	10-5-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	41783	2	54.1	1.0	0.47	RL
93-2870S	Source Term #1082 2-4'	10-5-93	JM	10-9-93	1200	1200	11-29-93	20	20	12	1173	76128	100.0	4398	7	5.8	0.5	0.44	RL
93-2871S	Source Term #1082 4-6'	10-5-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	1950	13	2.3	0.4	0.47	RL
93-2872S	Source Term #1082 6-8'	10-5-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	12590	4	13.3	0.6	0.49	RL@
93-2873S	Source Term #1081 0-2'	10-5-93	JM	10-9-93	1200	1159.2	11-6-93	20	20	156	97	77114	100.0	19262	3	25.7	0.8	0.48	RL
93-2874S	Source Term #1081 2-4'	10-5-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	18114	3	19.7	0.7	0.50	RL@
93-2875S	Source Term #1081 4-6'	10-5-93	JM	10-9-93	1200	1200	11-6-93	20	20	156	97	77114	100.0	7939	5	10.1	0.5	0.47	RL
93-2876S	Source Term #1081 6-8'	10-5-93	JM	10-9-93	1200	1200	11-6-93	20	20	276	69	90812	100.0	7697	5	8.2	0.5	0.50	RL@

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-2877S	Source Term #1080 0-2'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	18976	3	20.5	0.6	0.00	RR@
93-2878S	Source Term #1080 2-4'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	21907	2.62	28.5	0.8	0.40	RR
93-2879S	Source Term #1080 4-6'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	10669	4	11.5	0.5	0.45	RR@
93-2880S	Source Term #1080 6-8'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	6964	5	8.9	0.5	0.40	RR
93-2881S	Source Term #1077 0-2'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	16339	3	17.6	0.5	0.45	RR@
93-2882S	Source Term #1077 2-4'	10-5-93	JM	10-9-93	1200	1159.6	11-7-93	20	20	112	116	76690	100.0	7152	5	9.3	0.5	0.41	RR
93-2883S	Source Term #1077 4-6'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	2727	10	2.9	0.4	0.45	RR@
93-2884S	Source Term #1077 6-8'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	14493	3	18.8	0.7	0.40	RR
93-2885S	Source Term #1076 0-2'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	6995	6	7.5	0.5	0.45	RR@
93-2886S	Source Term #1076 2-4'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	8962	4	11.6	0.6	0.40	RR
93-2887S	Source Term #1076 4-6'	10-5-93	JM	10-9-93	1200	1101.1	11-7-93	20	20	13	1363	92702	100.0	12562	4	14.0	0.6	0.47	RR@
93-2888S	Source Term #1076 6-8'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	3303	8	4.2	0.4	0.40	RR
93-2889S	Source Term #1075 0-2'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	24229	3	26.1	0.7	0.45	RR@
93-2890S	Source Term #1075 2-4'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	26011	2	33.8	0.8	0.40	RR
93-2891S	Source Term #1075 4-6'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	5351	7	5.8	0.4	0.45	RR@
93-2892S	Source Term #1075 6-8'	10-5-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	5276	6	6.7	0.4	0.40	RR
93-2893S	Source Term #1074 0-2'	10-1-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	2859	11	3.1	0.4	0.45	RR@
93-2894S	Source Term #1074 2-4'	10-1-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	7289	5	9.4	0.5	0.40	RR
93-2895S	Source Term #1074 4-6'	10-1-93	JM	10-9-93	1200	1075.8	11-7-93	20	20	13	1363	92702	100.0	4006	8	4.5	0.4	0.47	RR@
93-2896S	Source Term #1074 6-8'	10-1-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	4890	7	6.2	0.5	0.40	RR
93-2897S	Source Term #1073 0-2'	9-30-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	9311	5	10.0	0.5	0.45	RR@
93-2898S	Source Term #1073 2-4'	9-30-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	8940	4	11.5	0.5	0.40	RR
93-2899S	Source Term #1073 4-6'	9-30-93	JM	10-9-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	14385	4	15.5	0.6	0.45	RR@
93-2900S	Source Term #1073 6-8'	9-30-93	JM	10-9-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	5324	6	6.8	0.4	0.40	RR

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI #1, Bi-214 609 kev BKG. COUNTS Area	%Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	%Error	Ra226 (pCi/gm) Conc.	Error*	LLD	Lab Tech.
93-2901S	Source Term #1072 0-2'	9-30-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	3817	9	4.1	0.4	0.45	RR@
93-2902S	Source Term #1072 2-4'	9-30-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	2440	10	3.0	0.4	0.40	RR
93-2903S	Source Term #1072 4-6'	9-30-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	4116	7	4.4	0.4	0.45	RR@
93-2904S	Source Term #1072 6-8'	9-30-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	9852	4	12.7	0.6	0.40	RR
93-2905S	Source Term #1079 0-2'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	2890	11	3.1	0.4	0.45	RR@
93-2906S	Source Term #1079 2-4'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	8323	5	10.7	0.5	0.40	RR
93-2907S	Source Term #1079 4-6'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	15031	3	16.2	0.6	0.45	RR@
93-2908S	Source Term #1079 6-8'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	5020	6	6.4	0.5	0.40	RR
93-2909S	Source Term #1078 0-2'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	5137	7	5.5	0.4	0.45	RR@
93-2910S	Source Term #1078 2-4'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	8677	5	11.2	0.5	0.40	RR
93-2911S	Source Term #1078 4-6'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	7638	5	8.2	0.5	0.45	RR@
93-2912S	Source Term #1078 6-8'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	4317	7	5.5	0.4	0.40	RR
93-2913S	Source Term #1070 0-2'	9-30-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	18183	3	19.6	0.6	0.45	RR@
93-2914S	Source Term #1070 2-4'	9-30-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	61311	2	79.9	1.3	0.40	RR
93-2915S	Source Term #1070 4-6'	9-30-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	4783	7	5.1	0.4	0.45	RR@
93-2916S	Source Term #1070 6-8'	9-30-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	1153	19	1.4	0.3	0.40	RR
93-2917S	Source Term #1069 0-2'	10-1-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	2612	12	2.8	0.4	0.45	RR@
93-2918S	Source Term #1069 2-4'	10-1-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	7588	5	9.8	0.5	0.40	RR
93-2919S	Source Term #1069 4-6'	10-1-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	15235	3	16.4	0.6	0.45	RR@
93-2920S	Source Term #1069 6-8'	10-1-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	9026	4	11.6	0.5	0.40	RR
93-2921S	Source Term #1064 0-2'	10-6-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	13152	4	14.2	0.6	0.45	RR@
93-2922S	Source Term #1064 2-4'	10-6-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	14706	3	19.1	0.6	0.40	RR
93-2923S	Source Term #1064 4-6'	10-6-93	JM	10-10-93	1200	1200	11-7-93	20	20	13	1363	92702	100.0	14585	3	15.7	0.6	0.45	RR@
93-2924S	Source Term #1064 6-8'	10-5-93	JM	10-10-93	1200	1200	11-7-93	20	20	112	116	76690	100.0	3028	9	3.8	0.4	0.40	RR

* Estimated Counting Error at 95% CL

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

Sample ID#	Sample Description	Sample Date	Field Tech.	Seal Date	Std. Wt. gms.	Samp. Wt. gms.	Count Date	Std. Cnt. Time	Samp. Count Time	ROI#1, Bi-214 609 kev BKG. COUNTS Area	BKG. COUNTS %Error	Std. Counts	Std. pCi/gm	SAMPLE COUNTS Area	SAMPLE COUNTS %Error	Ra226 (pCi/gm) Conc.	Ra226 (pCi/gm) Error*	LLD	Lab Tech.
93-3029S	Source Term #1089 0-2'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	20786	3	22.5	0.7	0.46	RR@
93-3030S	Source Term #1089 2-4'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	10446	4	13.3	0.6	0.40	RR
93-3031S	Source Term #1089 4-6'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	6509	6	6.9	0.5	0.46	RR@
93-3032S	Source Term #1089 6-8'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	6696	6	8.4	0.5	0.40	RR
93-3033S	Source Term #1071 0-2'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	13817	4	14.9	0.6	0.46	RR@
93-3034S	Source Term #1071 2-4'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	8977	4	11.4	0.5	0.40	RR
93-3035S	Source Term #1071 4-6'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	8819	5	9.4	0.5	0.46	RR@
93-3036S	Source Term #1071 6-8'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	893	24	0.9	0.3	0.40	RR
93-3037S	Source Term #1065 0-2'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	8456	5	9.0	0.5	0.46	RR@
93-3038S	Source Term #1065 2-4'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	4813	7	6.0	0.5	0.40	RR
93-3039S	Source Term #1065 4-6'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	9827	[illegible]	10.5	0.5	0.46	RR@
93-3040S	Source Term #1065 6-8'	10-8-93	JM	10-12-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	10109	4	12.8	0.6	0.40	RR
93-3051S	Source Term #1068 0-2'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	34457	2	37.5	0.8	0.46	RR@
93-3052S	Source Term #1068 2-4'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	16811	3	[illegible]	0.7	0.40	JS
93-3053S	Source Term #1068 4-6'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	9289	4	9.9	0.5	0.46	RR@
93-3054S	Source Term #1068 6-8'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	3694	[illegible]	4.6	0.4	0.40	JS
93-3055S	Source Term #1067 0-2'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	12789	4	13.8	0.5	0.46	RR@
93-3056S	Source Term #1067 2-4'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	4174	7	5.2	0.4	0.40	RR
93-3057S	Source Term #1067 4-6'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	8396	5	8.9	0.5	0.46	RR@
93-3058S	Source Term #1067 6-8'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	1779	13	2.1	0.3	0.40	RR
93-3059S	Source Term #1066 0-2'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	21965	3	23.8	0.7	0.46	RR@
93-3060S	Source Term #1066 2-4'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	5678	6	7.1	0.5	0.40	RR
93-3061S	Source Term #1066 4-6'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	231	77	91506	100.0	11616	4	12.5	0.5	0.46	RR@
93-3062S	Source Term #1066 6-8'	10-11-93	JM	10-13-93	1200	1200	11-10-93	20	20	171	76	77593	100.0	20690	3	26.5	0.7	0.40	RR

* Estimated Counting Error at 95% CL

BM-RPP-GSS-0002

ARCO BLUEWATER MILL

GAMMA SPECTROSCOPY SETUP AND CALIBRATION PROCEDURES

CANBERRA MODEL 1510, SERIES 100
INTEGRATED SIGNAL PROCESSOR

March 1991

First Revision
February 1992

SECOND REVISION
July 1992

THIRD REVISION
June 1993

APPROVED BY: [signature] 7/8/93

ARCO BLUEWATER MILL
GAMMA SPECTROSCOPY SETUP AND CALIBRATION PROCEDURES

1.0 Scope

This procedure covers setup and initial calibration of the gamma spectroscopy counting system. The system is used for determining Ra-226 concentrations in soil at the Bluewater Mill site.

This includes calibration of the sodium iodide detector, pre-amp, signal processor, energy calibration and regions of interest (ROIs).

On July 16, 1992, this setup configuration was modified to allow sample weight quantities of 350 grams. The LLD of the Ra-226 analyses by the system is less than 0.05 pCi/gm when using 1200 gms of sample and counting for 30 minutes. The processing (drying, crushing and splitting) of soil samples collected for a 1200 gms counting aliquot requires extensive time. During verification of cleanup of contaminated areas at the Bluewater Mill, several thousands soil samples will be collected. Reducing the soil sample counting aliquot to 350 gms will raise the LLD to 0.2 pCi/gm, which is adequate, but will aid in reducing sample processing time to accommodate completion of cleanup verification in a timely manner.

2.0 System Components

The following hardware is assembled to form the counting system:

2.1 Personal Computer with Color Monitor
2.2 Canberra Series 100 Signal Processor (Model #1510)
2.3 Bicron NaI(TI) 3" x 3" Detector (Model 802 Series)
2.4 Canberra Series 100 MCA Master Board
2.5 Canberra Photomultiplier Tube Based-Preamplifier (Model 2007P)
2.6 Canberra Series 100 software package
2.6 Lead Pig Counting Shield
2.7 Marinelli 3" Bore Sample Beakers (GA-MA Model #133N) (1200 gms samples)
2.8 Lermer Sample Cups - 3"x 2½"
2.9 Marinelli Beaker Insert for Lermer Cups
2.10 Voltmeter

3.0 References

3.1 Bluewater Mill Canberra Series 100 Gamma Spectroscopy Procedure (BM-RPP-GSS-001-01)

3.2 Bluewater Mill Soil Sampling Procedures (BM-RPP-SS0010-01)

3.3 Canberra Series 100 Users Manual (Windows software)

3.4 Canberra Integrated Signal Processor Model 1510 Operator's Manual

3.5 Canberra Photomultiplier Tube Base-Preamplifier Model 2007P Operator's Manual

3.6 NaI (Tl) Detectors Model 802 Series Operator's Manual

4.0 System Configuration

4.1 System configuration and setup were done with the assistance and consultation of a Canberra Instruments representative.

4.2 The system components were assembled and hooked up as described in the Canberra operator's manuals. Factory calibration and settings on the signal processor and the preamp were not altered.

4.3 A Canberra Series 100 computer master board was installed in the computer to collect the data from the signal processor, Canberra 1510 (Ref. 3.3, section 1.1). Canberra Series 100 software was loaded into the computer to process the data. The software is designed to work in the Microsoft Windows environment.

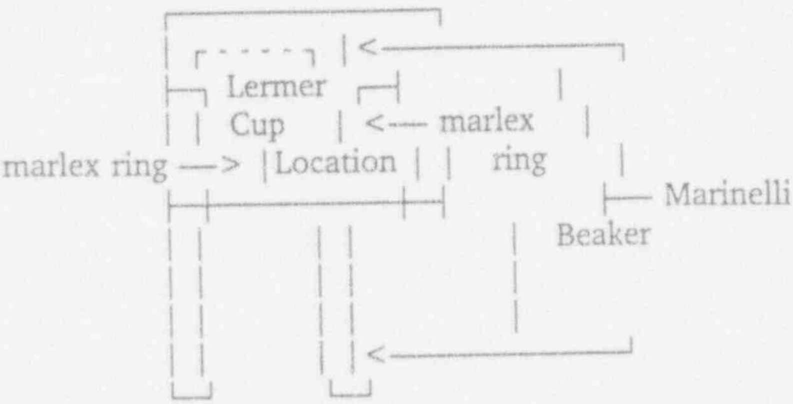
4.4 The preamp was coupled with the detector and photomultiplier tube (Ref 3.6). This assembly was placed into a lead pig for shielding. The lead pig was custom designed and fabricated for sample geometry to be used at the site.

4.5 The preamp was then hooked up to the signal processor, Canberra 1510 (Ref. 3.5) with the voltmeter in line connected by a T-connector. The processor houses a high voltage power supply and amplifier. The processor and Series 100 master board were then connected by 25-pin ribbon interface cable (Ref. 3.4).

4.6 The Canberra 1510 comes with a high Voltage (HV) pot adjuster for HV supply to the detector. However, with this pot adjuster alone, a precise HV to the detector may not be reproduced every time the system is turned on. Consistency of the HV to the detector could be critical to minimize spectrum shift from day to day operation. An external digital voltmeter was connected in order to maintain precise detector HV within $\pm$5 volts,

4.7 The system configuration is illustrated in Attachment One. Marinelli beakers are placed into the space indicated as sample location in Attachment One.

The Marinelli beakers are either packed with sample material or used to place Lermer cup samples for counting. When the Marinelli beaker is packed with sample material, it holds 1200 grams of soil sample. The Lermer sample cups hold 350 grams sample material. A marlex ring was fabricated as an insert into a Marinelli beaker in which to place and count the Lermer cup samples. This is indicated in the Marinelli beaker crossection below:



5.0 System Parameters Setup

The system parameters must be adjusted initially to include all regions of interest within the gamma-ray energy spectrum. This is done by adjusting the amplifier gain and range on the MCA to display the gamma-ray photopeaks of interest.

The radionuclide of interest is Ra-226 which has a gamma-ray energy of 186 keV at a low abundance of about 3.3%. The low energy and abundance along with the NaI detector resolution makes this photopeak unsuitable for use in quantitative analysis of Ra-226. Instead, the gamma-ray emissions from the decay of Bi-214, a Ra-226 decay product, are measured after the sample has been sealed and the Ra-226 decay products have reached secular equilibrium with the Ra-226. The gamma-ray energies and abundances of the primary gamma rays are listed below.

609.3 keV peak	(46.1% yield)
1120.3 keV peak	(15.0% yield)
1764.5 keV peak	(15.9% yield)

In order to apply the photopeak efficiency data for the detector, the area of the primary photopeak (609 keV) in the spectrum must be determined. The 609 keV peak is superimposed on a continuum caused by Compton scattering and other effects of the high energy radiation interaction in the detector. Even after substraction of normal background, these unwanted counts of the continuum under the peak within the ROI must be subtracted.

The Area algorithm within the MCA software computes the counts (peak area) in the full absorption peak ROI above the Compton continuum by averaging the counts above and below the photopeak and drawing a straight line between the two regions. The counts beneath this line are assumed to be continuum and are subtracted from the total ROI counts in order to estimate the photopeak counts.

As seen in Attachment Two, the 609 keV peak is well isolated and not overlapped by any other peak found in Bluewater Mill tailings or local soil matrix. For the isolated peak on the continuum, a linear interpolation between the continuum values on either side of the peak, which the system software computes, gives sufficient accuracy for substraction of the counts due to Compton continuum under the ROI.

Eventhough the 609 keV peak would be sufficient for analyses, the desired spectrum width was about 2000 keV in order to accommodate the other Bi-214 peaks for cross checking.

5.1 From consultation with the Canberra representative and a CHP (J. Johnson, CSU), the following parameters were preliminarily determined appropriate for the Ra-226 analyses at the Bluewater Mill site:

AMP Gain, Coarse	100
Fine	1.00
Shaping:	0.5
Range Gain:	4K
Range:	4K
High Voltage:	800

The Range and Range Gain were later changed to 2K in order to obtain a more precise continuum subtraction for the background runs.

5.2 Cs-137 provides a single distinguishable peak, at 661.7 keV, close to the Bi-214 609.3 keV peak providing relative spectrum position. To begin determining the optimum spectrum energy range, Cs-137 source #S3363 (9.78 μCi, 5-13-83) was placed on the detector and counted.

Since the extent of the spectrum would be about 2000 keV, the gain and range were adjusted until the Cs-137 full absorption peak (661.7 keV) appeared near channel #1400 (700 for a 2K gain), about 1/3 of the spectrum width. The manufacturer's peak shaping calibration was not altered.

5.3 A NBL certified Ra-226 standard (CRM-3B, 3.9% U3O8 pitchblende uranium ore, 11,076 pCi/gm Ra-226) was then counted to qualitatively verify the Bi-214 peaks and the spectrum. The following settings were determined from the setup:

AMP Gain, Coarse	50
Fine	0.93
Shaping:	0.5
Range Gain:	4K
Range:	4K
High Voltage:	800

5.4 A spectrum was then obtained by counting the above CRM-3B for 60 minutes. An energy calibration of the channels was performed on the peaks in accordance with Ref. 3.3. From the count data, Regions of Interest (ROI) were formed (Ref. 3.3) for the three Bi-214 peaks. The ROIs were formed from the beginning of each peak to the end of each peak. The energy calibration and the ROIs were stored in the memory for operation.

The most recent energy calibration and the established ROIs will come up and stay during the operation every time the Canberra is turned on unless a spectrum file with different calibration is retrieved.

5.5 Eventhough the Compton scattering interference, including from K-40 1460 keV peak, is eliminated by the software of the system by using Area algorithm, an ROI for K-40 peak (1460 keV) was established to qualitatively monitor K-40 in soil. A Marinelli beaker was filled with potassium chloride, which naturally contains K-40, and counted (Attachment Six and Seven). From the KCl count data, an ROI was formed for the K-40 peak. The peak area counts, above the continuum, in the 609 keV ROI due to 1460 keV Compton scattering of K-40 was less than one percent of the 1460 keV ROI peak area counts. (Ret 8.2)

6.0 Calibration Standards and System Background

6.1 The gamma spectroscopy will be used during excavation control and verification of cleanup of contaminated soil. The system geometry was established to use 1200 grams of sample for Ra-226 analyses in soil. The counting geometry was modified on July 16, 1992 to also use 350 grams of sample. The Marinelli beaker selected holds 1200 grams of soil sample, and Lermer sample cups hold 350 grams. Matrix standards were prepared for calibration of the system by blending local matrix soil and DOE's NBL Certified Reference Material (CRM). See Attachments Eight and Nine.

6.2 By obtaining counts with an empty Marinelli beaker or Lermer cup may not give an accurate background of the system since it will not allow for attenuation, as provided by sample or standard material geometry, of any background radiation penetrating to the detector from outside the sample chamber. Sugar was selected as a matrix material to determine the counting background of the system. Sugar is material known to have the lowest or undetectable amount of the radioactivity. A Marinelli beaker with 1200 gms sugar and a Lermer cup with 350 gms sugar were used as background counts for the system. Data for the standards and background material are given below.

Standard	pCi/gm	Seal Date	Weight grams
#RaM1	100.0	12-19-90	1200
#RaM2	28.6	12-19-90	1200
#RaM3	100.6	6-08-92	350
Background	0.0		1200
Background	0.0		350

7.0 System Calibration After Setup

The 609 keV peak of Bi-214 will be used for determination of Ra-226 in the soil samples. Bi-214 is a decay product of the gaseous Rn-222. The analysis is performed after the sample has been sealed for a minimum of 28 days. This 28-day period is sufficient for the Rn-222 and Bi-214 to reach secular equilibrium with the Ra-226.

For #RaM1

7.1 The initial calibration was performed following setup of the system and after full ingrowth of 28 days to attain equilibrium between Ra-226 and Bi-214 in standard #RaM1.

7.2 The Standard #RaM1 was placed in the counting chamber and counted for 60 minutes.

7.3 The center of each peak was determined from the channel with the highest integrated count. Following the #RAM1 counts, the 609.3 keV Bi-214 peak centroid fit at 609.2 keV, the 1120.3 peak fit at 1120.6, and the 1764.5 peak fit at 1761.2 keV. See Attachments Two and Three.

7.4 The Peak Area of the 609 keV peak was obtained to determine efficiency of the detector. The Ra-226 in soil samples will be determined by relative comparison of 609 keV peak area of the sample to that of the standard, #RaM1.

<u>For #RaM3</u>

7.5 Standard #RaM3 was made by spiking Chinle matrix, and is used for daily calibration when counting Chinle matrix samples.

7.6 Calibration of this standard was performed following original setup of the system and after full ingrowth of 28 days to attain equilibrium between Ra-226 and Bi-214 in standard #RaM3. The calibration was performed on July 6, 1992.

7.7 The Standard #RaM3 was placed in the counting chamber and counted for 150 minutes.

7.8 The center of each peak was determined from the channel with the highest integrated count. Following the #RAM1 counts, the 609.3 keV Bi-214 peak centroid fit at 609.3 keV, the 1120.3 peak fit at 1119.4, and the 1764.5 peak fit at 1763.5 keV. See Attachments Eleven and Twelve.

7.9 The Peak Area of the 609 keV peak was obtained to determine efficiency of the detector. The Ra-226 in soil samples will be determined by relative comparison of 609 keV peak area of the sample to that of the standard, #RaM3.

The gamma spectroscopy system was set up to include daily calibration check of the MCA and the detector by counting either standard #RAM1, #RaM3, or #RaM4, and the background for at least 20 minutes. Each day prior to counting the samples, the beginning and end of the peak ROI will be checked and the centroid of the peak will be assured at 609 ± 5 keV to maintain MCA calibration. After a HV stabilization and PM tube warm up time of about one hour, it may only require, if any, a minor adjustment of the amplifier's fine gain to fit the ROI and the centroids. Then the peak area of 609 keV peak of the standard #RaM1 and the background will be determined for determining daily efficiency of the system.

8.0 Calculations

8.1 The Ra-226 in soil samples will be calculated by relative comparison of 609 keV peak Area of the sample to that of standard. A Lotus 123 spreadsheet was developed for calculations and data management (see Attachment Ten). The system provides the integral counts, the error, and the peak area for each ROI. The peak areas of the background, standard, and samples are used in the calculations to determine Ra-226 concentrations in the samples.

The errors in determining the photopeak areas are used in determining the LLD and measurement errors. Since the errors in determining the peak areas for the standard are insignificant compared the those of the sample or background, they can be ignored without affecting the LLD and error calculation. Therefore the formulas in Section 8.2 do not include errors associated with running the standard.

8.2 An algorithm was developed to correct the indicated Ra-226 concentration when a partially-filled Marinelli beaker contains a mass of 500 - 1200 grams. A mass correction factor (MCF) based on the mass of the partially-filled Marinelli beaker is as follows:

$$MCF = 0.000055\,W + 0.34$$

where W is the mass of the soil in grams.

No MCF has been developed for use with the 350 gram sample containers (Lermer cups) since all sample containers contained 350 grams. Attachment XIV contains the details of the development of the MCF algorithm.

The formulas utilized by the spreadsheet for calculations are given below.

Ra-226 Concentration in sample:

$$\text{Ra-226, pCi/gm} = \frac{(PAs/CTs) - (PAb/CTb)}{(WTs, gms)} \times \frac{(CNst, pCi/gm)(WTst, gms)(MCF)}{(PAst/CTst - PAb/CTb)}$$

where: PAs = Peak area counts of the sample
CTs = Sample Count time, minutes
PAb = Peak area counts of the background
CTb = Background Count time, minutes
PAst = Peak area counts of the standard
CTst = Standard Count time, minutes
CNst = Ra-226 concentration of standard, pCi/gm
WTs = Weight of sample, grams
WTst = Weight of standard, grams

MCF = Mass Correction Factor

Error Estimate @ 95% (1.96 sigma) Confidence Level

$$\text{Error, pCi/gm} = \frac{1.96((Es/CTs)^2 + (Eb/CTb)^2)^{.50}}{(WTs,\ gms)} \times \frac{(CNst,\ pCi/gm \times WTst,\ gms)(MCF)}{(PAst/CTst) - (PAb/CTb)}$$

where Es = error in peak area counts of the sample (1 std dev)
Eb = error in peak area counts of the background (1 std dev)

Lower Limit of Detection (LLD):

$$\text{LLD, pCi/gm} = \frac{4.66\ (Eb/CTb)}{(WTs,\ gms)} \times \frac{(CNst,\ pCi/gm \times WTst,\ gms)(MCF)}{(PAst/CTst) - (PAb/CTb)}$$

In order to maintain consistent counting geometry, the weight of the sample must be same as the standard except when there is no sufficient sample. The sample and the background counting time must be same in order to use above formula to determine the LLD of the analysis.

8.3 As discussed earlier, the system software computes full absorption peak area counts only above the Compton continuum using Area Logrithim functions and thus corrects for continuum interference from higher energy radiations. The calculation for K^{40} manual stripping in the Lotus spreadsheet was removed in February 1992 as calculations by both methods did not show significant difference. For example:

Sample #	Sample Date	Conc. (pCi/gm) with K^{40} Strip	Conc. (pCi/gm) without K^{40} Stripping
TDBW120	6-26-91	81.0	81.0
TDBW128	6-26-91	116.6	116.6
91-031S	7-30-91	3.3	3.3
91-037S	7-31-91	1.0	1.0
91-041S	8-01-91	2.1	2.2
91-043S	8-01-91	2.4	2.5
91-047S	8-08-91	8.3	8.3
91-055S	8-08-91	15.6	15.6

9.0 QA/QC

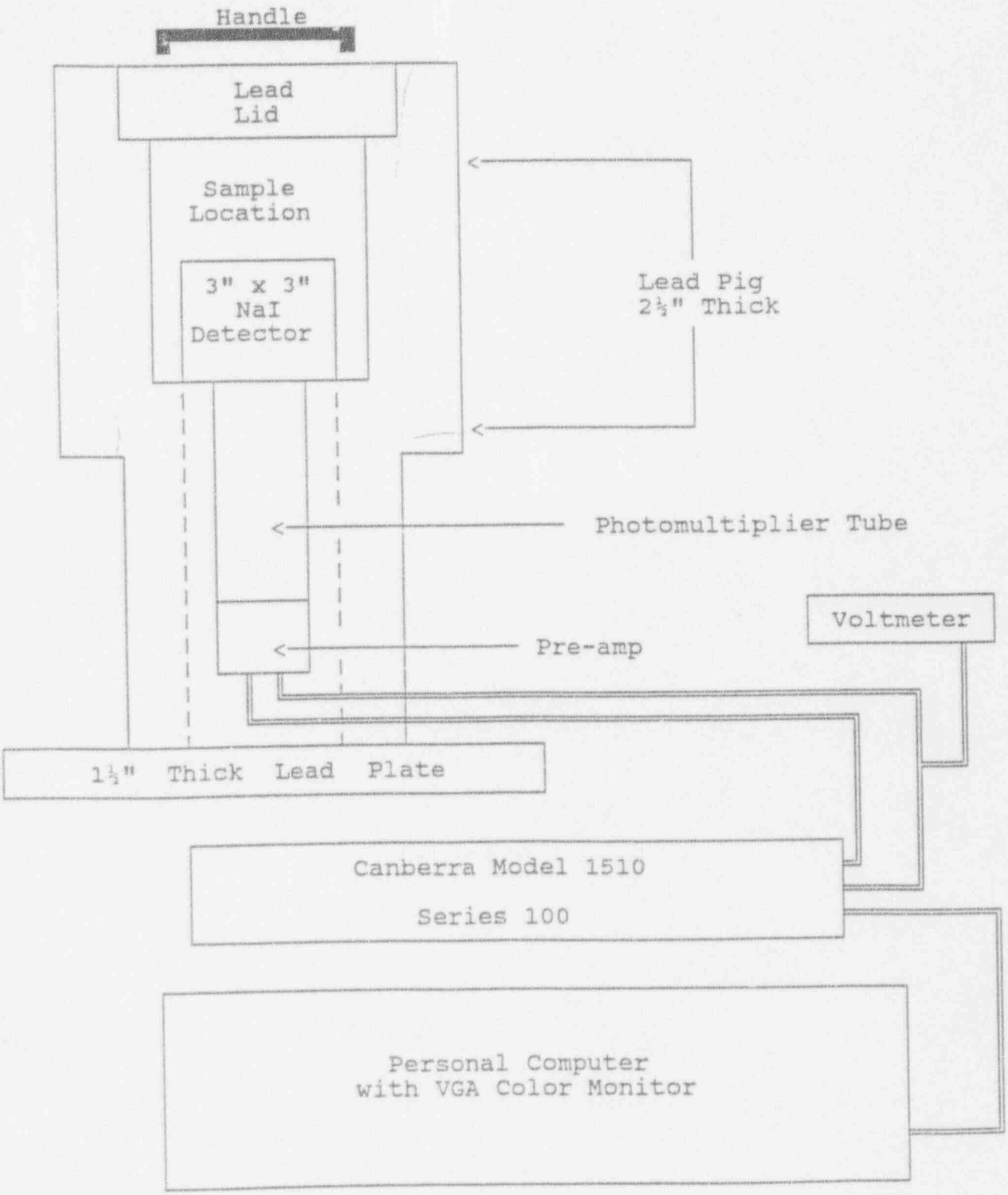
9.1 After initial calibration of the system, some 39 samples collected for correlation study were analyzed for Ra-226. These samples were also analyzed for Ra-226 by two vendor laboratories using gamma spectroscopy and wet chemistry methods. The comparison confirmed the proper setup and calibration of the system. See Attachment Thirteen for analyses data.

9.2 Five percent of the samples analyzed by this system are being sent out to vendor laboratories for Ra-226 analyses for QA/QC.

A complete energy calibration of the MCA and ROI establishment should be performed every six months using RaM standard.

ATTACHMENT ONE

Below is an illustration of the system configuration (not to scale):

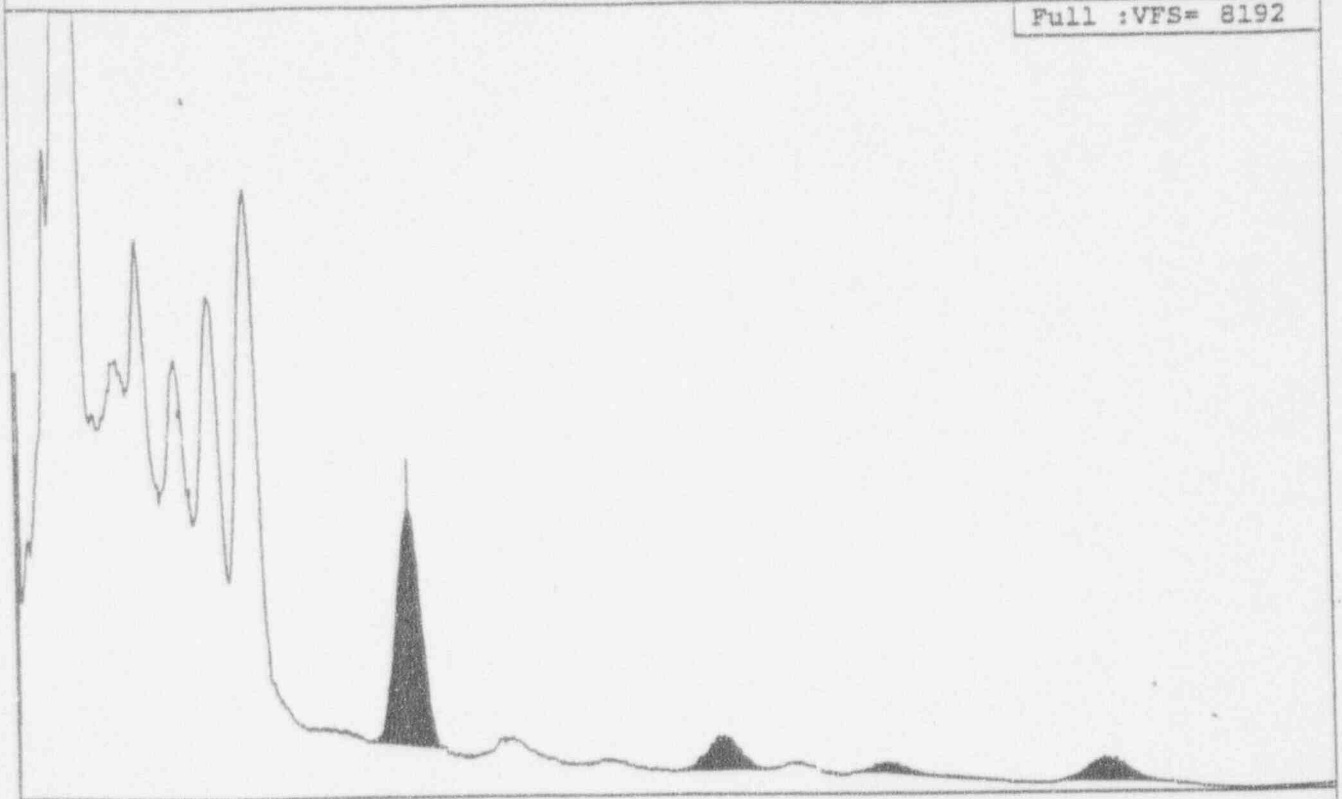


MCA #1 - Canberra S100 - RAM01.MCA - NBS mixed standard

Tag Number : 73 Plotted On : Thu 17 Jan 1991 @ 22:27:34

Dead Time : 1.56% Acquire Started : Thu 17 Jan 1991 @ 21:19:02

Full :VFS= 8192



Cursor=609.8keV From 551.0keV To 665.6keV Pset(Lm)= 60.00

Counts=2997 Int=334880 Area=220485+-1.35% Elap(Lm)= 60.00

ATTACHMENT TWO

MCA #1 - Canberra S100 - RAM01.MCA - NBS mixed standard

Tag Number: 73
Report Group: Full
Group Size: 4096

Readout: Thu 17 Jan 1991 @ 22:25:53
Acquire Started: Thu 17 Jan 1991 @ 21:19:02

Elapsed Live Time: 60.00 min.
Elapsed True Time: 60.95 min.
Dead Time: 1.56 %

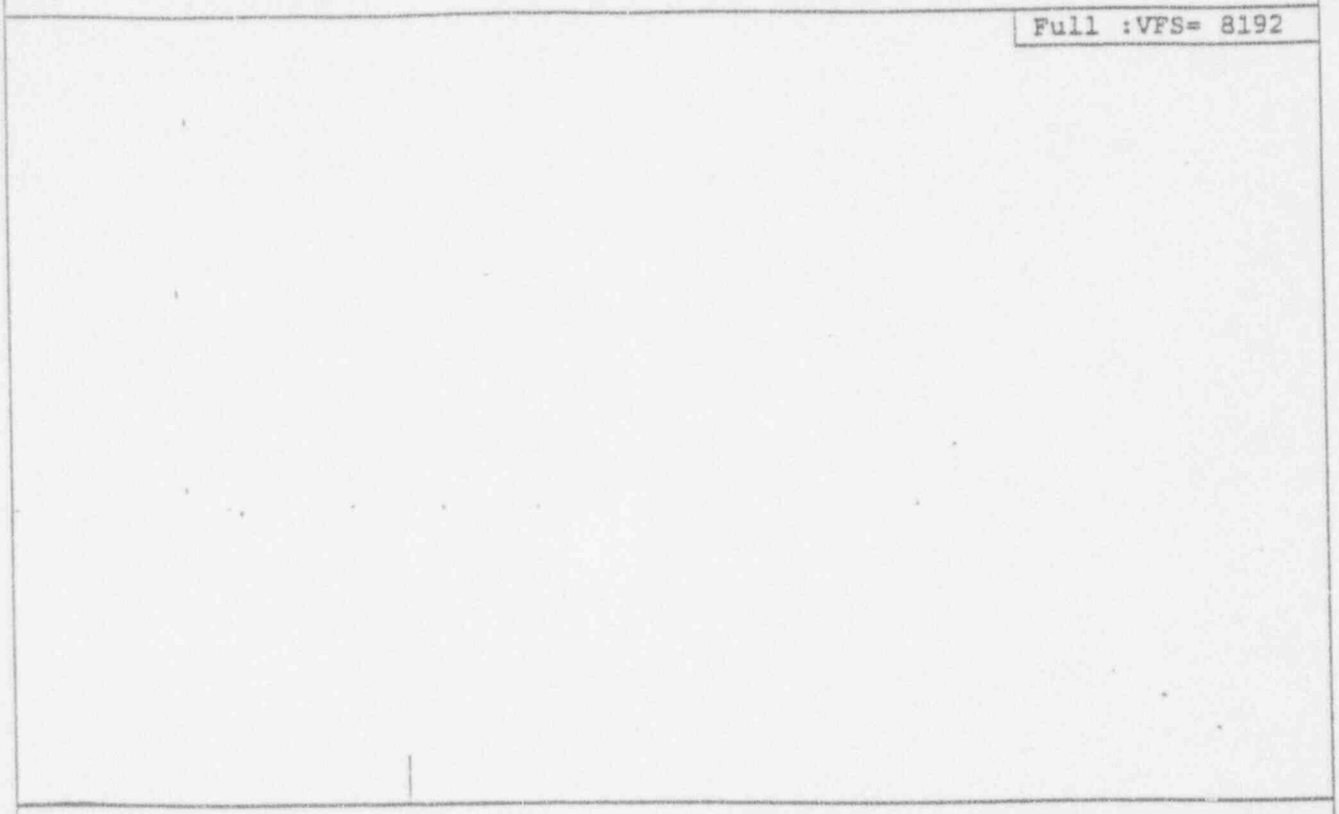
REGION OF INTEREST REPORT

ROI #	From(keV) To (keV)	Integral CPS	Area %Error	Peak(keV) FWHM(keV)
1	551.0 665.6	334880 93.02	220485 1.35	609.2 43.52
2	1048.9 1191.1	104223 28.95	40941 5.85	1120.6 51.93
3	1346.8 1575.4	84464 23.46	13529 23.55	1391.0 39.32
4	1677.4 1851.4	68262 18.96	37994 4.81	1761.2 67.73

ATTACHMENT THREE

MCA #1 - Canberra S100 - SPECT1.MCA - BACKGROUND (30 MIN.)

Tag Number : 18   Plotted On : Wed 07 Nov 1990 @ 11:15:35
Dead Time : 0.02%   Acquire Started : Wed 07 Nov 1990 @ 10:25:42



Cursor=1216	From 1105	To 1325	Pset(Lm)=	30.00
Counts=13	Int=1471	Area=366+-77.81%	Elap(Lm)=	29.99

ATTACHMENT FOUR

MCA #1 - Canberra S100 - SPECT1.MCA - BACKGROUND (30 MIN.)

Tag Number: 18
Report Group: Full
Group Size: 4096

Readout: Wed 07 Nov 1990 @ 11:12:21
Acquire Started: Wed 07 Nov 1990 @ 10:25:42

Elapsed Live Time: 29.99 min.
Elapsed True Time: 30.00 min.
Dead Time: 0.02 %

REGION OF INTEREST REPORT

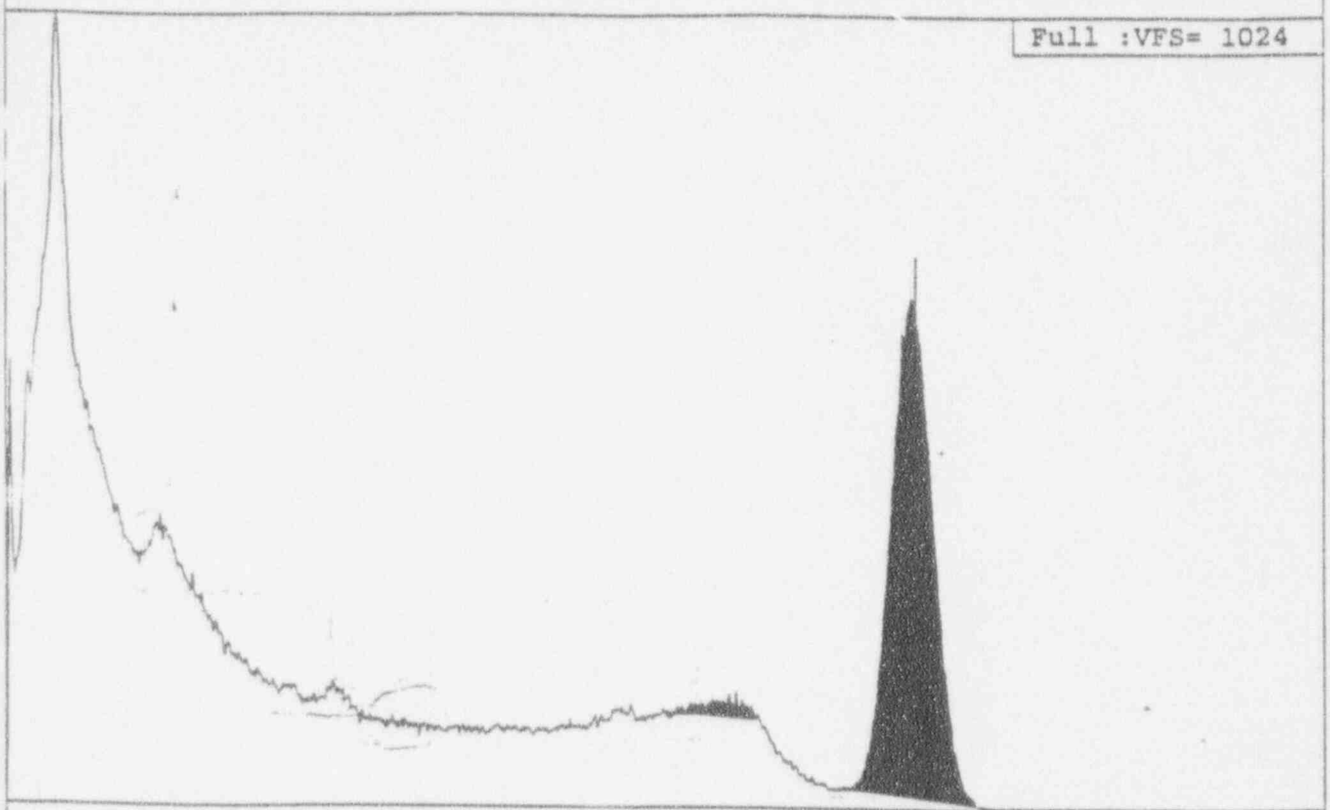
ROI #	From(Ch) To (Ch)	Integral CPS	Area %Error	Peak(Ch) FWHM(Ch)
1	1105	1471	366	1189.36
	1325	0.82	77.81	5.34
2	2054	897	191	2150.07
	2322	0.50	131.75	1.33
3	2614	957	50	2886.46
	3040	0.53	725.21	1.00
4	3229	636	193	3253.71
	3550	0.35	113.18	1.00

ATTACHMENT FIVE

MCA #1 - Canberra S100 - KCL.MCA - ROI #3

Tag Number : 74 Plotted On : Fri 18 Jan 1991 @ 07:02:40

Dead Time : 0.30% Acquire Started : Thu 17 Jan 1991 @ 21:33:35



Cursor=1461.3keV	From 1339.2keV	To 1581.8keV	Pset(Lm)=	60.00
Counts=653	Int=103221	Area=96539+-1.17%	Elap(Lm)=	60.00

ATTACHMENT SIX

MCA #1 - Canberra S100 - KCL.MCA - ROI #3

Tag Number: 74
Report Group: Full
Group Size: 4096

Readout: Fri 18 Jan 1991 @ 07:03:29
Acquire Started: Thu 17 Jan 1991 @ 21:33:35

Elapsed Live Time: 60.00 min.
Elapsed True Time: 60.18 min.
Dead Time: 0.30 %

REGION OF INTEREST REPORT

ROI #	From(keV) To (keV)	Integral CPS	Area %Error	Peak(keV) FWHM(keV)
1	542.6	26897	770	597.0
	677.0	7.47	194.01	2.98
2	1046.2	35879	2708	1160.2
	1192.6	9.97	64.42	4.52
3	1339.2	103221	96539	1456.7
	1581.8	28.67	1.17	71.57
4	1649.2	482	94	1813.4
	1888.8	0.13	254.39	1.27

ATTACHMENT SEVEN

DATE: 12-19-90

SUBJECT: PREPARATION OF Ra-226 MATRIX STANDARDS

PREPARED BY: NAT PATEL

Matrix standards were prepared by blending local matrix soil and Certified Reference Material (CRM) from the Department of Energy's New Brunswick Laboratory. These standards will be used to calibrate the Gamma Spectroscopy which will be utilized for determination of Ra-226 content in soil during excavation control verification. The matrix blending will provide additional compensation for local background interference. Also the higher radium content CRM needs to be dilute in order to bring concentrations close to field measurement to increase range accuracy.

STANDARD #RaM1

34.7 grams of CRM 101A @ 3424 pCi/gm =	118,813 pCi
1165.3 grams of Matrix Soil (TS-4-A) @ 1.0 pCi/gm =	1,165 pCi
1200.0 grams Total =	119,978 pCi

Final concentration = 100 pCi/gm Ra-226

STANDARD #RaM2

9.7 grams of CRM 101A @ 3424 pCi/gm =	33,213 pCi
1190.3 grams of Matrix Soil (TS-4-A) @ 1.0 pCi/gm =	1,190 pCi
1200.0 grams Total =	34,313 pCi

Final concentration = 28.6 pCi/gm Ra-226

A total of 1200 grams per matrix standard was prepared. Since the soil sample aliquots for analyses were selected to be 1200 grams, the matrix soil was weighed using the Ohaus 1500D electronic balance, SN#05531. The CRM was weighed with the Mettler H5 electronic balance, SN#58395. The soil and CRM was transferred into a gallon glass jar and mixed by rolling. The entire 1200 gram standard then was transferred into a Marinelli beaker and sealed. The Marinelli beaker was then marked and dated.

ARCO Internal Correspondence

DATE: JUNE 17, 1992

SUBJECT: PREPARATION OF Ra^{226} MATRIX STANDARDS

TO: FILE

PREPARED BY: NAT PATEL

Matrix standards were prepared by blending loca[illegible] soil and Certified Reference Material (CRM) from the Department of Energy's N[illegible] Brunwick Laboratory. These standards will be used to calibrate the gamma spectroscopy system. The gamma spec system will be utilized for determination of Ra^{226} content in soil during excavation control and verification. The matrix blending provides additional compensation for local background. To increase range accuracy, the higher Radium conte[illegible]M was diluted with the local matrix to bring the standard concentrations close to ac[illegible]ld concentrations.

Standard #RaM3 (Soil Type "A" Matrix - Chinle Alluvial)

3.15 grams of CRM-3B @ 11,076 pCi/gm	=	34,889.4 pCi
346.85 grams of Matrix Soil (TS-4-A) @ 1.0 pCi/gm	=	34[illegible] [illegible]Ci
350.00 grams	Total =	35,236.3 pCi

Concentration = 100.6 pCi/gm Ra^{226} (Sealed June 8, 1992)

Standard #RaM4 (Soil Type "B" Matrix - San Andres)

3.0 grams of CRM-3B @ 11,076 pCi/gm	=	33,228.0 pCi
347.0 gra[illegible] of Matrix Soil (TS-26-B) @ 2.0 pCi/gm	=	694.0 pCi
350.0 grams	Total =	33,922.0 pCi

Concentration = 96.9 pCi/gm Ra^{226} (Sealed June 17, 1992)

The matrix soil was weighed using the Ohaus 1500D electronic balance, SN#05531. The CRM was weighed with the Mettler H5 electronic balance, SN#58395. The soils and CRM were transferred into a gallon glass jar and mixed by rolling. The entire 350 grams of the standards were transferred into Lermer sample cups and sealed. The cups were marked and dated when sealed.

ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

18-Jun-93
10:19 AM

#	Sample ID#	Sample Description	Sample Date	Field Tech	Seal Date	Std. Wt gms	Samp Wt gms	Cnt Date Initial/ 28-Day	Std Cnt Time	Samp Cnt Time	ROI# 1, Bi-214 609 kev BKG Area	CNTS %Error	STD CNTS	STD pCi/gm	SAMPLE CNTS Area	%Error	Ra226 (pCi/gm) Conc	Error*	LLD	Lab Tech		ROI#4, Bi-214, 1764 kev BKG CNTS	STD CNTS	STD pCi/gm	SAMPLE CNTS	Ra226 (pCi/gm) Conc	Error*
		Grid Block:																									
1		-1-8				1200	1200														1						
						1200	1200		20	20				100.0			ERR	ERR	ERR		8			100.0		ERR	ERR
2		-1-11				1200	1200														1						
						1200	1200		20	20				100.0			ERR	ERR	ERR		11			100.0		ERR	ERR
3		-1-26				1200	1200														1						
						1200	1200		20	20				100.0			ERR	ERR	ERR		26			100.0		ERR	ERR

ATTACHMENT TEN

```
A13: [W1] ^|
C13: [W1] ^|
E13: [W1] '|
G13: [W1] ^|
I13: [W1] ^|
K13: [W1] ^|
M13: [W1] ^|
N13: [W5] +N11
O13: [W1] ^|
P13: [W5] +P11
Q13: [W1] ^|
S13: [W1] ^|
T13: U [W4] 20
U13: [W1] ^|
V13: U [W5] 20
W13: [W1] ^|
Y13: [W1] ^|
AA13: [W1] ^|
AC13: [W1] ^|
AD13: (F1) U [W6] 100
AE13: [W1] ^|
AG13: [W1] ^|
AI13: [W1] ^|
AJ13: (F1) [W7] ((AF13-X13)/V13)*AD13*N13*BF13/(((AB13/T13)-(X13/V13))*P13)
AK13: [W1] ^|
AL13: (F1) [W6] 1.96*@SQRT(((AH13*AF13/196)^2/V13^2)+((Z13*X13/196)^2/V13^2))*AD13*N13*BF13/(((AB13/T13)-(X13/V13))*P13)
AM13: [W1] ^|
AN13: (F2) [W6] (4.66*AD13*N13*BF13*((Z13*X13/196)/V13))/(((AB13/T13)-(X13/V13))*P13)
AO13: [W1] ^|
AQ13: [W1] ^|
AR13: [W5] '8
AS13: [W1] ^|
AU13: [W1] ^|
AW13: [W1] ^|
AX13: (F1) [W7] +AD13
AY13: [W1] ^|
BA13: [W1] ^|
```

* Estimated counting error at 95% CL (1.96 sigma)

```
BB13: (F1) [W7] ((AZ13-AT13)/V13)*AX13*N13/(((AV13/T13)-(AT13/V13))*P13)
BC13: [W1] ^|
BD13: (F1) [W6] 1.96*@SQRT((AZ13/V13^2)+(AT13/V13^2))*AX13*N13/(((AV13/T13)-(AT13/V13))*P13)
BE13: [W1] ^|
```

MCA #1 - Canberra S100 - RAM3.MCA - 100 pCi/gm Standard

Tag Number: 313
Report Group: Full
Group Size: 4096

Readout: Mon 06 Jul 1992 @ 17:10:10
Acquire Started: Mon 06 Jul 1992 @ 14:37:59

Elapsed Live Time: 150.00 min.
Elapsed True Time: 150.47 min.
Dead Time: 0.31 %

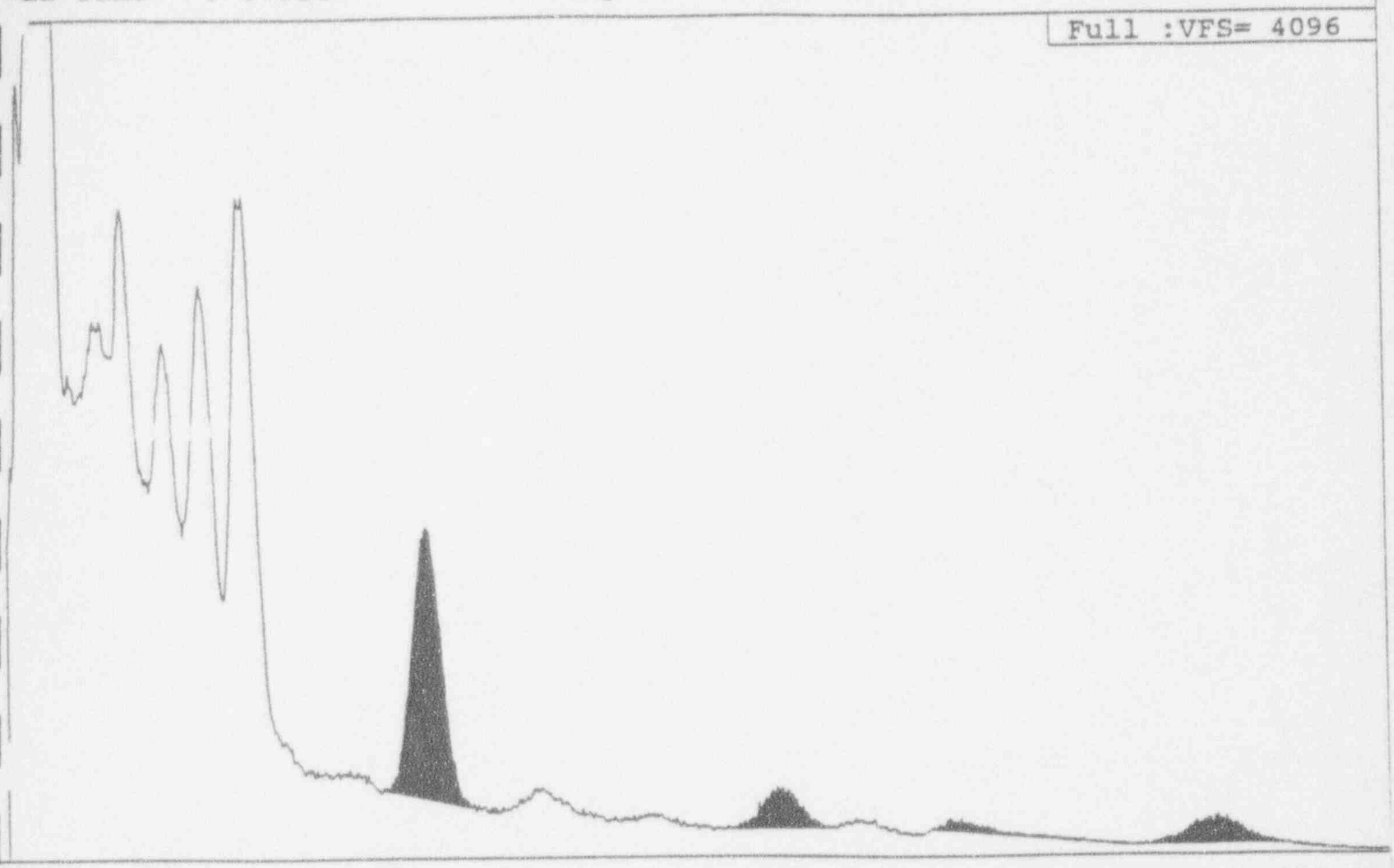
REGION OF INTEREST REPORT

ROI #	From(keV) To (keV)	Integral CPS	Area %Error	Peak(keV) FWHM(keV)
1	547.3	197597	126293	609.3
	672.4	21.96	1.99	43.82
2	1049.1	58341	22956	1119.4
	1189.3	6.48	7.96	49.70
3	1351.5	45566	6399	1386.7
	1570.3	5.06	37.17	14.72
4	1664.0	39387	22144	1763.5
	1865.7	4.38	6.88	64.00

ATTACHMENT ELEVEN

MCA #1 - Canberra S100 - RAM3.MCA - 100 pCi/gm Standard

ag Number : 313 Plotted On : Mon 06 Jul 1992 @ 17:12:41
Dead Time : 0.31% Acquire Started : Mon 06 Jul 1992 @ 14:37:59



Cursor=-15.0keV From 547.3keV To 672.4keV Pset(Lm)= 150.00
Counts=0 Int=197597 Area=126293+-1.99% Elap(Lm)= 150.00

ATTACHMENT TWELVE

October 1990 Correlation Soil Samples
Ra-226 Lab Analysis Comparison

Sample Description	Ra-226, pCi/gm Gamma Spec ALR	HRL	ARCO	Wet Alpha HRL
TS-4-A	0.9	2.0	1.3	0.0
TS-3-A	0.6	1.0	0.5	0.0
TS-2-A	2.5	3.0	2.7	3.6
TS-5-A	2.7	4.0	3.2	0.4
TS-6-A	5.6	7.0	5.6	2.9
TS-7-A	6.8	8.0	8.0	3.7
TS-9-A	6.1	7.0	7.6	5.3
TS-8-A	8.6	9.0	10.4	5.6
TS-10-A	9.3	10.0	8.3	6.8
TS-11-A	13.0	14.0	13.1	12.0
TS-14-A	19.0	18.0	18.5	14.0
TS-12-A	20.0	18.0	21.8	18.0
TS-13-A	26.0	27.0	27.4	24.0
TS-26-B	1.4	2.0	1.0	2.5
TS-17-B	10.0	12.0	11.9	10.0
TS-22-B	5.0	5.0	4.5	3.6
TS-16-B	12.0	14.0	13.8	12.0
TS-23-B	9.6	10.0	10.9	10.0
TS-15-B	15.0	17.0	15.1	12.0
TS-18-B	19.0	19.0	19.4	30.0
TS-24-B	26.0	20.0	28.5	27.0
TS-21-B	41.0	42.0	42.4	42.0
TS-19-B	36.0	37.0	41.1	33.0
TS-20-B	42.0	38.0	43.0	37.0
TS-25-B	110.0	96.0	111.4	93.0
TS-30-C	3.7	4.0	4.4	4.0
TS-29-C	5.2	3.0	1.9	3.0
TS-28-C	2.5	4.0	2.0	3.3
TS-40-C	3.0	4.0	3.5	4.0
TS-33-C	4.8	6.0	5.6	5.1
TS-38-C	11.0	9.0	9.7	9.5
TS-34-C	19.0	19.0	19.0	20.0
TS-35-C	22.0	23.0	23.7	20.0
TS-37-C	19.0	20.0	20.7	21.0
TS-32-C	46.0	43.0	48.2	44.0
TS-31-C	56.0	55.0	65.4	52.0
TS-36-C	62.0	58.0	60.5	57.0
TS-39-C	330.0	310.0	350.3	350.0

ALR = Acculabs Research. Gamma spec analysis performed by GeLi detector.

HRL = Hazen Research Labs. Gamma spec analysis performed by NaI detector.
Wet alpha analysis performed by alpha spectroscopy of precipitated Ra-226.

..RCO = ARCO Bluewater Mill. Gamma spec analysis performed by NaI detector.

ATTACHMENT THIRTEEN

Ra-226 Algorithm for Analyzing Partially-Filled Marinelli Beakers

The algorithm for calculating the Ra-226 concentration was revised to allow partially-filled Marinelli beakers to be analyzed by gamma-ray spectroscopy. The standard 1-liter Marinelli beaker holds approximately 1200 grams of soils and tailings material typical of the ARCO Bluewater site. A previously reported study (attached) developed a correction factor for partially filled beakers which compensated for the fact that the spectrometer is calibrated using a full beaker and the necessary geometry correction factor due to the partially-filled beaker.

The correction factors were plotted and a linear regression done to see the relationship between the correction factor and the weight of material in the beaker. This approximate linear relationship is shown in the attached plot. Since most of the samples analyzed will be 1200 grams, it was decided to adjust the curve to make the correction factor exactly 1.0 at 1200 g. This was done by using only 2 points (600 and 1200 grams) to develop the linear relationship. As can be seen in the attached figure, this line lies very close to the linear regression and has the advantage that it does not introduce an error for the normal 1200 g samples.

The algorithms within the spreadsheet were changed by the factor,

$$CF = (0.000055)(W) + 0.34$$

where CF is the correction factor and W is the weight in grams.

A new master spreadsheet File Name VERMASTB.WK1 was developed to include this change to the algorithm. This spreadsheet will be used for all future calculations. A printout of the LOTUS 123 cell formulas is attached.

Approved [signature] Date 6/15/93

Natver Patel, Radiation Safety Officer

Development of Sample Mass Correction Factor

Introduction

This special project was done to allow partially-filled soil sample beakers to be analyzed in the ARCO gamma-ray spectroscopy laboratory using standard operating procedures. A standard counting geometry consists of using a Marinelli beaker that holds approximately 1200 grams of local soils and tailings. The spectrometer is calibrated using a 1200 pCi/g standard reference material of 1200 g mass. This work was done to empirically develop a correction factor for use when analyzing partially-filled containers without having to recalibrate the spectrometer to accommodate the partially filled container.

Method

A mixture of sand tailings and soil was prepared suing the normal ARCO sample preparation procedure. The material was dried, ground, mixed, and split into eight samples ranging from 500 to 1200 grams, in 100 grams increments.

The samples were sealed and analyzed along with a 1200 gram standard three days after sealing (The standard was in full radioactive equilibrium). The standard and the eight tailings/soil samples were later analyzed at 7, 14, 22, and 28 days after sealing to follow the ingrowth of radon and radon progeny.

Results

The counting results for each sample, counted at the various intervals after the samples were sealed, are given in Table 1. The reported Ra-226 concentrations were calculated using the standard calibration factor (i.e., a full 1200 g standard beaker with radon daughters in full equilibrium with the Ra-226). The actual sample mass was used in the calculations.

The data in Table 1 were used to develop the concentration correction factors given in Table 2. Some care must be exercised in the application of the factors for fewer than 28 days ingrowth period. Generally, the emanation fraction for mill tailings ranges from 0.2 to 0.35. The emanation fraction has a large influence on the correction factors for fewer than 14 days ingrowth interval. The relatively low emanation fraction for the tailings sample that was used to prepare the eight samples may not be representative of the site and may underestimate the actual concentration. Therefore it is suggested that all samples be recounted after 28 days when the data are used for compliance purposes or high accuracy is desired.

Procedure

For a partially filled 1200 g Marinelli beaker, weigh the sample and note the ingrowth period. For samples between 500 and 1200 grams, the following procedure may be used.

1. Analyze the sample using the 1200 gram 100 pCi/g standard calibration factor.

2. Input the data into the spread sheet that calculates the concentration using the actual mass of the sample.

3. Choose the appropriate correction factor given in Table 2 that most closely represents your sample. A linear interpolation may be used to improve the accuracy of the correction factor.

4. Multiply the measured concentration by the correction factor.

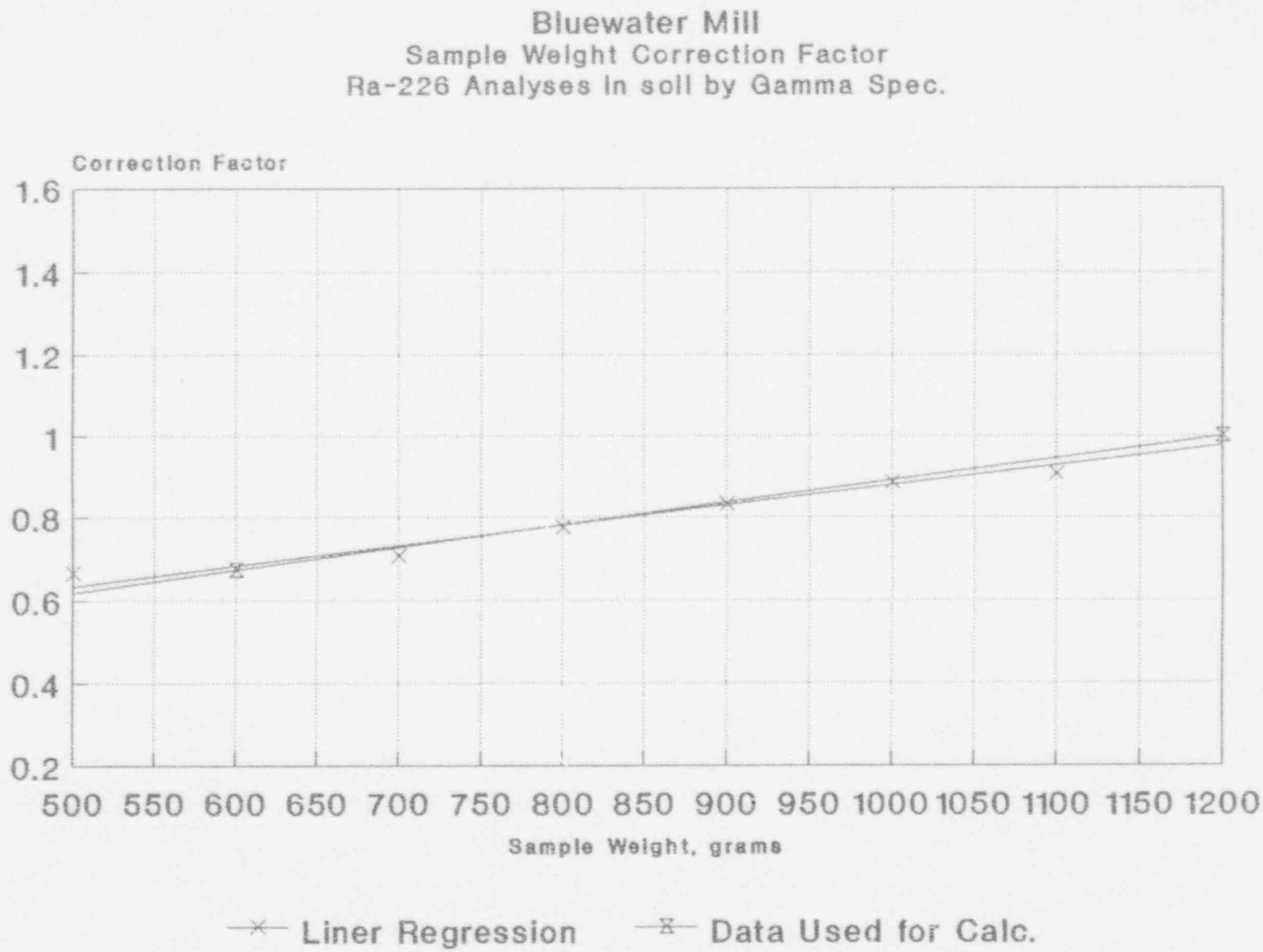
5. If the ingrowth period is less than 28 days and the result is either to be used for regulatory compliance purposes or high accuracy is desirable, the sample must be recounted after the 28 days ingrowth period.

Table 1. Counting Data for Partially-Filled Marinelli Beakers

Sample#	Sample Aliquot Grams	Seal Date	COUNT DATA 02-04-93 Ingrth days	Counts	pCi/gm	% Over Est.	% Ingrth	COUNT DATA 02-08-93 Ingrth days	Counts	pCi/gm	% Over Est.	% Ingrtl	COUNT DATA Ingrth days	Counts	pCi/gm
=====	====	=======	===	=====	====	=====	=====	===	=====	====	=====	====	===	=====	=====
93-170S	500	02-01-93	3	39384	120.9	47	90.7	7	42084	128.9	53	96.7	14	42430	133.0
93-171S	600	02-01-93	3	46687	119.6	45	91.2	7	50036	127.8	52	97.5	14	50338	131.5
93-172S	700	02-01-93	3	51670	113.5	38	91.0	7	54949	120.3	43	96.5	14	55818	125.0
93-173S	800	02-01-93	3	53897	103.6	26	90.5	7	56989	109.1	30	95.3	14	58524	114.7
93-174S	900	02-01-93	3	56928	97.3	18	92.5	7	59432	101.2	20	96.2	14	61632	107.4
93-175S	1000	02-01-93	3	58928	90.6	10	90.2	7	62061	95.1	13	94.6	14	63846	100.1
93-176S	1100	02-01-93	3	63827	89.3	9	92.2	7	66197	92.2	10	95.2	14	68935	98.3
93-177S	1200	02-01-93	3	64158	82.3	0	92.7	7	65898	84.1	0	94.8	14	67059	87.6
STD (#RaM1, 100 pCi/gm)				77948			=====		78322			====		76502	
BKG				205			91.4		18			95.8		59	

Table 2. Concentration Correction Factors for Partially–Filled Marinelli Beakers

Sample Mass	Ingrowth Period				
	3 days	7 days	14 days	22 days	28 days
500	0.73	0.69	0.67	0.67	0.66
600	0.74	0.69	0.67	0.67	0.68
700	0.78	0.74	0.71	0.70	0.71
800	0.86	0.81	0.77	0.78	0.77
900	0.91	0.88	0.83	0.82	0.84
1000	0.98	0.93	0.89	0.88	0.88
1100	0.99	0.96	0.90	0.90	0.92
1200	1.08	1.05	1.01	1.01	1.00



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ARCO Bluewater Mill

MCA Ra-226 Analyses on Soil Samples

17-Jun-93
06:00 AM

#	Sample ID#	Sample Description	Sample Date	Field Tech	Seal Date	Std. Wt gms	Samp. Wt gms	Cnt Date Initial/ 28-Day	Std. Cnt Time	Samp. Cnt Time	ROI#1, Bi-214 609 kev BKG Area	CNTS %Error	STD CNTS	STD pCi/gm	SAMPLE CNTS Area	%Error	Ra226 (pCi/gm) Conc	Error*	LLD	Lab Tech
Grid Block:																				
Grid Block:																				
1		-1-8				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
2		-1-11				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
3		-1-26				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
4		-1-29				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
5		-2-8				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
6		-2-11				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
7		-2-26				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
8		-2-29				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
9		-3-8				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
10		-3-11				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
11		-3-26				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
12		-3-29				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
13		-4-8				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
14		-4-11				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	
15		-4-26				1200	1200													
						1200	1200		20	20				100.0			ERR	ERR	ERR	

APPENDIX G

Ra-226 Analysis QA Data

INTERLABORATORY COMPARISON OF QA SAMPLE RESULTS

Sample Number	Sample Weight	ACCULAB Conc.	ACCULAB Error*	ARCO Conc.	ARCO Error*	Diff.	Error*
93- 2800 S	967	9.0	+/- 0.5	8.3	+/- 0.5	-0.7	+/- 0.7
93- 2800 S**	967	9.0	+/- 0.5	6.5	+/- 0.5	-2.5	+/- 0.7
93- 2820 S	1200	0.4	+/- 0.1	0.2	+/- 0.3	-0.2	+/- 0.3
93- 2820 S**	1200	0.4	+/- 0.1	0.2	+/- 0.3	-0.2	+/- 0.3
93- 2840 S	1200	20.0	+/- 1.0	15.6	+/- 0.6	-4.4	+/- 1.2
93- 2840 S**	1200	20.0	+/- 1.0	14.8	+/- 0.6	-5.2	+/- 1.2
93- 2860 S	1200	3.4	+/- 0.3	3.2	+/- 0.4	-0.2	+/- 0.5
93- 2860 S**	1200	3.4	+/- 0.3	3.1	+/- 0.4	-0.3	+/- 0.5
93- 2880 S	1200	10.0	+/- 1.0	8.9	+/- 0.5	-1.1	+/- 1.1
93- 2880 S**	1200	10.0	+/- 1.0	9.1	+/- 0.5	-0.9	+/- 1.1
93- 2900 S	1200	8.1	+/- 0.5	6.8	+/- 0.4	-1.3	+/- 0.6
93- 2900 S**	1200	8.1	+/- 0.5	6.2	+/- 0.4	-1.9	+/- 0.6
93- 2920 S	1200	18.0	+/- 1.0	11.6	+/- 0.5	-6.4	+/- 1.1
93- 2920 S**	1200	18.0	+/- 1.0	11.6	+/- 0.5	-6.4	+/- 1.1
93- 2940 S	350	88.0	+/- 2.0	88.0	+/- 5.8	0.0	+/- 6.1
93- 2960 S	1200	9.1	+/- 0.5	6.9	+/- 0.4	-2.2	+/- 0.6
93- 2960 S**	1200	9.1	+/- 0.5	6.5	+/- 0.6	-2.6	+/- 0.8
93- 2980 S**	885	7.6	+/- 0.5	5.9	+/- 0.5	-1.7	+/- 0.7
93- 2980 S	885	7.6	+/- 0.5	5.8	+/- 0.5	-1.8	+/- 0.7
93- 3000 S**	777	11.0	+/- 1.0	12.1	+/- 0.6	1.1	+/- 1.2
93- 3000 S	777	11.0	+/- 1.0	10.2	+/- 0.2	-0.8	+/- 1.0
93- 3020 S**	1200	1.2	+/- 0.3	1.1	+/- 0.3	-0.1	+/- 0.4
93- 3020 S	1200	1.2	+/- 0.3	1.1	+/- 0.3	-0.1	+/- 0.4
93- 3040 S	1200	19.0	+/- 1.0	12.8	+/- 0.6	-6.2	+/- 1.2
93- 3040 S**	1200	19.0	+/- 1.0	13.2	+/- 0.6	-5.8	+/- 1.2
93- 3060 S	1200	9.6	+/- 0.5	7.1	+/- 0.5	-2.5	+/- 0.7
93- 3060 S**	1200	9.6	+/- 0.5	7.3	+/- 0.5	-2.3	+/- 0.7
93- 3080 S	350	14.0	+/- 1.0	13.1	+/- 3.3	-0.9	+/- 3.4
93- 3100 S	350	12.0	+/- 1.0	9.3	+/- 3.6	-2.7	+/- 3.7
93- 3120 S	350	11.0	+/- 1.0	12.7	+/- 3.1	1.7	+/- 3.3
93- 3140 S	350	110.0	+/-10.0	116.1	+/- 7.5	6.1	+/-12.5
93- 3160 S	1200	6.6	+/- 0.5	5.3	+/- 0.4	-1.3	+/- 0.6
93- 3160 S**	1200	6.6	+/- 0.5	4.9	+/- 0.4	-1.7	+/- 0.6
93- 3180 S**	1200	44.0	+/- 1.0	35.7	+/- 0.9	-8.3	+/- 1.3
93- 3180 S	1200	44.0	+/- 1.0	38.9	+/- 1.0	-5.1	+/- 1.4
93- 3200 S	1150	3.6	+/- 0.3	1.4	+/- 0.4	-2.2	+/- 0.5
93- 3200 S**	1150	3.6	+/- 0.3	1.7	+/- 0.4	-1.9	+/- 0.5
93- 3220 S	350	170.0	+/-10.0	193.2	+/- 8.8	23.2	+/-13.3
93- 3240 S	350	7.8	+/- 0.5	5.8	+/- 2.9	-2.0	+/- 2.9
93- 3260 S	350	220.0	+/-10.0	203.0	+/- 9.9	-17.0	+/-14.1
93- 3280 S	350	110.0	+/-10.0	100.9	+/- 7.1	-9.1	+/-12.3
93- 3300 S	350	94.0	+/- 2.0	96.1	+/- 6.2	2.1	+/- 6.5
93- 3320 S	350	130.0	+/-10.0	126.5	+/- 7.2	-3.5	+/-12.3
93- 3340 S	350	200.0	+/-10.0	177.3	+/- 8.2	-22.7	+/-12.9
93- 3360 S	1200	2.6	+/- 0.3	2.8	+/- 0.4	0.2	+/- 0.5
93- 3360 S**	1200	2.6	+/- 0.3	2.8	+/- 0.4	0.2	+/- 0.5

*Error at 95% CL. ** Counted on Auxiliary Spectrometer

APPENDIX H

Moisture Data for the MTP Tailings and Radon Barrier

SERGENT, HAUSKINS & BECKWITH — CONSULTING GEOTECHNICAL ENGINEERS

APPLIED SOIL MECHANICS • ENGINEERING GEOLOGY • MATERIALS ENGINEERING

MOISTURE TESTS

Job No. C92544O

Date

Tested by M. Neas

Test Hole No.	N315 E221	N315 E221	N315 E231	N315 E240	N315 E240	N315 E240	N317 E226
Depth	0 5	1. 0	2 0	0 5	1 0	2 0	0 5
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	277.7	278.1	278.0	278.0	277.3	277.3	279.0
Dry Wt. & ~~Tare~~	250.2	247.6	244.7	242.8	249.3	256.2	258.0
Loss	27.5	30.5	33.3	35.2	28.0	21.1	21.0
Tare Wt.	—	—	—	—	—	—	—
Dry Wt.	—	—	—	—	—	—	—
% Moisture	11.0	12.3	13.6	14.5	11.2	8.2	8.1

Test Hole No.	N317 E226	N317 E226	N318 E239	N318 E239	N318 E239	N318 E242	N318 E242
Depth	1 0	2 0	0 5	1 0	2 0	0 5	1 0
Can #	—	—	—	—	—	—	—
Wet Wt. & Tare	279.7	274.5	276.3	276.1	273.5	273.5	276.6
Dry Wt. & Tare	246.9	249.6	244.0	241.0	248.4	234.9	241.1
Loss	32.8	24.9	32.3	35.1	25.1	38.6	35.5
Tare Wt.	—	—	—	—	—	—	—
Dry Wt.	—	—	—	—	—	—	—
% Moisture	73.3	10.0	13.2	14.6	10.1	16.4	14.7

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MOISTURE TESTS

Job No. C92-5440

Date

Tested by M. Neves

Test Hole No.	N318 E242	N318 E247	N318 E247	N318 E247	N320 E230	N320 E230	N320 E230
Depth	2^{0}	0^{5}	1^{0}	2^{0}	0^{5}	1^{0}	2^{0}
Can #	—	—	—	—	—	—	—
Wet Wt. & Tare	273.7	276.5	276.1	278.5	276.3	274.1	278.2
Dry Wt. & Tare	255.5	236.8	243.0	256.9	240.0	243.6	249.8
Loss	18.2	39.7	33.1	21.6	36.3	30.5	28.4
Tare Wt.	—	—	—	—	—	—	—
Dry Wt.	—	—	—	—	—	—	—
% Moisture	7.1	16.8	13.6	8.4	15.1	12.5	11.4

Test Hole No.	N322 E242	N322 E242	N322 E242	N322 E248	N322 E248	N322 E248	N323 E236
Depth	0^{5}	1^{0}	2^{0}	0^{5}	1^{0}	2^{0}	0^{5}
Can #	—	—	—	—	—	—	—
Wet Wt. & Tare	272.0	274.8	277.8	278.7	271.0	273.6	276.2
Dry Wt. & Tare	247.6	241.5	254.9	241.6	242.7	243.3	249.1
Loss	24.4	33.3	22.9	37.1	28.3	30.3	27.1
Tare Wt.	—	—	—	—	—	—	—
Dry Wt.	—	—	—	—	—	—	—
% Moisture	9.8	13.8	9.0	15.4	11.7	12.4	10.9

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MOISTURE TESTS

Job No. C92-5440

Date ______

Tested by M. Nevis

Test Hole No.	N 325 E 236	N 325 E 236	N 323 E 223	N 323 E 223	N 323 E 223	N 325 E 219	N 325 E 219
Depth	1.0	2.0	0.5	1.0	2.0	0.5	1.0
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	279.0	271.0	273.1	277.5	274.0	277.9	274.7
Dry Wt. & ~~Tare~~	249.0	242.0	238.4	243.0	232.1	245.9	234.7
Loss	30.0	29.0	34.7	34.5	41.9	32.0	40.0
Tare Wt.	—	—	—	—	—	—	—
Dry Wt.	—	—	—	—	—	—	—
% Moisture	12.0	12.0	14.6	14.2	18.0	13.0	17.0

Test Hole No.	N 325 E 226	N 325 E 226	N 325 E 226	N 325 E 230	N 325 E 230	N 325 E 230	N 325 E 234
Depth	0.5	1.0	2.0	0.5	1.0	2.0	0.5
Can #	—	—	—	—	—	—	—
Wet Wt. & Tare	278.0	274.8	277.0	272.4	276.4	278.6	272.8
Dry Wt. & Tare	252.0	246.2	246.6	241.6	243.7	246.3	238.7
Loss	26.0	28.6	31.4	30.8	32.7	31.3	34.1
Tare Wt.	—	—	—	—	—	—	—
Dry Wt.	—	—	—	—	—	—	—
% Moisture	10.3	11.6	12.3	12.7	13.4	13.1	14.3

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MOISTURE TESTS

Job No. C92-5440

Date ______

Tested by M. Nejos

Test Hole No.	N 325 E 234	N 325 E 234	N 325 E 241	N 325 E 241	N 325 E ~~24~~	N 329 E 219	N 329 E 219
Depth	1.0	2.0	0.5	1.0	2.0	0.5	1.0
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	278.1	271.0	274.7	279.0	274.0	272.6	279.1
Dry Wt. & ~~Tare~~	239.4	239.0	250.5	244.8	245.5	238.0	247.9
Loss	38.7	32.0	24.2	34.2	28.5	34.6	31.2
Tare Wt.	—	—	—	—	—	—	—
Dry Wt.	—	—	—	—	—	—	—
% Moisture	16.2	13.4	9.7	14.0	11.6	14.5	12.6

Test Hole No.	N 329 E 232	N 329 E 232	N 329 E 232	N 329 E 226	N 329 E 226	N 329 E 226	N 329 E 237
Depth	0.5	1.0	2.0	0.5	1.0	2.0	0.5
Can #	—	—	—	—	—	—	—
Wet Wt. & Tare	273.4	273.8	274.0	276.6	278.5	270.0	277.9
Dry Wt. & Tare	245.1	244.5	250.2	248.9	251.5	243.0	252.6
Loss	28.3	29.3	23.8	27.7	27.0	27.0	25.3
Tare Wt.	—	—	—	—	—	—	—
Dry Wt.	—	—	—	—	—	—	—
% Moisture	11.5	12.0	9.5	11.1	10.7	11.1	10.0

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MOISTURE TESTS

Job No. C92-5440

Date ______________

Tested by M. Neves

Test Hole No.	N 329 E 237	N 329 E 237	N 322 E 234	N 322 E 234	N 322 E 234		
Depth	1^{0}	2^{0}	0^{5}	1^{0}	2^{0}		
Can #	—	—	—	—	—		
Wet Wt. & ~~Tare~~	273.4	276.0	271.8	278.7	275.5		
Dry Wt. & ~~Tare~~	238.8	241.5	242.0	251.8	244.9		
Loss	34.6	34.5	29.8	26.9	30.6		
Tare Wt.	—	—	—	—	—		
Dry Wt.	—	—	—	—	—		
% Moisture	14.5	14.3	12.3	10.7	12.5		

Test Hole No.							
Depth							
Can #							
Wet Wt. & Tare							
Dry Wt. & Tare							
Loss							
Tare Wt.							
Dry Wt.							
% Moisture	—						

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MOISTURE TESTS

Job No. C92-5440

Date 10-26-93

Tested by MN

Test Hole No.	1022	1022	1022	1022	1020	1020	1020
Depth	0-2	2-4	4-6	6-8	0-2	2-4	4-6
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	210.4	159.5	167.5	174.8	173.7	175.3	209.8
Dry Wt. & ~~Tare~~	189.5	143.6	148.3	163.2	153.5	154.4	187.6
Loss	20.9	15.9	19.2	11.6	20.2	20.9	22.2
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	11.0	11.1	12.9	7.1	13.1	13.5	11.8

Test Hole No.	1020	1017	1017	1017	1017	1028	1028
Depth	6-8	0-2	2-4	4-6	6-8	0-2	2-4
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	230.6	170.8	186.9	152.3	166.1	181.0	220.6
Dry Wt. & ~~Tare~~	199.7	158.3	165.9	130.9	147.7	164.6	197.6
Loss	30.9	12.5	21.0	21.4	18.4	16.4	23.0
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	15.5	7.9	12.6	16.3	12.4	10.0	11.6

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MOISTURE TESTS

Job No. C92-5440

Date 10-26-93

Tested by MN

Test Hole No.	1028	1028	1018	1018	1018	1018	1029
Depth	4-6	6-8	0-2	2-4	4-6	6-8	0-2
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	153.5	186.8	157.3	187.2	230.3	177.9	184.2
Dry Wt. & ~~Tare~~	140.2	150.0	141.7	167.5	194.7	149.7	165.6
Loss	13.3	36.8	15.6	19.7	35.6	28.2	18.6
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	9.5	24.5	11.0	11.8	18.3	18.8	11.2

Test Hole No.	1029	1029	1029	1025	1025	1025	1025
Depth	2-4	4-6	6-8	0-2	2-4	4-6	6-8
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	155.1	156.5	162.6	153.6	157.2	160.6	187.9
Dry Wt. & ~~Tare~~	145.6	142.7	133.3	139.8	140.0	125.9	166.3
Loss	9.5	13.8	29.3	13.8	17.2	34.7	21.6
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	6.5	9.7	22.0	9.9	12.3	27.6	13.0

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MOISTURE TESTS

Job No. C92-5440

Date 10-26-93

Tested by M Novos

Test Hole No.	1033	1033	1033	1033	1031	1031	1031
Depth	0-2	2-4	4-6	6-8	0-2	2-4	4-6
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	156.3	202.9	190.2	158.4	241.3	314.1	156.1
Dry Wt. & ~~Tare~~	138.6	175.6	184.3	147.5	207.0	287.1	136.4
Loss	17.7	27.3	5.9	10.9	34.3	27.0	19.7
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	12.8	15.5	3.2	7.4	16.6	9.4	14.4

Test Hole No.	1031	1026	1026	1026	1026	1032	1032
Depth	6-8	0-2	2-4	4-6	6-8	2-4	0-2
Can #	—	—	—	—	—	—	—
Wet Wt. & ~~Tare~~	152.5	157.3	202.4	167.3	151.7	198.0	189.7
Dry Wt. & ~~Tare~~	141.7	144.0	167.5	133.3	123.2	169.4	160.9
Loss	10.8	13.3	34.9	34.0	28.5	28.6	28.8
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	7.6	9.2	20.8	25.5	23.1	16.9	17.9

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MOISTURE TESTS

Job No. C92-5440

Date 10-26-93

Tested by M. Neue

Test Hole No.	1032	1032	1032				
Depth	2-4	4-6	6-8				
Can #	—	—	—				
Wet Wt. & ~~Tare~~	171.3	153.5	277.3				
Dry Wt. & ~~Tare~~	152.7	136.0	244.0				
Loss	18.6	17.5	33.3				
Tare Wt.	NA	NA	NA				
Dry Wt.	NA	NA	NA				
% Moisture	12.2	12.9	13.6				

Test Hole No.							
Depth							
Can #							
Wet Wt. & Tare							
Dry Wt. & Tare							
Loss							
Tare Wt.							
Dry Wt.							
% Moisture							

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MOISTURE TESTS

Job No. C92-5140

Date 10/1/93

Tested by

Test Hole No.	1049	1049	1049	1049	1050	1050	1050
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & ~~Tare~~	158.0	169.6	142.1	274.2	235.6	273.5	100.4
Dry Wt. & ~~Tare~~	142.6	151.0	111.1	218.2	209.0	229.5	74.9
Loss	15.4	18.6	31.0	56.0	27.6	43.9	25.5
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	10.8	12.3	27.9	25.7	13.3	19.1	34.0

Test Hole No.	1050	1052	1052	1052	1052	1053	10[illegible]
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	8	9	10	11	12	13	14
Wet Wt. & ~~Tare~~	190.4	272.1	274.1	276.8	278.1	272.6	272.[illegible]
Dry Wt. & ~~Tare~~	168.1	249.0	236.3	226.2	236.3	240.1	233.6
Loss	22.3	23.1	37.8	50.6	41.8	32.5	38.5
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	13.3	9.3	16.0	22.4	17.7	13.5	16.5

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MOISTURE TESTS

Job No. CG2-5440

Date 10/1/93

Tested by

Test Hole No.	1053	1053	1051	1051	1051	1051	1072
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'
Can #	15	16	17	18	19	20	21
Wet Wt. & ~~Tare~~	278.3	238.2	272.9	279.1	277.2	278.9	[illegible]
Dry Wt. & ~~Tare~~	234.3	213.3	232.7	253.4	248.7	235.6	245.9
Loss	44.0	24.9	40.2	25.7	28.5	43.3	29.2
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	18.8	11.7	17.3	10.1	11.5	18.4	11.9

Test Hole No.	1072	1072	1072	1070	1070	1070	1070
Depth	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'
Can #	22	23	24	25	26	27	28
Wet Wt. & ~~Tare~~	273.9	276.5	276.3	277.3	270.7	272.8	277.1
Dry Wt. & ~~Tare~~	251.0	229.5	218.5	235.4	234.2	231.7	230.0
Loss	22.9	47.0	57.8	41.9	36.5	41.1	47.1
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	9.1	20.5	26.4	17.8	15.6	17.7	20.5

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MOISTURE TESTS

Job No. C92-5440

Date 10/1/93

Tested by ______

Test Hole No.	1073	1073	1073	1073			
Depth	0'-2'	2'-4'	4'-6'	6'-8'			
Can #	29	30	31	32			
Wet Wt. & ~~Tare~~	275.9	278.4	274.4	277.6			
Dry Wt. & ~~Tare~~	232.6	241.0	224.8	224.5			
Loss	43.3	37.4	49.6	53.1			
Tare Wt.	NA	NA	NA	NA			
Dry Wt.	NA	NA	NA	NA			
% Moisture	18.6	15.5	22.1	23.6			

Test Hole No.							
Depth							
Can #							
Wet Wt. & Tare							
Dry Wt. & Tare							
Loss							
Tare Wt.							
Dry Wt.							
% Moisture	—						

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MOISTURE TESTS

Job No. C93-5416

Date 10/5/93

Tested by

Test Hole No.	1069	1069	1069	1069	1074	1074	1074
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & Tare	272.4	274.7	273.8	274.6	207.4	186.6	274.5
Dry Wt. & Tare	240.2	233.1	231.1	220.7	184.1	150.0	233.0
Loss	32.2	41.6	42.7	53.9	23.3	36.6	41.5
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	13.4	17.8	18.5	24.4	12.7	24.4	17.8

Test Hole No.	1074	1085	1085	1085	1085	1086	1086
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	8	9	10	11	12	13	14
Wet Wt. & Tare	276.5	205.2	270.4	271.4	278.4	271.3	279.1
Dry Wt. & Tare	221.4	177.5	230.0	226.5	220.3	251.5	249.5
Loss	55.1	27.7	40.4	44.9	58.1	19.8	29.6
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	24.9	15.6	17.6	19.8	26.4	7.9	11.9

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MOISTURE TESTS

Job No. C92-5440

Date 10/5/93

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Test Hole No.	1086	1056	1046	1046	1046	1046	1053
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'
Can #	15	16	17	18	19	20	21
Wet Wt. & ~~Tare~~	259.9	261.2	272.3	275.5	262.6	275.9	270.1
Dry Wt. & ~~Tare~~	231.7	216.8	244.9	228.8	229.7	191.3	226.9
Loss	28.2	44.4	27.4	46.7	32.9	84.6	43.2
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	12.2	20.5	11.2	20.4	14.3	44.2	19.0

Test Hole No.	1093	1093	1093	1087	1087	1087	1087
Depth	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'
Can #	22	23	24	25	26	27	28
Wet Wt. & ~~Tare~~	265.4	261.6	275.1	271.7	273.4	274.6	276.8
Dry Wt. & ~~Tare~~	225.5	209.7	231.2	245.8	243.4	228.1	221.5
Loss	39.9	51.9	43.9	25.9	30.0	46.5	55.3
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	17.7	24.7	19.0	10.5	12.3	20.4	25.0

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MOISTURE TESTS

Job No. C92-5440

Date 10-20-93

Tested by ____________

Test Hole No.	1013	1013	1013	1013	1007	1007	1007
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & ~~Tare~~	273.0	275.4	276.2	271.9	271.7	273.8	251.3
Dry Wt. & ~~Tare~~	233.7	222.7	245.7	252.0	256.3	259.4	229.[illegible]
Loss	39.3	52.7	30.5	19.9	15.4	14.4	22.3
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	16.8	23.7	12.4	7.9	6.0	5.6	9.7

Location 1005 CAN 4: [illegible] 4! 4!

Test Hole No.	1007	N-323 E-256	N-323 E-256	N-323 E-246	N-323 E-256	1015	1015
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	8	9	10	11	12	13	14
Wet Wt. & ~~Tare~~	252.8	218.9	229.7	276.1	272.8	273.0	273.7
Dry Wt. & ~~Tare~~	235.0	205.2	208.2	248.8	245.7	251.8	253.[illegible]
Loss		13.2	21.5	27.3	27.1	21.2	20.0
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	-	6.2	10.3	11.0	11.0	8.4	7.9

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MOISTURE TESTS

Job No. C92-5440

Date 10-20-93

Tested by ____________

Test Hole No.	1015	1015	1014	1014	1014	1014	1024
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'
Can #	15	16	17	18	19	20	21
Wet Wt. & ~~Tare~~	276.2	275.6	273.2	279.0	272.3	271.4	271.9
Dry Wt. & ~~Tare~~	252.1	240.0	[illegible]	252.2	235.5	231.6	249.7
Loss		35.6	33.5	26.8	36.8	39.8	22.2
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture		14.8	14.0	10.6	15.6	17.2	8.9

Test Hole No.	1024	1024	1024	1009	1009	1009	1009
Depth	2'-4'	4'-6'	6'-8	0'-2'	2'-4'	4'-6'	6'-8'
Can #	22	23	24	25	26	27	28
Wet Wt. & ~~Tare~~	275.7	271.6	277.1	275.3	274.8	277.5	274.5
Dry Wt. & ~~Tare~~	248.4	235.7	236.3	253.5	255.9	249.3	250.1
Loss	27.3	35.9	40.8	21.8	19.3	28.2	24.4
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	11.0	15.2	17.3	8.6	7.5	11.3	9.8

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MOISTURE TESTS

Job No. C92-5440

Date 10-20-93

Tested by ____________

Location 1016
CAN 108-110

Test Hole No.	108-110	108-110	108-110	109-110	1019	1019	1019	1[illegible]
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2.4'	0'-2'	2'-4'	4[illegible]
Can #	29	30	31	32	33	31	3[illegible]	[illegible]
Wet Wt. & ~~Tare~~	274.0	274.2	277.9	270.5	272.0	273.6	273.[illegible]	2[illegible]
Dry Wt. & ~~Tare~~	249.2	249.1	247.6	240.2	247.5	251.8	250.[illegible]	2[illegible]
Loss	25.7	25.1	30.3	29.8	24.5	21.8	22.5	[illegible]
Tare Wt.	NA	NA	NA	NA	NA	NA	NA	N[illegible]
Dry Wt.	NA	NA	NA	NA	NA	NA	NA	N[illegible]
% Moisture	10.3	10.1	12.2	12.4	9.9	8.6	9.0	1[illegible]

Test Hole No.	1019	1063	1063	1063	1063	1062	1062
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	37	38	39	40	41	42	43
Wet Wt. & ~~Tare~~	276.6	274.8	277.0	273.9	275.5	274.6	277.0
Dry Wt. & ~~Tare~~	252.1	249.7	246.2	211.5	192.1	260.3	221.5
Loss	24.5	26.1	30.8	62.4	83.4	14.3	55.5
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	9.7	10.5	12.5	29.5	43.4	5.5	25.0

REPLY TO: 4700 LINCOLN ROAD, N.E., ALBUQUERQUE, NEW MEXICO 87109

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MOISTURE TESTS

Job No. (92-5240

Date 10-20-92

Tested by ____________

1005
CAN 21

Test Hole No.	1062	1062	[illegible]				
Depth	4'-6'	6'-8'	2.4				
Can #	44	45	46				
Wet Wt. & ~~Tare~~	277.4	275.5	86.0				
Dry Wt. & ~~Tare~~	243.3	228.0	80.7				
Loss	34.1	47.5	5.3				
Tare Wt.	NA	NA	NA				
Dry Wt.	NA	NA	NA				
% Moisture	14.0	20.8	6.6				

Test Hole No.							
Depth							
Can #							
Wet Wt. & Tare							
Dry Wt. & Tare							
Loss							
Tare Wt.							
Dry Wt.							
% Moisture	—						

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MOISTURE TESTS

Job No. C92-5410

Date 10-21-93

Tested by ____________

Test Hole No.	1061	1061	1061	1061	1060	1060	1060
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & ~~Tare~~	270.0	270.8	272.3	272.9	273.8	226.1	182.8
Dry Wt. & ~~Tare~~	250.8	228.7	244.8	219.1	216.4	228.7	152.1
Loss	19.2	42.1	27.5	53.8	57.4	47.4	26.7
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	7.6	16.4	11.2	24.5	26.5	20.7	17.0

230

Test Hole No.	1060	1008	1008	1008	1008	1006	1006
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	8	9	10	11	12	13	[illegible]
Wet Wt. & ~~Tare~~	273.9	278.1	272.7	279.5	275.2	273.9	274.7
Dry Wt. & ~~Tare~~	216.0	259.2	251.1	256.5	249.0	242.9	246.6
Loss	57.9	18.4	21.6	23.0	26.2	31.0	28.1
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	27.7	7.1	8.6	9.0	10.5	12.8	11.4

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MOISTURE TESTS

Job No. C92-5740

Date 10-21-93

Tested by ______________

Test Hole No.	1006	1006	1058	1058	1058	1058	1057
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'
Can #	15	16	17	18	19	20	21
Wet Wt. & ~~Tare~~	277.8	277.4	276.5	277.5	271.0	271.9	272.9
Dry Wt. & ~~Tare~~	252.5	242.7	245.2	238.5	229.4	217.2	237.4
Loss	25.3	34.7	31.3	39.0	41.6	54.7	35.5
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	10.0	14.3	12.7	16.3	18.1	25.2	14.9

Test Hole No.	1057	1057	1057	1056	1056	1056	1056
Depth	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'
Can #	22	23	24	25	26	27	28
Wet Wt. & ~~Tare~~	274.8	274.4	275.0	278.5	271.9	273.7	274.7
Dry Wt. & ~~Tare~~	243.0	232.7	235.0	251.5	233.0	234.3	229.6
Loss	31.8	41.7	40.0	27.0	38.9	39.4	45.1
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	13.1	17.9	17.0	10.7	16.7	16.8	19.6

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MOISTURE TESTS

Job No. C92-5710

Date 10-21-93

Tested by ____________

Test Hole No.	1055	1055	1055	1055	203 1002	1002	1002
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	29	[illegible]	31	32	33	34	[illegible]
Wet Wt. & ~~Tare~~	275.5	273.6	273.7	274.7	276.7	274.6	275.3
Dry Wt. & ~~Tare~~	241.1	216.5	176.9	184.2	254.3	254.9	259.7
Loss	34.4	57.1	96.8	90.5	22.4	19.7	15.6
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	14.3	26.4	54.7	49.1	8.8	7.7	6.0

Test Hole No.	1002	1004 N318 E242	N-318 E244	N318 E-244	N318 E-244	N318 E244	
Depth	6'-8'	2.4	0'2'	2'-4'	4'-6'	6'-8'	
Can #	36	37	38	39	40	4	
Wet Wt. & ~~Tare~~	275.9	241.3	162.1	271.7	217.3	230.8	
Dry Wt. & ~~Tare~~	246.1	218.5	150.4	250.9	198.3	222.0	
Loss	29.8	22.8	11.7	20.8	19.0	8.8	
Tare Wt.	NA	NA	NA	NA	NA	NA	
Dry Wt.	NA	NA	NA	NA	NA	NA	
% Moisture	12.1	10.4	7.8	8.3	9.6	4.0	

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MOISTURE TESTS

Job No. CS2-5440

Date 10-6-93

Tested by

Test Hole No.	1081	1091	1081	1081	1075	1075	1075
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & ~~Tare~~	275.4	274.5	278.0	275.9	278.9	277.6	277.8
Dry Wt. & ~~Tare~~	246.6	236.0	229.0	224.5	237.9	235.8	234.5
Loss	28.8	38.5	49.0	51.4	41.0	41.8	43.3
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	11.7	16.3	21.4	22.9	17.2	17.7	18.5

Test Hole No.	1075	1082	1082	1082	1082	10[illegible]	10[illegible]
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	8	9	10	11	12	13	14
Wet Wt. & ~~Tare~~	275.4	279.4	269.7	271.3	272.9	276.5	27[illegible]
Dry Wt. & ~~Tare~~	231.3	231.1	214.1	215.2	209.4	248.1	253.2
Loss	44.1	48.3	55.6	56.1	63.5	28.4	21.[illegible]
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	19.1	20.9	26.0	26.1	30.3	11.4	8.6

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MOISTURE TESTS

Job No. C92-5410

Date 10-6-93

Tested by ____________

Test Hole No.	1080	1080	1077	1077	1077	1077	
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	
Can #	15	16	17	18	19	20	
Wet Wt. & ~~Tare~~	278.5	279.5	272.4	276.5	274.9	274.5	
Dry Wt. & ~~Tare~~	240.6	222.2	224.3	250.3	223.4	220.1	
Loss	37.9	56.8	48.1	26.2	51.5	54.4	
Tare Wt.	NA	NA	NA	NA	NA	NA	
Dry Wt.	NA	NA	NA	NA	NA	NA	
% Moisture	15.7	25.5	21.4	10.5	23.0	24.7	

Test Hole No.							
Depth							
Can #							
Wet Wt. & Tare							
Dry Wt. & Tare							
Loss							
Tare Wt.							
Dry Wt.							
% Moisture							

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MOISTURE TESTS

Job No. C92-5445

Date 10-6-93

Tested by ______________

Test Hole No.	1084	1084	1084	1084	1076	1076	1076
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & ~~Tare~~	270.6	276.6	275.5	272.6	272.2	275.7	276.2
Dry Wt. & ~~Tare~~	232.2	245.5	240.5	232.1	237.8	230.2	229.7
Loss	38.4	31.1	35.0	40.5	34.4	45.5	46.5
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	16.5	12.7	14.5	17.4	14.5	19.8	20.2

Test Hole No.	1076	1083	1083	1083	1083	1088	1088
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	8	9	10	11	12	13	14
Wet Wt. & ~~Tare~~	272.7	273.4	275.0	271.3	272.2	279.6	271.1
Dry Wt. & ~~Tare~~	224.9	228.8	238.9	220.3	200.9	240.1	231.0
Loss	47.8	44.6	36.1	51.0	71.3	39.5	40.1
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	21.2	19.5	15.1	23.1	35.5	16.4	17.4

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MOISTURE TESTS

Job No. C92-5440

Date 10-6-93

Tested by

Test Hole No.	1088	1088	1092	1092	1092	1092	1091
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'
Can #	15	16	17	18	19	20	21
Wet Wt. & [redacted]	272.9	272.1	272.6	273.4	275.0	279.6	271.4
Dry Wt. & [redacted]	221.5	212.8	241.2	240.3	228.8	228.5	238.9
Loss	51.4	59.3	31.4	33.1	46.2	51.1	32.5
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	23.2	27.9	13.0	13.8	20.2	22.4	13.6

Test Hole No.	1091	1091	1091	1090	1090	1090	1090
Depth	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'
Can #	22	23	24	25	26	27	28
Wet Wt. & [redacted]	272.6	273.1	278.4	271.0	274.8	270.7	273.4
Dry Wt. & [redacted]	243.9	225.4	228.6	242.4	247.5	229.5	219.3
Loss	28.7	47.7	49.8	28.6	27.3	41.2	54.1
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	11.8	21.2	21.8	11.8	11.0	17.9	24.7

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MOISTURE TESTS

Job No. C92-5440

Date 10/7/93

Tested by

Test Hole No.	1064	1064	1064	1064	1078	1078	1078
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & Tare	273.0	271.5	272.7	274.6	276.6	271.5	276.9
Dry Wt. & Tare	238.7	245.8	233.9	236.6	249.0	239.1	240.2
Loss	34.3	25.7	38.8	38.0	27.6	32.4	36.7
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	14.4	10.4	16.6	16.1	11.1	13.5	15.3

Test Hole No.	1078	1079	1079	1079	1079		
Depth	6'-9'	0'-2'	2'-4'	4'-6'	6'-8'		
Can #	8	9	10	11	12		
Wet Wt. & Tare	278.2	270.2	272.3	273.4	277.1		
Dry Wt. & Tare	235.5	252.7	245.1	225.2	249.4		
Loss	42.7	17.5	27.2	48.2	27.7		
Tare Wt.	NA	NA	NA	NA	NA		
Dry Wt.	NA	NA	NA	NA	NA		
% Moisture	18.1	6.9	11.1	21.4	11.1		

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MOISTURE TESTS

Job No. C92-5440

Date 10/11/93

Tested by

Test Hole No.	1047	1047	1047	1047	1065	1065	1065
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & ~~Tare~~	277.0	271.2	278.4	274.8	274.5	275.9	271.3
Dry Wt. & ~~Tare~~	257.5	253.5	236.2	236.6	244.4	250.2	232.0
Loss	19.5	17.7	42.2	38.2	30.1	25.7	38.9
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	7.6	7.0	17.9	16.1	12.3	10.3	16.7

Test Hole No.	1065	1048	1048	1048	1048	1071	1071
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	8	9	10	11	12	13	14
Wet Wt. & ~~Tare~~	275.4	273.1	278.3	271.2	275.0	275.1	238.7
Dry Wt. & ~~Tare~~	218.3	245.0	244.0	227.9	230.3	250.3	226.8
Loss	57.1	28.1	34.3	43.3	44.7	24.8	11.9
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	-26.1	11.5	14.0	19.0	19.4	9.9	5.2

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MOISTURE TESTS

Job No. [illegible]

Date 10-11-93

Tested by ______________

Test Hole No.	1071	1071	1089	1089	1089	1089	
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	
Can #	15	16	17	18	19	20	
Wet Wt. & ~~Tare~~	275.3	272.1	274.8	275.2	271.0	276.1	
Dry Wt. & ~~Tare~~	214.1	247.2	244.9	253.8	240.3	232.8	
Loss	61.2	24.9	29.9	21.4	30.7	43.3	
Tare Wt.	NA	NA	NA	NA	NA	NA	
Dry Wt.	NA	NA	NA	NA	NA	NA	
% Moisture	28.6	10.1	12.2	8.4	12.8	18.6	

Test Hole No.							
Depth							
Can #							
Wet Wt. & Tare							
Dry Wt. & Tare							
Loss							
Tare Wt.							
Dry Wt.							
% Moisture	–						

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MOISTURE TESTS

Job No. C92-540

Date 10-13-93

Tested by ______

Test Hole No.	1066	1066	1066	1066	1067	1067	1067
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	1	2	3	4	5	6	7
Wet Wt. & Tare	272.1	276.3	229.7	261.3	223.6	220.9	167.7
Dry Wt. & Tare	250.5	258.2	199.2	230.0	171.7	193.4	144.2
Loss	21.6	18.1	30.5	31.3	51.9	27.5	23.5
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	8.6	7.0	15.3	13.6	30.2	14.2	16.3

Test Hole No.	1067	1069	1068	1068	1068	1047	047
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4
Can #	8	9	10	11	12	13	14
Wet Wt. & Tare	275.0	229.9	268.0	272.0	276.2	276.0	276.5
Dry Wt. & Tare	246.0	198.3	217.8	219.5	217.2	251.7	241.7
Loss	29.0	31.6	50.2	52.5	59.0	24.3	34.8
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	10.9	15.9	23.0	24.8	27.2	9.6	14.4

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MOISTURE TESTS

Job No. C92-5410

Date 10-13-93

Tested by ______________

Test Hole No.	1044	1044	1043	1043	1043	1043	1038
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'
Can #	15	16	17	18	19	20	21
Wet Wt. & Tare	272.6	279.5	271.3	276.3	202.6	246.1	277.0
Dry Wt. & Tare	226.5	222.5	249.7	242.1	175.3	205.1	252.9
Loss	46.1	51.0	21.6	34.2	27.3	41.0	24.1
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	20.3	22.4	8.6	14.1	15.6	20.0	9.5

Test Hole No.	1038	1038	1038	1037	1037	1037	1037
Depth	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'
Can #	22	23	24	25	26	27	28
Wet Wt. & Tare	273.2	278.5	271.0	273.8	277.7	272.4	276.7
Dry Wt. & Tare	256.2	244.3	220.4	234.8	248.4	234.5	238.8
Loss	17.0	34.2	50.6	39.0	29.3	37.9	37.9
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	6.6	14.0	22.9	16.6	11.8	16.2	15.9

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MOISTURE TESTS

Job No. C92-5440

Date 10-13-93

Tested by

Test Hole No.	1041	1041	1041	1041	1042	1042	1042
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	29	30	31	32	33	34	35
Wet Wt. & Tare	271.0	270.3	273.5	274.8	276.7	275.6	275.0
Dry Wt. & Tare	234.2	234.0	238.2	241.6	246.3	243.3	224.4
Loss	36.3	36.3	35.3	33.2	30.4	32.3	50.6
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	15.5	15.5	14.8	13.7	12.3	13.3	22.5

Test Hole No.	1042	1045	1045	1045	1045	1054	1052
Depth	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	36	37	38	39	40	41	42
Wet Wt. & Tare	276.7	273.0	277.5	275.5	278.0	274.2	278.2
Dry Wt. & Tare	220.5	252.5	249.7	247.6	192.7	212.0	23[illegible]
Loss	56.2	20.5	27.8	27.9	85.3	57.2	41.0
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	25.5	8.1	11.1	11.3	44.3	26.3	17.7

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MOISTURE TESTS

Job No. C92-5440

Date 10-13-93

Tested by ____________

Test Hole No.	1054	1054	1040	1040	1040	1040	1039
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'
Can #	43	44	45	46	47	48	49
Wet Wt. & Tare	278.0	273.0	271.0	272.8	274.7	270.2	271.2
Dry Wt. & Tare	214.6	183.5	235.7	222.3	229.0	240.6	244.0
Loss	63.4	89.5	35.3	50.5	45.7	29.6	27.2
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	29.5	48.8	15.0	22.7	19.7	12.3	11.1

Test Hole No.	1039	1039	1039	1036	1036	1036	1036
Depth	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'
Can #	50	51	52	53	54	55	56
Wet Wt. & Tare	277.3	273.6	275.2	273.1	273.8	[illegible]	[illegible]
Dry Wt. & Tare	250.0	234.0	226.4	246.3	249.7	257.1	235.9
Loss	27.3	39.6	48.8	26.8	24.1	22.8	43.0
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	10.9	16.9	21.5	10.9	9.6	9.0	18.2

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MOISTURE TESTS

Job No. C97-5490

Date 10-13-93

Tested by ______

Test Hole No.	1035	1035	1035	1035	1034	1034	1034
Depth	0'-2'	2'-4'	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'
Can #	57	58	59	60	61	62	63
Wet Wt. & Tare	272.0	277.4	277.5	275.7	273.0	273.0	274.5
Dry Wt. & Tare	228.1	239.4	258.4	237.6	241.3	237.4	249.2
Loss	43.9	38.8	19.1	38.1	31.7	35.6	25.3
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	19.2	15.9	7.4	16.0	13.1	15.0	10.1

Test Hole No.	1034						
Depth	6'-8'						
Can #	64						
Wet Wt. & Tare	276.1						
Dry Wt. & Tare	[illegible]						
Loss	17.6						
Tare Wt.	NA						
Dry Wt.	NA						
% Moisture	6.8						

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MOISTURE TESTS

Job No. C92-5740

Date 10-22-93

Tested by ____________

	1003					1001	
Test Hole No.	N-316 E-244	N-316 E-242	N 316 E 2??	N-316 E 24?	N 316 E 242	N 322 E 248	N 322 E 249
Depth	2.4	0'-2'	2'4'	4'-6'	6'-8'	0'-2'	2'-4'
Can #	1	2	3	4	5	6	7
Wet Wt. & ~~Tare~~	273.0	273.5	273.8	227.0	268.4	237.9	266.7
Dry Wt. & Tare	245.6	250.6	252.9	204.2	243.4	206.0	231.0
Loss	27.4	22.9	20.9	22.8	25.0	31.9	35.7
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	11.2	9.1	8.3	11.2	10.3	15.5	15.5

			1021				
Test Hole No.	N 322 E 249	N 322 E 248	N 318 E 229	N 318 E 229	N-318 E-229	N-318 E-229	[illegible]
Depth	4'-6'	6'-8'	2.4	0'-2'	2'-4'	4'-6'	6'-8
Can #	8	9	10	11	12	13	14
Wet Wt. & ~~Tare~~	121.2	274.5	272.1	274.4	277.1	277.6	224.4
Dry Wt. & ~~Tare~~	152.4	241.8	246.5	242.4	260.0	237.9	202.8
Loss	18.8	32.7	25.6	32.0	12.1	39.7	21.6
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	12.3	13.5	16.4	13.2	6.6	16.7	10.6

2488

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MOISTURE TESTS

Job No. C92-5420

Date 10-22-93

Tested by ______________

1012 / 1011

Test Hole No.	N-325 E237	N 325 E 237	N 325 E 237	N-325 E-237	N-325 E-237	N-322 E-238	N-322 E-238
Depth	2.4	0'-2'	2'-4'	4'-6'	6'-8'	2.4	0'-2'
Can #	15	16	17	18	19	20	21
Wet Wt. & ~~Tare~~	276.0	277.2	275.2	277.9	271.8	276.3	277.2
Dry Wt. & ~~Tare~~	247.4	253.9	258.8	259.6	252.9	250.3	257.9
Loss	[illegible]	23.3	16.9	18.3	18.9	26.0	19.3
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	11.6	9.2	6.5	7.0	7.5	10.4	7.5

1017

Test Hole No.	N 322 E 238	N 322 E 238	N 322 E 238	N-321 E 226	N 321 E 226	N 321 E 226	N 321 E 226
Depth	2'-4'	4'-6'	6'-8'	2.4	0'-2'	2'-4'	[illegible]
Can #	22	23	24	25	26	27	28
Wet Wt. & ~~Tare~~	274.4	273.2	278.2	271.4	277.3	274.0	2281
Dry Wt. & ~~Tare~~	240.4	242.7	247.0	241.2	251.7	252.7	259.1
Loss	34.0	30.0	31.2	30.2	25.6	21.3	19.0
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	14.1	12.3	12.6	12.5	10.2	8.4	7.3

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MOISTURE TESTS

Job No. CS2-5440

Date 10-22-93

Tested by

1010 1020

Test Hole No.	N 321 E226	N 318 E 238	N 318 E 238	N 318 E 239	N 318 E 238	N-318 E 238	N 325 E 223
Depth	6'-8'	2.4	0'-2'	2'-4'	4'-6'	6'-8'	2.4
Can #	29	30	31	32	33	34	35
Wet Wt. & ~~Tare~~	271.2	272.6	275.4	279.1	271.4	273.9	226.2
Dry Wt. & ~~Tare~~	237.1	243.9	244.7	240.7	248.4	242.2	226.2
Loss	34.1	28.7	30.7	38.4	23.0	31.7	30.0
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	14.4	11.8	12.5	15.9	9.2	13.1	12.2

1023

Test Hole No.	N 325 E 223	N 325 E 223	N 325 E 223	N 325 E 223	N-322 E 229	N 322 E 229	N 322 E 229
Depth	0'-2'	2'-4'	4'-6'	6'-8'	2.4	0'-2'	2'-4'
Can #	36	37	38	39	40	41	42
Wet Wt. & ~~Tare~~	274.4	271.7	275.6	273.7	275.0	277.2	275.2
Dry Wt. & ~~Tare~~	250.7	247.0	229.7	213.4	247.5	254.0	262.0
Loss	23.7	24.7	45.9	60.3	27.5	23.2	13.2
Tare Wt.	NA	NA	NA	NA	NA	NA	NA
Dry Wt.	NA	NA	NA	NA	NA	NA	NA
% Moisture	9.4	10.0	20.0	28.2	11.1	9.1	5.0

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MOISTURE TESTS

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Date 10-22-93

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Test Hole No.	N 322 E 229	N 322 E 229	1059	1059	1059	1059	
Depth	4'-6'	6'-8'	0'-2'	2'-4'	4'-6'	6'-8'	
Can #	43	44	45	46	47	48	
Wet Wt. & ~~Tare~~	277.3	276.6	277.5	275.1	278.7	279.6	
Dry Wt. & ~~Tare~~	246.6	248.2	226.2	238.6	241.4	212.9	
Loss	30.7	28.4	51.3	36.5	37.3	66.7	
Tare Wt.	NA	NA	NA	NA	NA	NA	
Dry Wt.	NA	NA	NA	NA	NA	NA	
% Moisture	12.4	11.4	22.7	15.3	15.4	31.3	

Test Hole No.							
Depth							
Can #							
Wet Wt. & Tare							
Dry Wt. & Tare							
Loss							
Tare Wt.							
Dry Wt.							
% Moisture	–						

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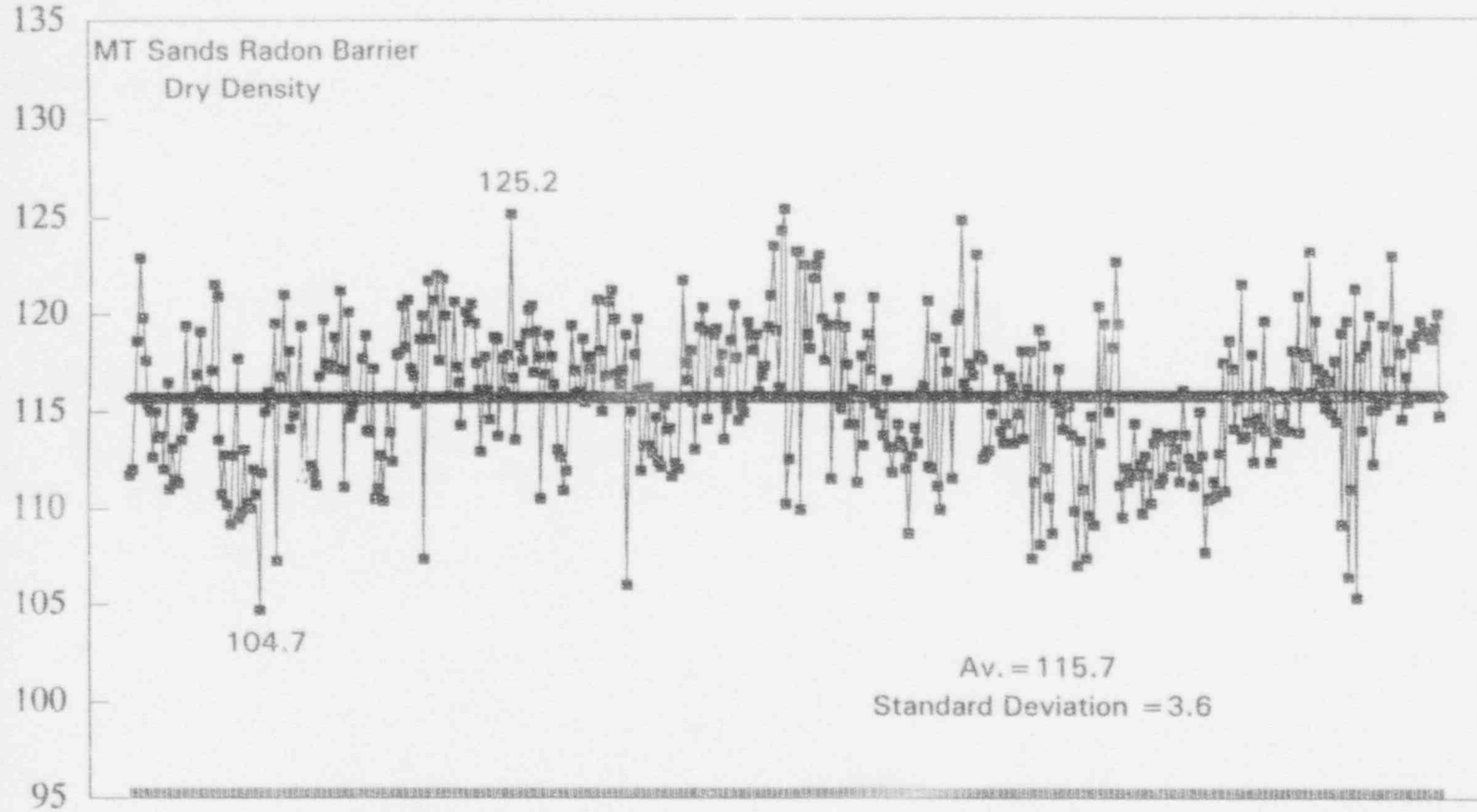
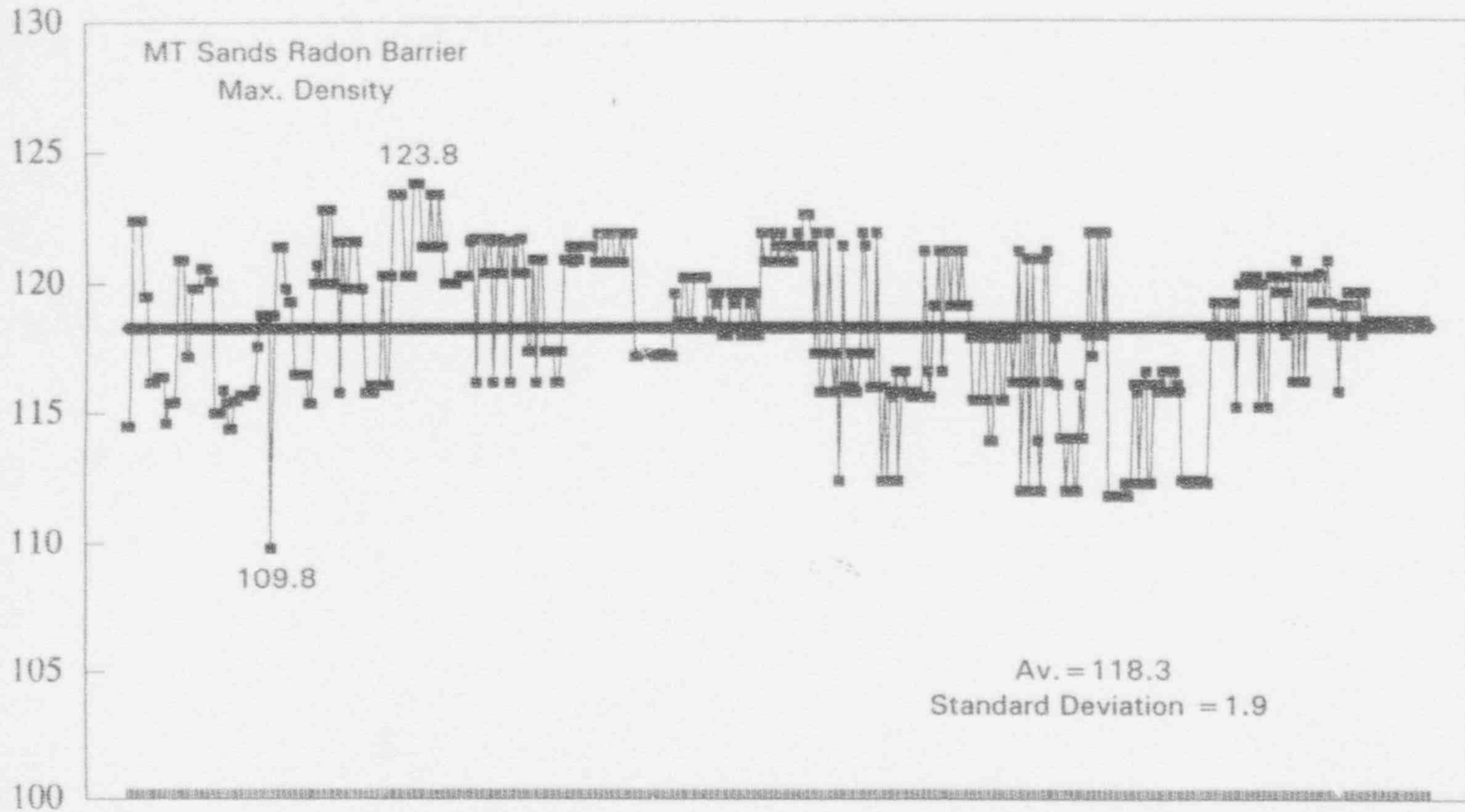
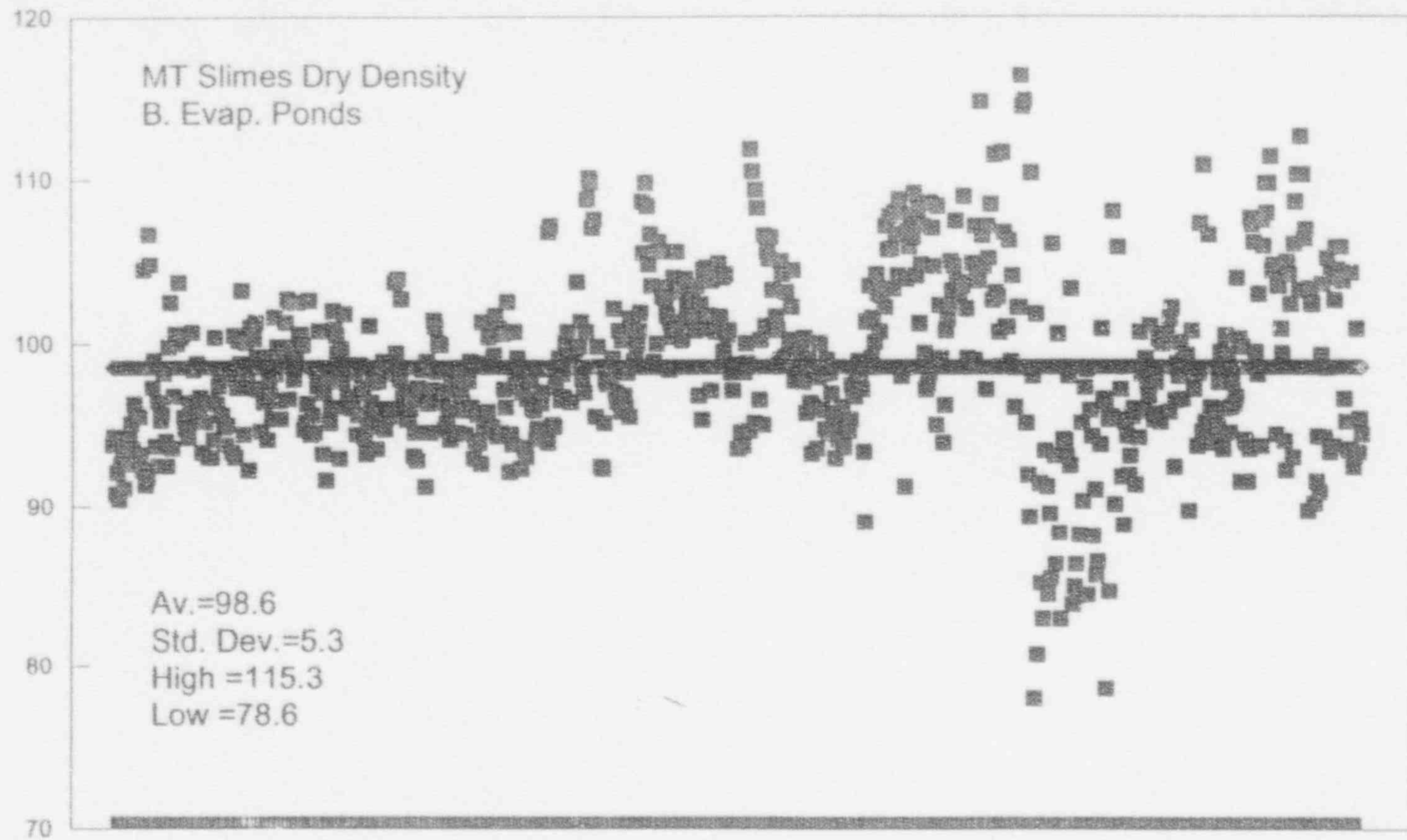
APPENDIX I

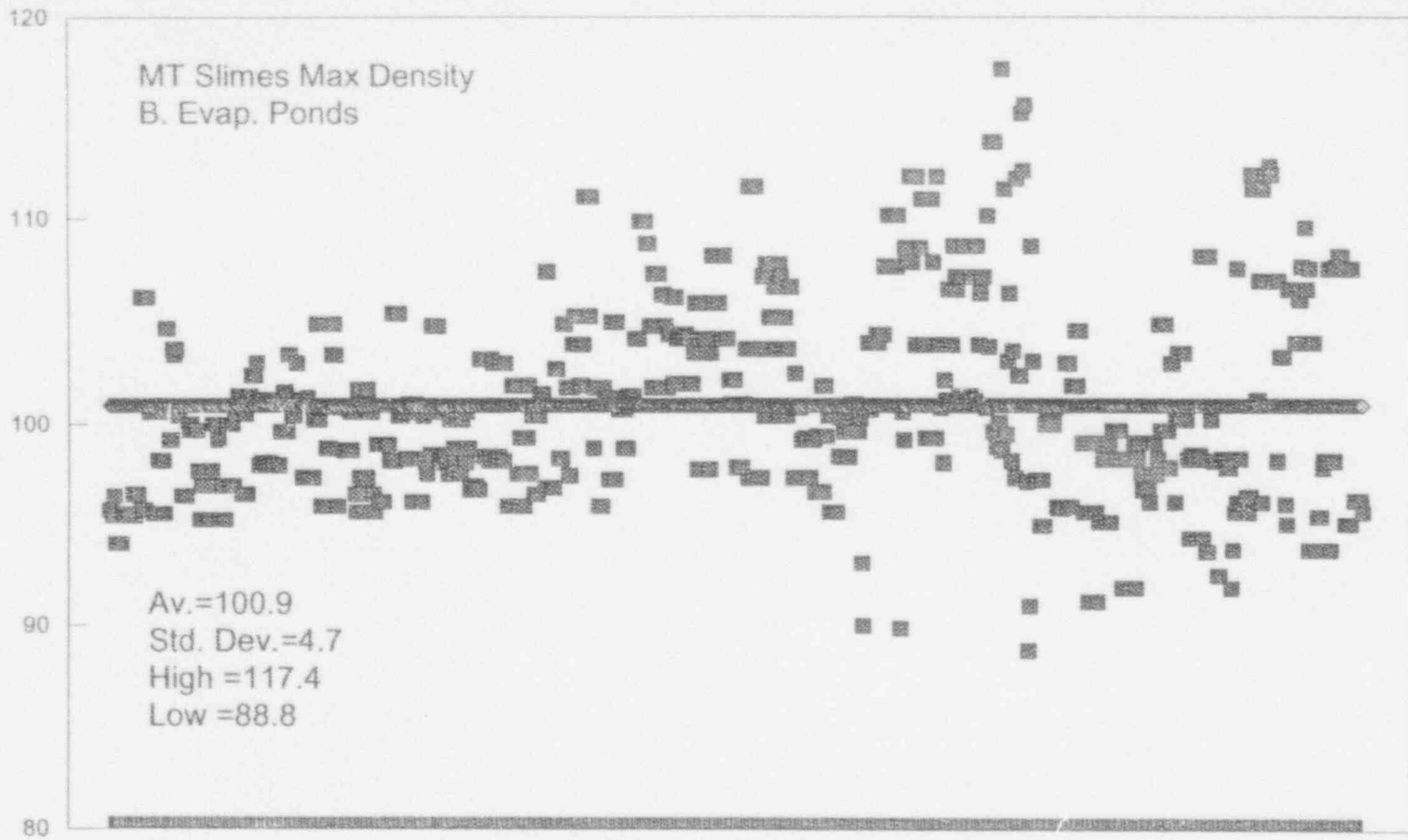
Main Tailings Pile Material Densities

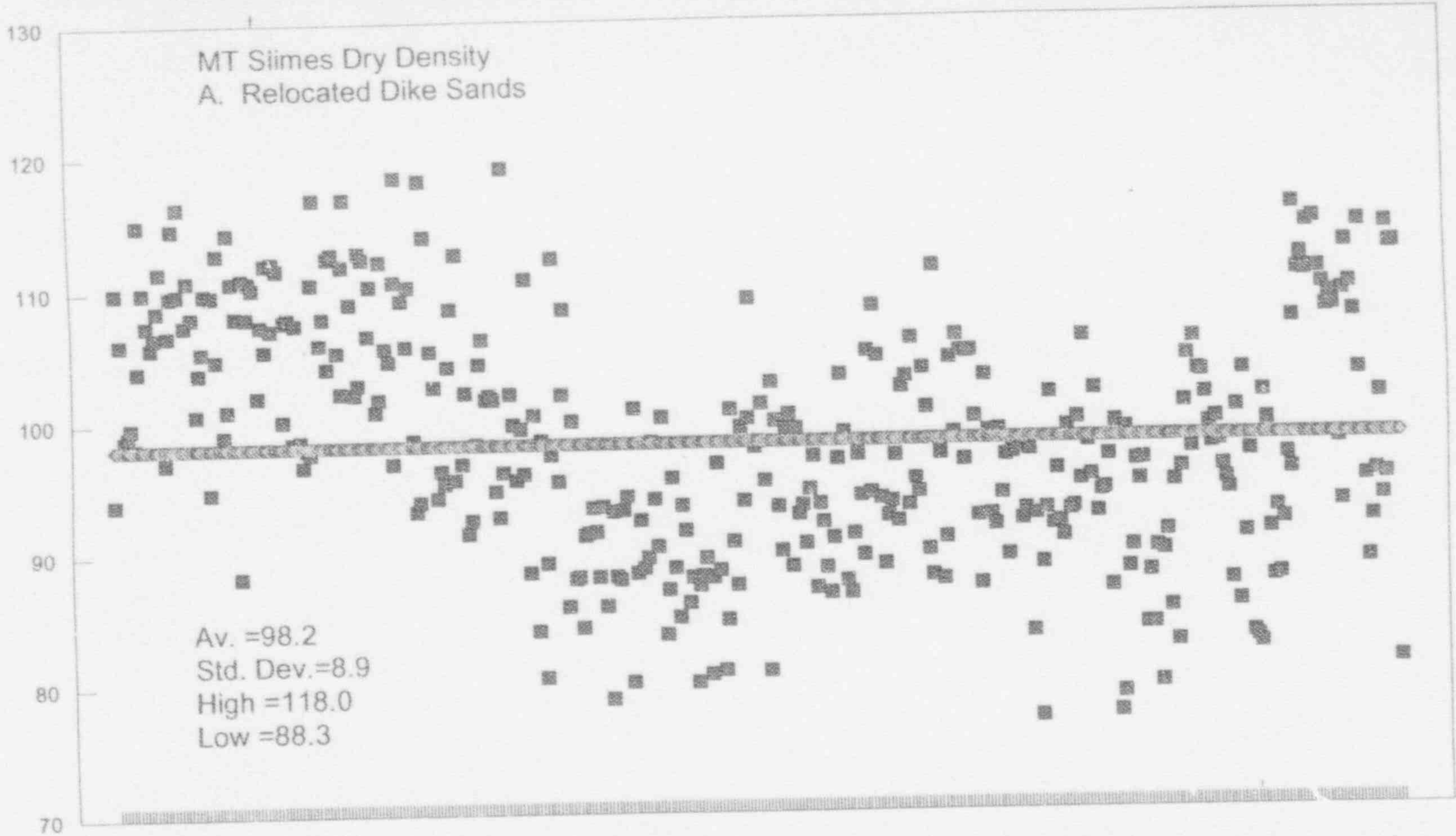

MT Sands Radon Barrier
Dry Density
125.2
104.7
Av. = 115.7
Standard Deviation = 3.6
135
130
125
120
115
110
105
100
95

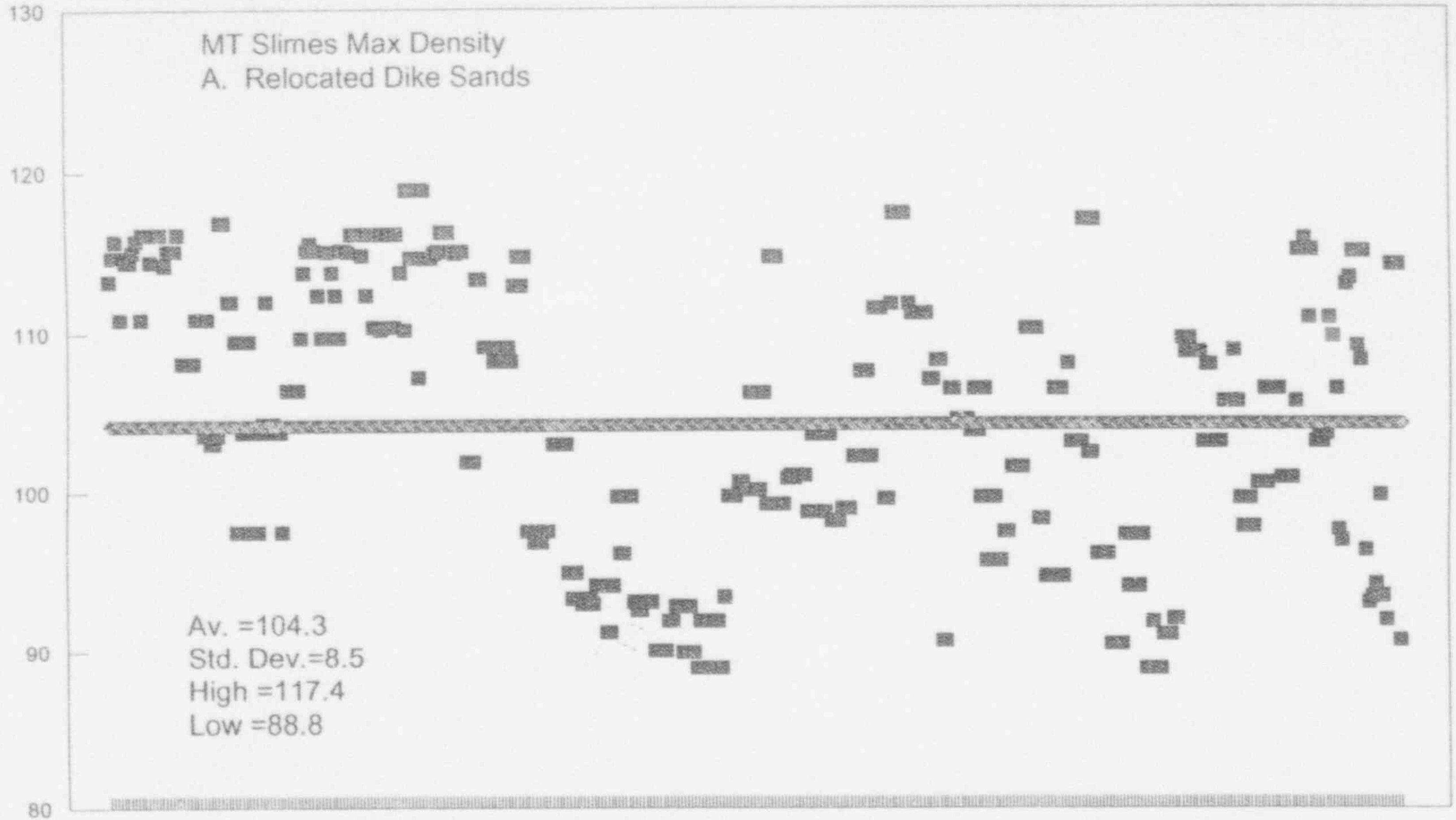


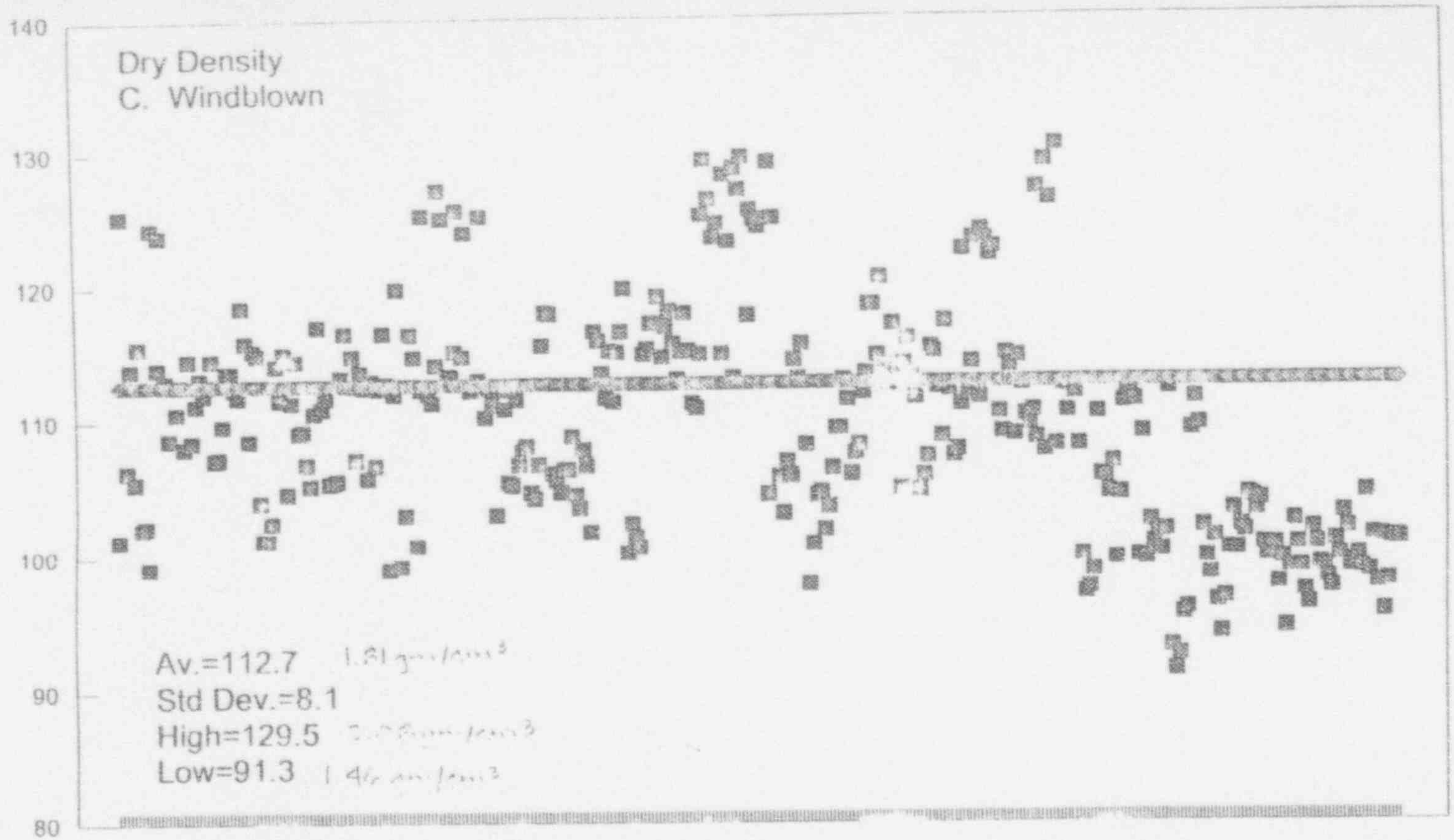
MT Sands Radon Barrier
Max. Density
130
125
120
115
110
105
100
123.8
109.8
Av. = 118.3
Standard Deviation = 1.9


MT Slimes Dry Density
B. Evap. Ponds
Av.=98.6
Std. Dev.=5.3
High =115.3
Low =78.6
120
110
100
90
80
70

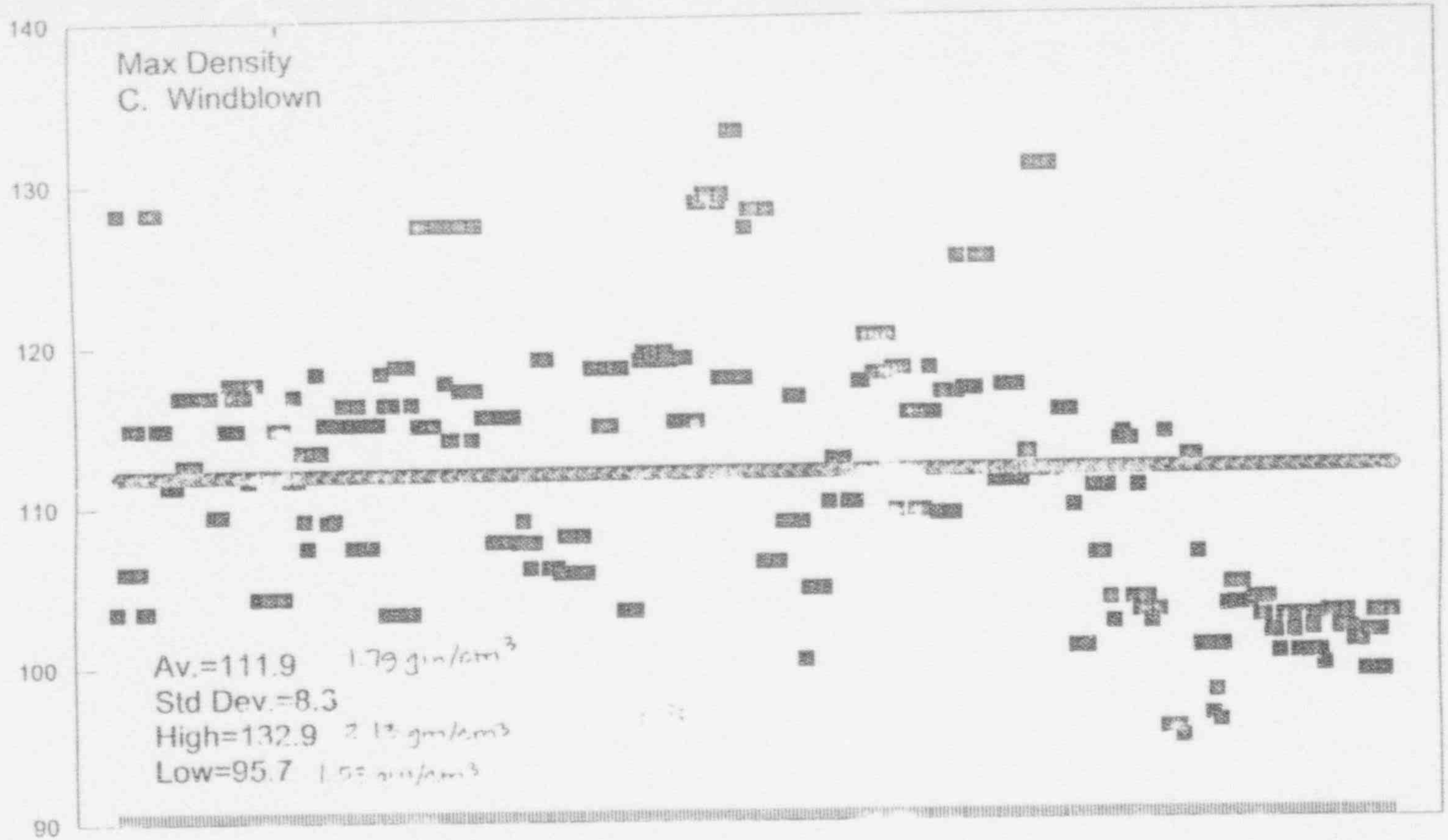

120
110
100
90
80
MT Slimes Max Density
B. Evap. Ponds
Av.=100.9
Std. Dev.=4.7
High =117.4
Low =88.8


MT Slimes Dry Density
A. Relocated Dike Sands
Av. =98.2
Std. Dev.=8.9
High =118.0
Low =88.3
130
120
110
100
90
80
70


MT Slimes Max Density
A. Relocated Dike Sands
Av. =104.3
Std. Dev.=8.5
High =117.4
Low =88.8
130
120
110
100
90
80



140
130
120
110
100
90
80
Dry Density
C. Windblown
Av.=112.7
Std Dev.=8.1
High=129.5
Low=91.3



140
130
120
110
100
90
Max Density
C. Windblown
Av.=111.9
Std Dev.=8.3
High=132.9
Low=95.7

APPENDIX J

Main Tailings Pile Core Logs

Memorandum

To: Christopher Sanchez, ARCO Project Engineer
From: Joel S. Martineau, Anderson Engineering Co, ~~Inc~~ DA

Date: 03 November, 1993
Subject: Fill Thicknesses/ Elevations on Main Tailings from Core Logs

I have completed the interpretation of corehole logs 1034 through 1055 and have calculated elevations and thicknesses where possible. The materials logged during the core drilling process have been generalized into 4 categories: windblown, slimes, dike, and tailings. It should be noted that the dike materials include some tailings, and that materials classified as slimes are generally diluted with soil materials and are sometimes difficult to distinguish from other soil materials. In difficult cases I relied on memory of what I observed during the placement of slime on the Main Tailings.

Memorandum

To: Christopher Sanchez, ARCO Project Engineer
From: Joel S. Martineau, Anderson Engineering Co, Inc.

Date: 04 November, 1993
Subject: Fill Thicknesses/ Elevations on Main Tailings from Core Logs 1056 to 1093

I have completed the extraction of elevations and thicknesses of fill units on the Main Tailngs surface. The fill units have been generalized into 4 categories: windblown, slimes, dike fill, and in-place tailings.

TABULATION OF MAIN TAILINGS SAND DRILLHOLE DATA
by J. Martineau, Anderson Engineering Co., Inc.

Abbreviations: Tailings Sand (t.s.) Sandy-clay (sc) Clay (cl) Well-graded gravel (gw)

Location Number	Top Elev.	Fill Thickness	Fill Visual Characterization	Tailings Sand Top Elevation	Sample Interval Characterization @ stated depth 0-2 ft.	2-4 ft.	4-6 ft.	6-8 ft.
1001	6642.2	>8 ft.	Raffinate line matl &misc	unknown	raff line sc-cl	raff line sc-cl	raff line sc-cl + gravel	raff line sc-cl + gravel
1002	6655.6	3.7	Reddish-brown soil	6651.9	sc-cl	sc-cl	1.0 sc-cl. 1.0 t.s.	tailings sand
1003	6666.1	0.0	No fill	6666.1	sc-cl	tailings sand	tailings sand	tailings sand
1004	6660.2	2.2	Stockpile area materials	6658.0	sc	sc-cl	1.0 t.s. 0.5 sc-sl 0.5 t.s.	tailings sand
1005	6642.4	6.5	Raffinate line materials & misc	6635.9	sc raff line	sc-cl + gravel raff line	cl + gravel raff line	0.5 t.s. 0.5 sc 1.0 t.s.
1006	6644.6	3.5	Raffinate line materials & misc	6641.1	sc-cl	sc-cl	1.0 sc-cl 1.0 t.s.	tailings sand
1007	6652.0	0.0	No fill	6652.0	0.7 sc 1.3 t.s.	tailings sand	tailings sand	tailings sand
1008	6663.4	0.9	Relocated tailings sands, soil	6662.5	0.7 sc-cl 1.3 t.s.	tailings sand	tailings sand	tailings sand
1009	6675.9	2.1	Relocated tailings sands, soil	6673.8	0.5 sc-cl 0.6 t.s. 0.9 sc-cl	1.3 sc 0.7 t.s.	tailings sand	tailings sand
1010	6670.4	1.0	Relocated tailings sand	6669.4	1.0 t.s. 0.4 cl 0.6 t.s.	tailings sand	tailings sand	tailings sand
1011	6658.5	1.8	Relocated tailings sands, soil	6656.7	1.6 t.s. 0.4 sc	tailings sand	tailings sand	tailings sand
1012	6651.0	1.0	Relocated tailings sand	6650.0	tailings sand	tailings sand	tailings sand	tailings sand
1013	6636.5	3.6	Relocated tailings sands, soil	6632.7	1.3 sc-cl 0.5 t.s. 0.2 cl	0.7 sc-cl 0.4 t.s. 0.4 sc 0.5	tailings sand	tailings sand
1014	6638.5	0.0	No fill	6638.5	1.6 sc 0.4 t.s.	tailings sand	tailings sand	tailings sand
1015	6653.5	2.0	Relocated tailings sands, soil	6651.5	0.7 sc 1.3 t.s.	tailings sand	tailings sand	tailings sand
1016	6658.8	0.0	No fill	6658.8	tailings sand	tailings sand	tailings sand	tailings sand
1017	6665.2	0.0	No fill	6665.2	1.0 sc-cl 1.0 t.s.	tailings sand	tailings sand	tailings sand
1018	6676.4	2.0	Soil Fill	6674.4	sc	1.5 sc 0.5 t.s.	tailings sand	tailings sand
1019	6680.4	3.7	Relocated tailings sands, soil	6676.7	0.3 sc-cl 1.7 t.s.	0.5 t.s. 0.3 cl 0.8 t.s. 0.2 cl	0.7 cl 1.3 t.s.	tailings sand
1020	6680.5	3.4	Relocated tailings sands, soil	6677.1	mixed layers sc, t.s.	0.6 sc 1.0 t.s. 0.4 sc	0.4 sc 1.6 t.s.	tailings sand
1021	6673.4	2.5	Relocated soils, minor tails	6670.9	sc-cl minor t.s.	sc-cl	tailings sand	tailings sand
1022	6669.8	2.0	Relocated soils, minor tails	6667.8	1.0 sc 1.0 t.s.	1.0 sc 1.0 t.s.	tailings sand	tailings sand
1023	6661.6	1.2	Relocated soils, tailings sand	6660.4	1.2 sc 0.3 t.s. 0.5 sc-cl	1.7 t.s. 0.3 sc-cl	tailings sand	tailings sand
1024	6652.7	0.5	Soil fill	6652.2	0.5 cl 1.5 t.s.	tailings sand	tailings sand	tailings sand
1025	6635.7	1.0	Soil fill	6634.7	0.9 sc 1.1 t.s.	tailings sand	tailings sand	tailings sand
1026	6644.6	0.7	Soil fill	6643.9	1.3 sc 0.7 t.s.	tailings sand	tailings sand	tailings sand
1027	6658.1	1.2	Tailings fill	6656.9	1.1 t.s. 0.9 sc	0.6 sc 1.4 t.s.	tailings sand	tailings sand
1028	6670.3	2.0	Relocated soils, tailings sand	6668.3	0.8 sc 1.2 t.s.	1.2 sc 0.8 t.s.	tailings sand	tailings sand
1029	6647.4	1.9	Relocated tailings sands, soil	6645.5	0.5 sc 1.5 t.s.	0.4 sc 1.6 t.s.	tailings sand	tailings sand
1030	6640.9	1.2	Relocated tailings sands, soil	6639.7	1.3 t.s. 0.7 sc-cl	tailings sand	tailings sand	tailings sand
1031	6643.7	4.0	Soil/Basalt mixture, windblown	6639.7	1.4 sc 0.6 sc-gw	sandy-clay + basalt gravel	tailings sand	tailings sand
1032	6638.6	0.6	Relocated tailings sands, soil	6638.0	1.7 sc 0.3 t.s.	tailings sand	tailings sand	tailings sand
1033	6634.1	3.5	Relocated tailings sands, soil	6630.6	mixed layers sc-cl + t.s.	sc-cl + gw layers	1.0 sc-cl 1.0 t.s.	tailings sand

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CALCULATION SHEET

JOB Bluewater Mill SHEET NO. 1 CALC JSM

CK'D BY ______ DATE 11-03-93 TITLE Main Tails Fill Thickness/Elevation

LOCATION NO.	SURFACE ELEVATION	WINDBLOWN FILL THICKNESS	TOP OF EVAP SLIMES	SLIMES THICKNESS	TOP OF DIKE FILL	DIKE FILL THICKNESS	TOP OF IN-PLACE TAILS
1034	6626.9	5.0	N/A	N/A	N/A	N/A	6621.9
1035	6627.1	6.3	N/A	N/A	N/A	N/A	6620.8
1036	6627.7	6.0	6621.7	UNK. (>2')	—	—	UNK.
1037	6623.1	UNK. >8'	—	—	—	—	UNK.
1038	6627.5	5.3	6622.2	UNK (>2.7)	—	—	UNK.
1039	6626.5	6.3	6620.2	UNK (>1.7)	—	—	UNK.
1040	6625.1	2.4	6622.7	UNK (>5.6)	—	—	UNK.
1041	6627.0	6.0	N/A	N/A	N/A	N/A	6621.0
1042	6627.2	3.8	N/A	N/A	N/A	N/A	6623.4
1043	6625.6	2.7	6622.9	4.5	N/A	N/A	6618.4
1044	6623.9	4.3	6619.6	UNK(>3.7)	—	—	UNK
1045	6626.3	3.6	N/A	N/A	N/A	N/A	6622.7
1046	6625.2	2.2	6623.0	2.3	6620.7	1.0	6619.7
1047	6624.3	5.0	6619.3	1.0	6613.3	1.0	6617.1
1048	6625.0	3.5	6621.5	UNK (>4.5)	—	—	UNK
1049	6626.3	4.0	6622.3	UNK (>4.0)	—	—	UNK
1050	6627.3	2.8	6624.5	4.4	6620.1	UNK	UNK
1051	6625.4	5.0	6620.4	UNK (>3.0)	—	—	UNK
1052	6626.3	4.0	6622.3	UNK (>4.0)	—	—	UNK
1053	6628.1	2.5	6625.6	UNK (>5.5)	—	—	UNK
1054	6626.3	N/A	N/A	N/A	—	—	6626.3
1055	6626.1	N/A	N/A	N/A	—	—	6626.1

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CALCULATION SHEET

NA = Not Applicable
UNK = Unknown

JOB Bluewater Mill SHEET NO. 1 of 2 CALC TSU

CK'D BY ______ DATE 11-04-93 TITLE Main Tailings Fill Thickness/Elev...

Location	Surface Elevation	Windblown Fill Thickness	Top of Evap Slimes	Slime Fill Thickness	Top of Dike Fill	Dike Fill Thickness	Top of In-Place Tails
1056	6623.7	N/A	N/A	N/A	N/A	N/A	6623.7
1057	6623.7	N/A	N/A	N/A	N/A	N/A	6623.7
1058	6631.0	N/A	N/A	N/A	N/A	N/A	6631.0
1059	6623.0	N/A	N/A	N/A	N/A	N/A	6623.0
1060	6630.3	N/A	N/A	N/A	N/A	N/A	6630.3
1061	6630.2	N/A	N/A	N/A	N/A	N/A	6630.2
1062	6625.4	N/A	N/A	N/A	N/A	N/A	6625.4
1063	6623.0	N/A	N/A	N/A	N/A	N/A	6623.0
1064	6624.1	5.0	6619.1	> 3.0'	UNK	UNK	UNK
1065	6623.0	3.5	6619.5	> 4.5	UNK	UNK	UNK
1066	6622.6	4.2	6615.4	> 3.8'	UNK	UNK	UNK
1067	6622.1	5.0 ±[illegible]	6617 ±2'	> 3.0	UNK	UNK	UNK
1068	6621.9	[illegible]	6619.2	> [illegible]	UNK	UNK	UNK
1069	6621.5	3.3	6617.7	> 4.2'	UNK	UNK	UNK
1070	6621.4	2.0 ± 1'	6619.4	> 6'	UNK	UNK	UNK
1071	6623.6	3.0	6620.6	3.4'	6614.2	UNK	UNK
1072	6621.0	4.0	6617.6	> 4'	UNK	UNK	UNK
1073	6620.5	4.0	6616.5	> 3.3	UNK	UNK	UNK
1074	6620.0	2.2	6613.0	> 5.5	UNK	UNK	UNK
1075	6620.2	4.0	6616.2	> 4.0	UNK	UNK	UNK
1076	6620.9	4.0	6616.9	> 4.0	UNK	UNK	UNK
1077	6621.4	4.0 ± 2	6617.4	> 4.0	UNK	UNK	UNK
1078	6623.2	4.0	6619.2	> 4.0	UNK	UNK	UNK
1079	6624.3	2.5	6621.3	> 5.5	UNK	UNK	UNK
1080	6623.2	5.0	6618.2	> 3.0	UNK	UNK	UNK
1081	6622.2	4.0	6618.2	> 4.0	UNK	UNK	UNK
1082	6620.5	4.0	6616.5	> 4.0	UNK	UNK	UNK
1083	6620.3	5.0	6615.3	> 3.0	UNK	UNK	UNK
1084	6619.9	> 3.0	UNK	UNK	UNK	UNK	UNK
1085	6620.0	4.0	6616.0	> 4.0	UNK	UNK	UNK
1086	6619.6	4.0	6615.6	> 4.0	UNK	UNK	UNK
1087	6618.5	3.5	6615.0	> 4.5	UNK	UNK	UNK
1088	6619.7	4.0	6615.7	> 4.0	UNK	UNK	UNK
1089	66[illegible].4	5.0	6614.4	> 3.0	UNK	UNK	UNK

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CALCULATION SHEET

JOB ______ SHEET NO. 2 OF 2 CALC JSM

CK'D BY ______ DATE 11-04-93 TITLE Main Tails Fill Thickness/Elevation

LOCATION	SURFACE ELEVATION	WINDBLOWN FILL THICKNESS	TOP OF EVAP SLIMES	SLIMES FILL THICKNESS	TOP OF DIKE FILL	DIKE FILL THICKNESS	TOP OF IN-DIKE TAILINGS
1090	6620.9	5.0	6615.9	>3.0	UNK	UNK	UNK
1091	66[illegible].7	4.5	6614.2	>3.5	UNK	UNK	UNK
1092	6615.3	4.0	6614.3	>4.0	UNK	UNK	UNK
1093	6618.6	5.7	6612.9	>2.3	UNK	UNK	UNK

APPENDIX K

Evaluation of the Radon Barrier Thickness for the Main Tailings Pile at the Bluewater Mill Site

RAE-9300/17-1

EVALUATION OF THE RADON BARRIER THICKNESS FOR THE MAIN TAILINGS PILE AT THE BLUEWATER MILL SITE

By

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K.K. Nielson

Prepared for

Atlantic Richfield Company

November 1993

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1. INTRODUCTION

Initial estimates were made in 1990 of the required radon barrier thickness for the main tailings pile at the Bluewater Uranium Mill Site (ARCO90). The proposed embankment configuration included placing approximately 1,624,000 yd^3 of soils consolidated from windblown contamination areas, evaporation pond residues, and tailings sands contained in the embankment berms on the slimes tailings area. The radon barrier design assumed that these materials were placed on the various areas of the pile at prescribed thicknesses and compactions, and that the Ra-226 concentrations and other parameters necessary to model the radon flux were either measured or assigned a reasonable value.

During reclamation of the site, volumes of materials, as well as assumed Ra-226 concentrations, were found to be quite different than those assumed in the original design. This led to a detailed measurement program on the tailings pile in its existing configuration and to a re-determination of the calculated earthen cover thickness required to reduce the surface radon flux to the 20 pCi m^{-2} s^{-1} standard specified by the U.S. Nuclear Regulatory Commission (NRC) in 10 CFR 40, Appendix A. As with the initial cover thickness calculations, the new calculations were made using the NRC computer code RAECOM (NRC84). The data used in the RAECOM calculations were mainly obtained from ARCO93, which also contains the measured radon fluxes. Other necessary data not explicitly given in ARCO93 were obtained from ARCO90. Variations in the long-term moisture contents were not investigated.

2. MEASUREMENTS OF THE COVER RADON DIFFUSION COEFFICIENT

Presently, the moisture content of the cover over the sand tailings is higher than the long-term predicted value. Furthermore, the cover has been placed at a higher compaction than the initial design specifications require. Since some of the calculations require parameter values for present conditions, the diffusion coefficient (D) of the cover material was measured for present moisture and compaction conditions. Table 1 contains the new measurements of D for the cover material, including a new measurement at the long-term moisture content at the present compaction.

Table 1. Measured diffusion coefficients for cover material.

Moisture (dry wt, %)	D (cm^2 s^{-1})	Density (g cm^{-3})	Saturation (%)
9.5[a]	0.0086	1.83	54
11.2	0.0021	1.84	65
14.0	0.00021	1.84	81
15.6	0.00028	1.84	90

a. Estimated long-term moisture content from ARCO90.

3. SITE CALIBRATION OF THE RAECOM MODEL

The applicability of the RAECOM code to the site was examined by comparing the measured average radon flux for the bare sands portion of the pile with the flux calculated using measured or best-estimate values for the input parameters. The data used for this calibration came from the 20 test locations for which both bare and covered fluxes were measured (ARCO93). The measured average flux fr r the bare sands was 29.4 pCi m^{-2} s^{-1}, and the calculated flux was 49.6 pCi m^{-2} s^{-1}. The calculation overestimates the measured flux by 69 percent. The calculations used a tailings D ranging from 0.011 to 0.17 cm^2 s^{-1} based on the tailings D from ARCO90 and the present measured dry-weight moistures. The default D correlation, given in the RAECOM code (NRC84) was used to obtain the Ds in ARCO90 to the present densities and moistures. In order to match the measured radon flux, the tailings' Ds were multiplied by 0.468. The RAECOM analysis for these calculations is given on pages A-2 and A-3 of the appendix.

New site data were obtained from the top 244 cm of the pile. The impact on surface radon flux from radon generated beneath this depth is minimal. A conservative estimate of this impact was made by calculating the surface radon flux from only the top 244 cm of material. The resulting flux of 46.6 pCi cm^{-2} s^{-1} is within 6 percent of the 49.6 pCi m^{-2} s^{-1} flux calculated for pile depths similar to those in ARCO90 The RAECOM output for this analysis is given on page A-4 of the appendix. For conservatism, all RAECOM analyses were performed for depths similar to those in ARCO90, even though the impact from the materials deeper than 244 cm was negligible.

The radon flux from the covered sands measured 1.6 pCi m^{-2} s^{-1}. The corresponding calculated flux using the calibrated tailings diffusion coefficients with the measured moisture contents was 2.0 pCi m^{-2} s^{-1}, which exceeds the measured flux by only 25 percent. Thus, the RAECOM code can be calibrated to the site by using the lower tailing D. The RAECOM output for this calculation is given on page A-5.

4. SANDS TAILINGS AREA

The sands tailings area is covered with an average of 51 cm of earthen cover material, compacted to an average density of 1.85 g cm^{-3}. The measured flux for the cover averaged 1.3 pCi m^{-2} s^{-1}, and the calculated flux, assuming a cover thickness of 51 cm, was 2.3 pCi m^{-2} s^{-1}. Using long-term moisture contents of 8 percent for the sands and 9.5 percent for the cover gives a calculated cover thickness of 39 cm to achieve a long-term flux of 20 pCi m^{-2} s^{-1}. Again, the default D correlation in RAECOM was used to obtain the tailings D for the long-term moisture from the measured Ds given in ARCO90. The cover D of 0.0075 cm^2 s^{-1} used in the calculations was obtained by interpolating the measured cover Ds given in Table 1 using the default D correlation in RAECOM. These calculations show that the present cover is more than sufficient to meet the requirement for long-term radon control. The RAECOM calculations for these three cases are given on pages A-6 and A-7 in the appendix.

5. SLIMES TAILINGS AREA

The slimes area of the main mill tailings pile has off-pile materials placed on them, but no earthen covers, yet; therefore, all measured fluxes are for the bare piles. Table 2 presents the results of the measured and calculated fluxes. The measured bare flux for the slimes tailings was 11.2 pCi m^{-2} s^{-1}, and the calculated flux, using measured Ds and moistures, was 14.6 pCi m^{-2} s^{-1}. The calculated flux equaled the measured bare flux when the Ds were multiplied by 0.786. The calculation for predicting the required cover for long-term protection used a moisture content of 30 percent for the slime tailings and 9.5 percent for the windblown, sand berm, and evaporation pond materials placed over the slime tailings. Since the calculated long-term flux from the uncovered materials in the slime tailings area is 10 pCi m^{-2} s^{-1}, no additional radon barrier cover is needed. The RAECOM calculations for these cases are given on pages A-8 through A-10 in the appendix.

Table 2. Slimes and mixed tailings area fluxes.

Area	Measured Bare Flux (pCi m^{-2} s^{-1})	Calculated Bare Flux (pCi m^{-2} s^{-4})	Percent Reduction in Source D for Calibration	Required Long-Term Cover Thickness[a] (cm)
Slimes	11.2	14.6	21	0
Mixed	14.4	26.0	63	27

a. To achieve a surface radon flux less than 20 pCi m^{-2} s^{-1}.

6. MIXED TAILINGS AREA

The mixed tailings area has a measured bare surface flux of 14.4 pCi m^{-2} s^{-1}, compared to a calculated flux of 26.0 pCi m^{-2} s^{-1} using measured Ds and moistures. Lowering the source Ds by 63 percent resulted in agreement between the calculated and measured fluxes. Using long-term moistures of 15 percent for the mixed tailings and 9.5 percent for the windblown, evaporation pond materials and radon barrier cover gives a required cover thickness of 27 cm in order to meet the 20 pCi m^{-2} s^{-1} criterion. The RAECOM output for these cases is given on pages A-11 through A-13 of the appendix.

7. CONCLUSION

New measurements have been made on the main tailings pile at the Bluewater Uranium Mill. The calculated estimate of the required cover thickness for radon control has been improved by using the new specific site data for the source term in the RAECOM calculations. Present moisture conditions and surface radon flux measurements allow for estimating the conservatism in the RAECOM calculations for this site, and yield specific calibration factors for the sands, the slimes, and the mixed tailings areas of the pile. The corresponding calculations for the projected long-term site conditions give required cover thicknesses of 39 cm, 0 cm, and 27 cm for the sands, slimes and mixed pile areas, respectively.

REFERENCES

ARCO90 "Radon Barrier Thickness for the Main Tailings Pile at the Bluewater Mill Site," Atlantic Richfield Company, February 15, 1990.

ARCO93 "Evaluation of the Radon Barrier Design: ARCO Bluewater Mill Main Tailings Pile," Atlantic Richfield Company, November 1993.

NRC84 "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design," U.S. Nuclear Regulatory Commission report, NUREG/CR-3533, April 1984.

APPENDIX

RAECOM OUTPUT

Bluewater, bare sands, present (20)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 11:46

NUMBER OF LAYERS :	10	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	197.3	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	305.	1.0700E-02	.4037	409.00	1.610	.2000	13.220
2	305.	1.0700E-02	.4037	137.00	1.610	.2000	13.220
3	122.	1.0700E-02	.4037	210.00	1.610	.2000	13.220
4	122.	1.0700E-02	.4037	186.00	1.610	.2000	13.220
5	61.	1.0700E-02	.4037	252.00	1.610	.2000	13.220
6	61.	1.0700E-02	.4037	203.00	1.610	.2000	13.220
7	61.	1.0700E-02	.4037	132.00	1.610	.2000	13.220
8	61.	1.2400E-02	.4037	117.00	1.610	.2000	12.450
9	61.	1.6200E-02	.4037	78.60	1.610	.2000	10.890
10	61.	1.6800E-02	.4037	55.80	1.610	.2000	10.640

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	305.	65.40	2.1812E+05	.6099	3.5766E+05
2	305.	-15.87	1.3852E+05	.6099	2.2714E+05
3	122.	1.585	1.5489E+05	.6099	2.5398E+05
4	122.	-6.039	1.5999E+05	.6099	2.6235E+05
5	61.	15.50	1.5369E+05	.6099	2.5201E+05
6	61.	26.31	1.2585E+05	.6099	2.0635E+05
7	61.	24.54	9.1982E+04	.6099	1.5083E+05
8	61.	31.49	6.2949E+04	.6326	9.9512E+04
9	61.	36.69	3.6949E+04	.6786	5.4448E+04
10	61.	49.56	.0000	.6860	.0000

Bluewater, bare sands, present (22)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 11:57

NUMBER OF LAYERS :	10	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	135.1	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	305.	5.0100E-03	.4037	409.00	1.610	.2000	13.220
2	305.	5.0100E-03	.4037	137.00	1.610	.2000	13.220
3	122.	5.0100E-03	.4037	210.00	1.610	.2000	13.220
4	122.	5.0100E-03	.4037	186.00	1.610	.2000	13.220
5	61.	5.0100E-03	.4037	252.00	1.610	.2000	13.220
6	61.	5.0100E-03	.4037	203.00	1.610	.2000	13.220
7	61.	5.0100E-03	.4037	132.00	1.610	.2000	13.220
8	61.	5.7800E-03	.4037	117.00	1.610	.2000	12.450
9	61.	7.5500E-03	.4037	78.60	1.610	.2000	10.890
10	61.	7.8700E-03	.4037	55.80	1.610	.2000	10.640

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	305.	44.89	2.1780E+05	.6099	3.5713E+05
2	305.	-11.69	1.3792E+05	.6099	2.2615E+05
3	122.	2.442	1.5685E+05	.6099	2.5719E+05
4	122.	-6.279	1.6470E+05	.6099	2.7007E+05
5	61.	12.19	1.5679E+05	.6099	2.5710E+05
6	61.	26.62	1.0462E+05	.6099	1.7154E+05
7	61.	47.83	8012.	.6099	1.3137E+04
8	61.	15.67	6.8065E+04	.6326	1.0760E+05
9	61.	18.19	4.1779E+04	.6786	6.1565E+04
10	61.	29.38	.0000	.6860	.0000

Bluewater, bare sands, present (21)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 11:49

NUMBER OF LAYERS :	4	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	44.18	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	61.	1.0700E-02	.4037	132.00	1.610	.2000	13.220
2	61.	1.2400E-02	.4037	117.00	1.610	.2000	12.450
3	61.	1.6200E-02	.4037	78.60	1.610	.2000	10.890
4	61.	1.6800E-02	.4037	55.80	1.610	.2000	10.640

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	61.	12.54	7.5397E+04	.6099	1.2363E+05
2	61.	25.37	5.6247E+04	.6326	8.8917E+04
3	61.	33.06	3.4137E+04	.6786	5.0304E+04
4	61.	46.63	.0000	.6860	.0000

Bluewater, covered sands, present (25)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 12: 1

NUMBER OF LAYERS :	13	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	135.1	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	305.	5.0100E-03	.4037	409.00	1.610	.2000	13.220
2	305.	5.0100E-03	.4037	137.00	1.610	.2000	13.220
3	122.	5.0100E-03	.4037	210.00	1.610	.2000	13.220
4	122.	5.0100E-03	.4037	186.00	1.610	.2000	13.220
5	61.	5.0100E-03	.4037	252.00	1.610	.2000	13.220
6	61.	5.0100E-03	.4037	203.00	1.610	.2000	13.220
7	61.	5.0100E-03	.4037	132.00	1.610	.2000	13.220
8	61.	5.7800E-03	.4037	117.00	1.610	.2000	12.450
9	61.	7.5500E-03	.4037	78.60	1.610	.2000	10.890
10	61.	7.8700E-03	.4037	55.80	1.610	.2000	10.640
11	15.	3.0300E-03	.3133	1.00	1.854	.2000	10.940
12	15.	1.0200E-03	.3133	1.00	1.854	.2000	13.050
13	15.	1.1800E-03	.3133	1.00	1.854	.2000	12.800

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	305.	44.89	2.1780E+05	.6099	3.5713E+05
2	305.	-11.69	1.3792E+05	.6099	2.2615E+05
3	122.	2.442	1.5685E+05	.6099	2.5719E+05
4	122.	-6.279	1.6470E+05	.6099	2.7007E+05
5	61.	12.19	1.5679E+05	.6099	2.5710E+05
6	61.	26.62	1.0462E+05	.6099	1.7154E+05
7	61.	47.83	8012.	.6099	1.3137E+04
8	61.	12.96	7.4217E+04	.6326	1.1733E+05
9	61.	9.928	5.8503E+04	.6786	8.6209E+04
10	61.	6.395	4.4648E+04	.6860	6.5086E+04
11	15.	3.587	2.6120E+04	.5209	5.0141E+04
12	15.	2.288	8208.	.4285	1.9154E+04
13	15.	1.999	.0000	.4395	.0000

Bluewater, covered sands, present (27)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 12: 7

NUMBER OF LAYERS : 11
RADON FLUX INTO LAYER 1 : .000 pCi/m2/sec
SURFACE RADON CONCENTRATION : .000 pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 : 135.1 pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	305.	5.0100E-03	.4037	409.00	1.610	.2000	13.220
2	305.	5.0100E-03	.4037	137.00	1.610	.2000	13.220
3	122.	5.0100E-03	.4037	210.00	1.610	.2000	13.220
4	122.	5.0100E-03	.4037	186.00	1.610	.2000	13.220
5	61.	5.0100E-03	.4037	252.00	1.610	.2000	13.220
6	61.	5.0100E-03	.4037	203.00	1.610	.2000	13.220
7	61.	5.0100E-03	.4037	132.00	1.610	.2000	13.220
8	61.	5.7800E-03	.4037	117.00	1.610	.2000	12.450
9	61.	7.5500E-03	.4037	78.60	1.610	.2000	10.890
10	61.	7.8700E-03	.4037	55.80	1.610	.2000	10.640
11	51.	1.7800E-03	.3133	1.00	1.854	.2000	12.070

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	305.	44.89	2.1780E+05	.6099	3.5713E+05
2	305.	-11.69	1.3792E+05	.6099	2.2615E+05
3	122.	2.442	1.5685E+05	.6099	2.5719E+05
4	122.	-6.279	1.6470E+05	.6099	2.7007E+05
5	61.	12.19	1.5679E+05	.6099	2.5710E+05
6	61.	26.62	1.0462E+05	.6099	1.7154E+05
7	61.	47.83	8012.	.6099	1.3137E+04
8	61.	12.93	7.4283E+04	.6326	1.1743E+05
9	61.	9.839	5.8682E+04	.6786	8.6473E+04
10	61.	6.149	4.5126E+04	.6860	6.5782E+04
11	51.	2.285	.0000	.4714	.0000

Bluewater, Cover Calc. Sand, L.Term, to match Dmeas(26)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 12:10

NUMBER OF LAYERS :	11	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
LAYER11 ADJUSTED TO MEET Jcrit :	20.0	+/- 1.00E-03 pCi/m2/sec
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	292.5	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	305.	2.3800E-02	.4037	409.00	1.610	.2000	8.000
2	305.	2.3800E-02	.4037	137.00	1.610	.2000	8.000
3	122.	2.3800E-02	.4037	210.00	1.610	.2000	8.000
4	122.	2.3800E-02	.4037	186.00	1.610	.2000	8.000
5	61.	2.3800E-02	.4037	252.00	1.610	.2000	8.000
6	61.	2.3800E-02	.4037	203.00	1.610	.2000	8.000
7	61.	2.3800E-02	.4037	132.00	1.610	.2000	8.000
8	61.	2.3800E-02	.4037	117.00	1.610	.2000	8.000
9	61.	2.3800E-02	.4037	78.60	1.610	.2000	8.000
10	61.	2.3800E-02	.4037	55.80	1.610	.2000	8.000
11	15.	7.5300E-03	.3133	1.00	1.854	.2000	9.500

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	305.	96.23	2.1890E+05	.7639	2.8656E+05
2	305.	-18.22	1.4179E+05	.7639	1.8561E+05
3	122.	1.261	1.5151E+05	.7639	1.9834E+05
4	122.	-1.840	1.5184E+05	.7639	1.9877E+05
5	61.	24.69	1.4478E+05	.7639	1.8953E+05
6	61.	38.20	1.2535E+05	.7639	1.6409E+05
7	61.	33.70	1.0313E+05	.7639	1.3500E+05
8	61.	34.03	8.2197E+04	.7639	1.0760E+05
9	61.	29.12	6.2681E+04	.7639	8.2054E+04
10	61.	24.11	4.6229E+04	.7639	6.0517E+04
11	39.	20.02	.0000	.5840	.0000

Bluewater, Bare Slime, present (28)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 10:19

NUMBER OF LAYERS :	11	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	82.59	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	31.	9.0000E-03	.4850	483.00	1.410	.2000	21.860
2	61.	9.0000E-03	.4850	522.00	1.410	.2000	21.860
3	61.	9.0000E-03	.4850	450.00	1.410	.2000	21.860
4	61.	9.0000E-03	.4850	424.00	1.410	.2000	21.860
5	61.	9.0000E-03	.4850	434.00	1.410	.2000	21.860
6	40.	9.0000E-03	.4850	157.00	1.410	.2000	21.860
7	37.	9.0000E-03	.4850	71.10	1.410	.2000	21.860
8	61.	9.0000E-03	.4850	10.72	1.410	.2000	21.860
9	61.	1.3190E-02	.4850	10.57	1.410	.2000	19.550
10	61.	2.5690E-02	.4850	13.11	1.410	.2000	14.190
11	61.	2.4700E-02	.4850	14.75	1.410	.2000	14.560

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	31.	.1277	2.8040E+05	.5297	5.2934E+05
2	61.	16.72	2.6942E+05	.5297	5.0861E+05
3	61.	18.96	2.4615E+05	.5297	4.6468E+05
4	61.	28.07	2.1548E+05	.5297	4.0678E+05
5	61.	67.53	1.5312E+05	.5297	2.8906E+05
6	40.	53.75	9.9218E+04	.5297	1.8730E+05
7	37.	39.57	6.0685E+04	.5297	1.1456E+05
8	61.	19.09	2.2424E+04	.5297	4.2331E+04
9	61.	12.45	1.0191E+04	.5794	1.7589E+04
10	61.	11.39	6528.	.6947	9397.
11	61.	14.63	.0000	.6868	.0000

Bluewater, Bare Slime, present (29)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 10:32

NUMBER OF LAYERS :	11	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	81.11	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	31.	7.0800E-03	.4850	483.00	1.410	.2000	21.860
2	61.	7.0800E-03	.4850	522.00	1.410	.2000	21.860
3	61.	7.0800E-03	.4850	450.00	1.410	.2000	21.860
4	61.	7.0800E-03	.4850	424.00	1.410	.2000	21.860
5	61.	7.0800E-03	.4850	434.00	1.410	.2000	21.860
6	40.	7.0800E-03	.4850	157.00	1.410	.2000	21.860
7	37.	7.0800E-03	.4850	71.10	1.410	.2000	21.860
8	61.	7.0800E-03	.4850	10.72	1.410	.2000	21.860
9	61.	1.0370E-02	.4850	10.57	1.410	.2000	19.550
10	61.	2.0190E-02	.4850	13.11	1.410	.2000	14.190
11	61.	1.9410E-02	.4850	14.75	1.410	.2000	14.560

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	31.	-.6785	2.8319E+05	.5297	5.3460E+05
2	61.	13.99	2.7234E+05	.5297	5.1412E+05
3	61.	14.52	2.4911E+05	.5297	4.7026E+05
4	61.	21.39	2.1985E+05	.5297	4.1503E+05
5	61.	58.44	1.5481E+05	.5297	2.9226E+05
6	40.	44.89	9.6905E+04	.5297	1.8294E+05
7	37.	31.93	5.6867E+04	.5297	1.0735E+05
8	61.	13.65	1.9736E+04	.5297	3.7257E+04
9	61.	8.284	9061.	.5794	1.5638E+04
10	61.	7.793	6012.	.6947	8654.
11	61.	11.16	.0000	.6868	.0000

Bluewater, Cover Calc. Slime, L.Term, to match Dmeas (30)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 11:12

NUMBER OF LAYERS :	12	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
LAYER12 ADJUSTED TO MEET Jcrit :	20.0	+/- 1.00E-03 pCi/m2/sec
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	47.00	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	31.	6.3500E-04	.4850	483.00	1.410	.2000	30.000
2	61.	6.3500E-04	.4850	522.00	1.410	.2000	30.000
3	61.	6.3500E-04	.4850	450.00	1.410	.2000	30.000
4	61.	6.3500E-04	.4850	424.00	1.410	.2000	30.000
5	61.	6.3500E-04	.4850	434.00	1.410	.2000	30.000
6	40.	2.1370E-02	.4170	157.00	1.574	.2000	9.500
7	37.	2.1070E-02	.4148	71.10	1.580	.2000	9.500
8	61.	2.1070E-02	.4148	10.72	1.580	.2000	9.500
9	61	2.1070E-02	.4148	10.57	1.580	.2000	9.500
10	61.	2.1070E-02	.4148	13.11	1.580	.2000	9.500
11	61.	9.7400E-03	.3311	14.75	1.806	.2000	9.500
12	15.	7.5300E-03	.3133	1.00	1.854	.2000	9.500

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	31.	1.0000E+04	2.9184E+05	.3546	8.2303E+05
2	61.	3.689	2.8202E+05	.3546	7.9533E+05
3	61.	1.465	2.5461E+05	.3546	7.1802E+05
4	61.	.6212	2.4351E+05	.3546	6.8673E+05
5	61.	36.46	4.6325E+04	.3546	1.3064E+05
6	40.	47.47	7.7382E+04	.7346	1.0533E+05
7	37.	43.18	5.8155E+04	.7322	7.9423E+04
8	61.	23.20	3.5683E+04	.7322	4.8732E+04
9	61.	12.03	2.3757E+04	.7322	3.2445E+04
10	61.	6.550	1.7467E+04	.7322	2.3854E+04
11	61.	10.03	8.4386E-12	.6165	1.3687E-11
12	0.	10.03	.0000	.5840	.0000

Bluewater, Bare Mixed, present (31)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 12:31

NUMBER OF LAYERS : 7
RADON FLUX INTO LAYER 1 : .000 pCi/m2/sec
SURFACE RADON CONCENTRATION : .000 pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 : 28.41 pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	91.	2.5300E-04	.4110	323.00	1.590	.2400	23.800
2	61.	2.5300E-04	.4110	272.00	1.590	.2400	23.800
3	61.	2.5300E-04	.4110	242.00	1.590	.2400	23.800
4	61.	2.5300E-04	.4110	122.00	1.590	.2400	23.800
5	61.	2.9000E-03	.4110	59.50	1.590	.2400	18.900
6	61.	7.9500E-03	.4110	47.10	1.590	.2400	15.300
7	61.	1.2100E-02	.4110	37.20	1.590	.2400	13.200

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	91.	2.248	2.7616E+05	.3187	8.6664E+05
2	61.	1.349	2.3849E+05	.3187	7.4842E+05
3	61.	5.331	1.6852E+05	.3187	5.2885E+05
4	61.	12.61	-1.9415E+04	.3187	-6.0927E+04
5	61.	8.726	3.3991E+04	.4589	7.4066E+04
6	61.	14.68	2.1408E+04	.5620	3.8092E+04
7	61.	26.02	.0000	.6221	.0000

Bluewater, Bare Mixed, D to match Jmeas, present (32)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 12:39

NUMBER OF LAYERS :	7	
RADON FLUX INTO LAYER 1 :	.000	pCi/m2/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	17.28	pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	91.	9.3600E-05	.4110	323.00	1.590	.2400	23.800
2	61.	9.3600E-05	.4110	272.00	1.590	.2400	23.800
3	61.	9.3600E-05	.4110	242.00	1.590	.2400	23.800
4	61.	9.3600E-05	.4110	122.00	1.590	.2400	23.800
5	61.	1.0800E-03	.4110	59.50	1.590	.2400	18.900
6	61.	2.9500E-03	.4110	47.10	1.590	.2400	15.300
7	61.	4.1600E-03	.4110	37.20	1.590	.2400	13.200

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	91.	1.364	2.7622E+05	.3187	8.6680E+05
2	61.	.8030	2.3861E+05	.3187	7.4880E+05
3	61.	3.096	1.7096E+05	.3187	5.3649E+05
4	61.	3.4545E-04	1.1328E+05	.3187	3.5549E+05
5	61.	3.574	3.9366E+04	.4589	8.5776E+04
6	61.	5.907	2.8520E+04	.5620	5.0748E+04
7	61.	14.48	.0000	.6221	.0000

Bluewater, Mixed, cover calc., long-term (33)

***** I N P U T   P A R A M E T E R S ***** RAECOM2 11/30/1993 @ 12:54

NUMBER OF LAYERS : 8
RADON FLUX INTO LAYER 1 : .000 pCi/m2/sec
SURFACE RADON CONCENTRATION : .000 pCi/liter
LAYER 8 ADJUSTED TO MEET Jcrit : 20.0 +/- 1.00E-03 pCi/m2/sec
BARE SOURCE FLUX (Jo) FROM LAYER 1 : 146.8 pCi/m2/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm2/sec)	POROSITY	Ra-226 (pCi/g)	DENSITY (g/cm3)	EMANATION (fraction)	MOISTURE (dry wt.%)
1	91.	8.5000E-03	.4110	323.00	1.590	.2400	15.000
2	61.	8.5000E-03	.4110	272.00	1.590	.2400	15.000
3	61.	8.5000E-03	.4110	242.00	1.590	.2400	15.000
4	61.	2.1070E-02	.4110	122.00	1.590	.2000	9.500
5	61.	2.1070E-02	.4110	59.50	1.590	.2000	9.500
6	61.	2.1070E-02	.4110	47.10	1.590	.2000	9.500
7	61.	2.1070E-02	.4110	37.20	1.590	.2000	9.500
8	30.	7.5300E-03	.3133	1.00	1.854	.2000	9.500

** R E S U L T S   O F   R A D O N   D I F F U S I O N   C A L C U L A T I O N **

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m2/sec)	EXIT CONC. (pCi/liter)	MIC	AIR CONC. (pCi/liter)
1	91.	24.18	2.5050E+05	.5706	4.3903E+05
2	61.	37.42	2.0049E+05	.5706	3.5138E+05
3	61.	70.77	1.1266E+05	.5706	1.9745E+05
4	61.	56.68	1.0020E+05	.7280	1.3763E+05
5	61.	37.21	6.8113E+04	.7280	9.3557E+04
6	61.	26.60	4.6306E+04	.7280	6.3605E+04
7	61.	21.88	2.9738E+04	.7280	4.0847E+04
8	27.	19.98	.0000	.5840	.0000