TIM- 46-1
Rev. 1

TECHNICAL INFORMATION MEMORANDUM

SUBJECT: REVIEW OF THE SHIPROCK REMEDIAL ACTION PLAN AND CONCEPTUAL DESIGN

BY: V.C. Rogers
K.K. Nielson

FOR: Dr. Donald R. Phoenix
Weston
5301 Central Ave., N.E., Suite 1700
Albuquerque, NM 87108

DATE: March 26, 1984

8701230185 850524
PDR WASTE
WM-58 PDR

Rogers & Associates Engineering Corporation R A E

INTRODUCTION

The purpose of this Technical Information Memorandum is to document the review of the Remedial Action Plan (RAP) and Site Conceptual Design (SCD) for the Shiprock, NM UMTRAP site. This documentation is in accordance with Task 4a of the contract No. ASD-34-6702-S-83-0029 between Jacobs Engineering Group (JEG) and Rogers and Associates Engineering Corporation (RAE). In the review, particular emphasis was placed upon the radon source term characterization and the cover design for radon control; however, the entire RAP and SCD were reviewed and general comments are given.

RADON SOURCE TERM

The degree of detail used to quantify the radon source term in the SCD is more than adequate for cover design purposes, given the uncertainties and variabilities resulting from pile recontouring. It is significantly more detail than is generally done. Site-specific input data were used for the radium concentrations, emanating powers and diffusion coefficients (Appendix A of this memo. The values are reasonably conservative and consistent with good engineering practice.

COVER DESIGN ANALYSIS

The analysis for determining the cover thickness was performed using acceptable procedures and models. However, there is one significant ommission in the draft RAP-SCD. No justification is given for the selection of residual soil moistures in the cover. The reported values of 7.5 dry wt. percent (dwp), except for 5 dwp in the top 30 cm, are reasonable and conservative, but they are sufficiently important that technical information be given supporting these values. It is suggested that the following sentence be inserted in line 8 of the first paragraph on page 22 of Appendix E of the RAP (the SCD):

"These values are consistent with moistures in undisturbed similar soils in the Shiprock area (Section 2 of Attachment A)."

It is also suggested that the following be inserted into the second paragraph of Section IIIA on page 13 of Attachment A to Appendix E:

"In-situ measurements of soil moistures have been made in the Shiprock area (Rogers, V.C., et al 1981b). Annual average moistures in a similar soil as the candidate cover material ranged from five percent at a depth of 1.3 ft as eight percent at a depth of 4.2 ft. The site of the measurements had no rock covering nor vegetation. These soil moistures are also consistent with an estimate of 7.7 percent obtained from an engineering correlation using Shiprock climatological parameters with a soil texture parameter representative of the cover soil (Rogers, V.C. and K.K. Nielson, 1981). Based upon this information it has been estimated that the top foot of cover under the rock cover will maintain a moisture content of five percent, and cover materials below that depth will have a moisture content of 7.5 percent. The data in Table 2.1 indicates the diffusion coefficient of the top foot of cover is 0.025 cm^2/sec, and the remainder of the cover has a diffusion coefficient of 0.017 cm^2/sec.

NEW REFERENCES

Rogers, V.C., K.K. Nielson and D.C. Rich, "Ambient Soil Moistures in Western Uranium Milling Regions," RAE-UMTRA Project report no. RAE-9-4 (September 1981)."

As a further check on the calculated cover thickness, independent calculations were performed at RAE using the RAECOM code. The results were in agreement with the calculations performed by the TAC.

Site specific values were used for key cover soil parameters and the input

data and procedures used in the cover design analysis are consistent with prudent engineering practice.

GENERAL REVIEW COMMENTS

General comments about the RAP-SCD document are as follows:

1. Several references should be incorporated in the text.
2. Additional figures should be used to supplement and clarify sections of the text.
3. Values should be given for a few key parameters.
4. A section should be added in the front of the report that lists all related UMTRAP documents and their purpose. A diagram would be useful.

DETAILED COMMENTS

Detailed comments about the RAP-SCD document are as follows:

No.	Page	Line	
1.	1	3	Long-Term Control
2.	3	Bottom	Describe content and objective of Appendices. Technical people need to read Appendix E and Attachment A first, then read RAP.
3.	6	Tab.2.1	Add: Groundwater Standard into Table.
4.	10	13	.02WL, including background. (Also, add gamma limit.)
5.	14	Fig.3.2	Show location of ore storage area (same as area of residual contamination)
6.	18	16	Give average Rn Flux value.
7.	19	2	Add: reference to Figure 4.1.
8.	19	3	Add: Figure showing Geohydrology. References to basic data.
9.	20	16,20	Add: parameter values and "minor" communication.
10.	21	9	Add: Background values and range - is range given on background value?

11.	24	1.3	Add: values.
12.	29	8	Does Appendix A include all items in SDC report?
13.	30		Add figure showing final design configuration (simple plot plan).
14.	40		Rearrange paragraphs to five EHS policy and objectives first.
15.	57	1	State the objectives of a maintenance and surveillance plan.
16.	58	12	Give one or two examples of measurements that may be done in Phase II.
17.	59		RAE reference is not appropriate for general bibliography and was not used in design analysis of cover - omit it.
18.	71		Definition of maintenance includes passive?
19.	App. E-3		Section 2 is not needed in the Appendix. Key information in this section should be incorporated into the RAP and this section eliminated.
20.	App.E	General	Need not be a stand-alone report. Integrate it better with main report.
21.	App.E Att.A		Almost all of Attachment A could be incorporated into Appendix E.
22.	App.E	Sec.4	Site Design Criteria should be discussed at the first of Appendix E, not 4th.
23.	App.E	Sec.5	Some of the drawings should be in Section 3 of Appendix E- at least the Plot Plan, Grading Plan and Sections. The other drawings are or could be incorporated elsewhere in the RAP and need not be given as a separate section in Appendix E. (They may be given as an attachment to Appendix E in addition to being in Section 3, if necessary.
24.	Att.A	22	Line 2 needs a flow rate value.
25.	Att.A	22	PMP intensity of 24 inch/hr should have more justification.
26.	Att.A	30	No mention of ground settling is given in Appendix E. It should be briefly addressed in Chapter 3 of Appendix E. It affects sequences.
27.	Att.A	47	Effective porosity of 0.04 too low - too conservative, leading to high groundwater velocities.
28.	Att.A	48	V calculation - estimate of conservatism should be given,

gw does not move at 13 ft/yr. It could be much lower. Give a best value estimate.

29. Att.A 49 — Maximum infiltration calculation. Simplistic model that does not necessarily give upper bound for I. In unsaturated zone infiltration could be much different than .04 inch/yr.

30. Att.A 54 — Incomplete. Water Balance should be more quantitative and moistures of soils also given.

APPENDIX A

Rogers & Associates Engineering Corporation

REPORT OF RADIUM AND EMANATION COEFFICIENT MEASUREMENTS
(LAB PROCEDURE RAE-SQAP-3.1)

REPORT DATE 11-Nov-83

CONTRACT C-46-3a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering, Albuquerqu DATE RECEIVED Samples 16-Sep-83 Parameters 4-Oct-83

SAMPLE NUMBER	MOISTURE (DRY WT. %)	RADON EMANATION COEFFICIENT [a]	RADIUM [a] (pCi/gram)	COMMENTS
TP-2 Sands	5.2	0.12±0.01	204±2	
TP-2 Sands	5.4	.12±.01	211±2	
TP-2 Sands	5.6	.15±.01	219±2	
TP-2 Sands	5.6	.14±.01	211±2	
TP-2 Sands	9.2	.19±.01	214±2	
TP-2 Sands	9.2	.15±.01	216±2	
TP-2 Sands	12.8	.14±.01	220±2	
TP-2 Sands	13.5	.14±.01	227±2	

[a] UNCERTAINTIES BASED ON GAMMA-RAY COUNTING STATISTICS ONLY.

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REPORT OF RADIUM AND EMANATION COEFFICIENT MEASUREMENTS
(LAB PROCEDURE RAE-SQAP-3.1)

REPORT DATE 11-Nov-83

CONTRACT C-46-?a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering, Albuquerque DATE RECEIVED Samples 16-Sep-83 Parameters 4-Oct-83

SAMPLE NUMBER	MOISTURE (DRY WT. %)	RADON EMANATION COEFFICIENT [a]	RADIUM [a] (pCi/gram)	COMMENTS
TP-1 Slimes	12.2	0.16±0.01	1444±5	
TP-1 Slimes	12.7	.16± .01	1515±5	
TP-1 Slimes	17.9	.17±.01	1473±5	
TP-1 Slimes	19.8	.17±.01	1527±5	
TP-1 Slimes	46.4	.13±.01	1529±5	
TP-1 Slimes	48.3	.15±.01	1614±6	
TP-1 Slimes	49.8	.16±.01	1634±6	
TP-1 Slimes	50.2	.15±.01	1670±6	

[a] UNCERTAINTIES BASED ON GAMMA-RAY COUNTING STATISTICS ONLY.

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REPORT DATE 11-Nov-83

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BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering, Albuquerque DATE RECEIVED Samples 16-Sept-83 Parameters 4-Oct-83

SAMPLE NUMBER	MOISTURE (DRY WT. %)	RADON EMANATION COEFFICIENT [a]	RADIUM [a] (pCi/gram)	COMMENTS
TP-3 Mixed	7.0	0.28±0.01	405±2	
TP-3 Mixed	7.0	.30±.01	421±2	
TP-3 Mixed	8.2	.28±.01	405±2	
TP-3 Mixed	8.5	.28±.01	410±2	
TP-3 Mixed	14.7	.29±.01	432±3	
TP-3 Mixed	15.0	.27±.01	388±2	
TP-2 Mixed	10.6	.15±.01	312±2	
TP-2 Mixed	10.8	.15±.01	319±2	

[a] UNCERTAINTIES BASED ON GAMMA-RAY COUNTING STATISTICS ONLY.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS

(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 4 Nov 83

CONTRACT C-46-2A

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED Samples 16 Sep 83 Parameters 4 Oct 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] ($M\rho/P$)	COMMENTS
TP-2 Sands	6.0	1.50	4.0×10^{-2}	0.22	
TP-2 Sands	6.8	1.50	3.8×10^{-2}	0.25	
TP-2 Sands	9.3	1.51	3.3×10^{-2}	0.34	
TP-2 Sands	9.4	1.51	1.9×10^{-2}	0.35	
TP-2 Sands	13.3	1.51	1.0×10^{-2}	0.49	
TP-2 Sands	13.5	1.51	9.8×10^{-3}	0.50	

[a]BASED ON A SPECIFIC GRAVITY OF 2.55 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS (TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 4 Nov 83

CONTRACT C-46-2a

BY KKN/DJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED Samples 16 Sep 83 Parameter 4 Oct 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] ($M\rho/P$)	COMMENTS
TP-2 Mixed	6.8	1.61	4.8×10^{-2}	0.31	Sands & Slimes
TP-2 Mixed	7.2	1.59	4.3×10^{-2}	0.31	" "
TP-2 Mixed	9.7	1.61	3.0×10^{-2}	0.44	" "
TP-2 Mixed	9.7	1.61	2.1×10^{-2}	0.44	" "
TP-2 Mixed	11.5	1.59	2.7×10^{-2}	0.50	" "
TP-2 Mixed	13.3	1.61	8.3×10^{-3}	0.62	" "

[a]BASED ON A SPECIFIC GRAVITY OF 2.51 g/cm^3.

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(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 4 Nov 83

CONTRACT C-46-2a

BY KKM/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED Samples 16 Sep 83 Parameters 4 Oct 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mρ/P)	COMMENTS
TP-3 Mixed	6.5	1.68	4.0×10^{-2}	0.33	Sands & Slimes
TP-3 Mixed	7.2	1.67	4.1×10^{-2}	0.35	" "
TP-3 Mixed	9.7	1.70	2.9×10^{-2}	0.50	" "
TP-3 Mixed	9.9	1.70	1.8×10^{-2}	0.51	" "
TP-3 Mixed	12.9	1.71	7.1×10^{-3}	0.68	" "
TP-3 Mixed	13.4	1.71	5.9×10^{-3}	0.71	" "

[a] BASED ON A SPECIFIC GRAVITY OF 2.53 g/cm^3.

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REPORT DATE 4 Nov 83

CONTRACT C-46-2a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings Samples

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED Parameters 16 Sep 83 4 Oct 83

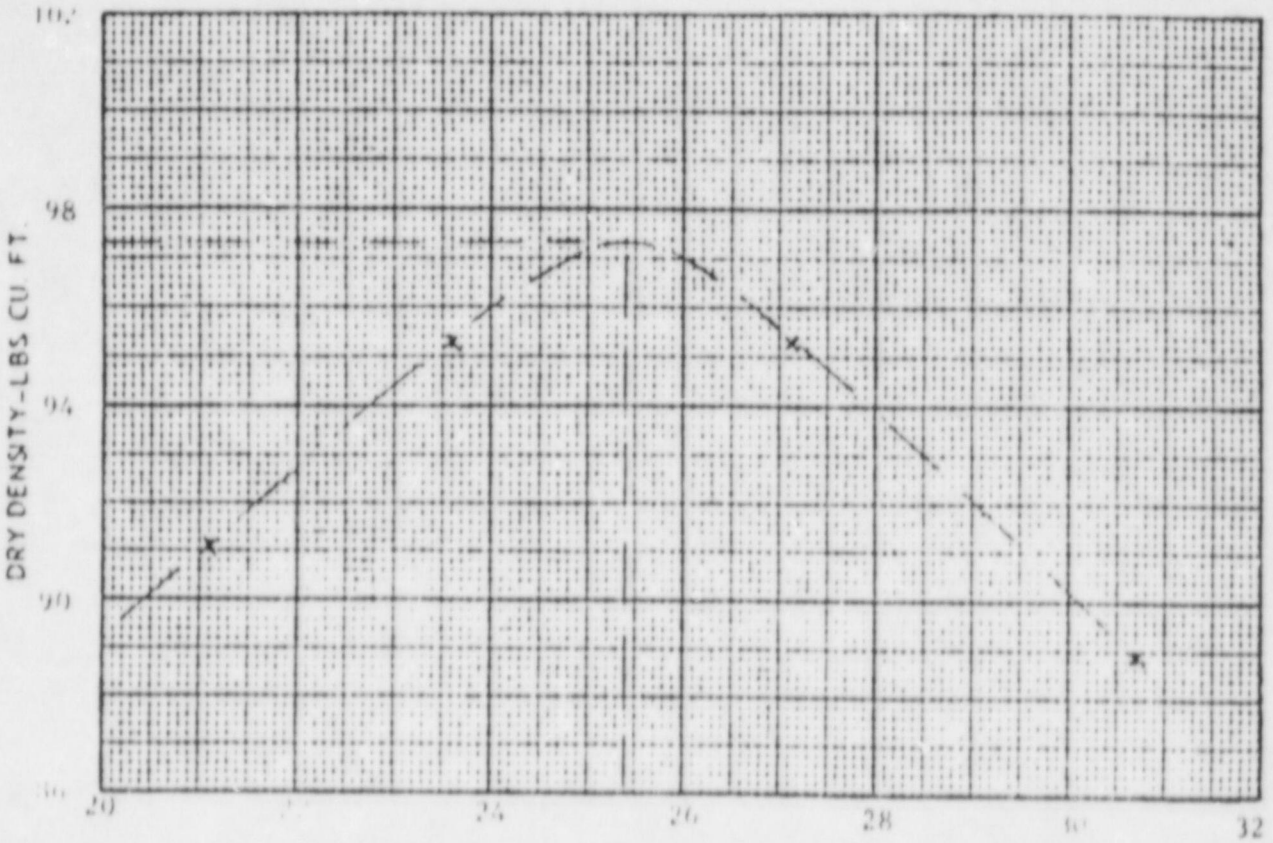
SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (M_p/P)	COMMENTS
TP-1 Slimes	11.5	1.38	2.3×10^{-2}	0.36	
TP-1 Slimes	11.7	1.38	2.1×10^{-2}	0.37	
TP-1 Slimes	16.0	1.37	2.5×10^{-2}	0.49	
TP-1 Slimes	16.8	1.39	2.2×10^{-2}	0.54	
TP-1 Slimes	26.7	1.40	6.0×10^{-4}	0.86	
TP-1 Slimes	29.5	1.39	5.1×10^{-4}	0.94	

[a] BASED ON A SPECIFIC GRAVITY OF 2.466 g/cm^3.

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SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Shiprock Site, New Mexico **JOB NO.** LTR3-2604



CURVE	SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT	MAXIMUM DRY DENSITY LBS/CU FT	TEST DESIGNATION	TEST METHOD	LAB NO
1	TP-1, Stiff [illegible]	25.4	97.3	D698	A	2604-1

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

AASHTO T99 and ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT-LBS/CU FT
A	#4	4	4.58	3	25	5.5 LBS	12	12,375
B	#4	4	4.58	3	56	5.5 LBS	12	12,375
C	3/4	6	4.58	3	56	5.5 LBS	12	12,375
D	3/4	6	4.58	3	56	5.5 LBS	12	12,375

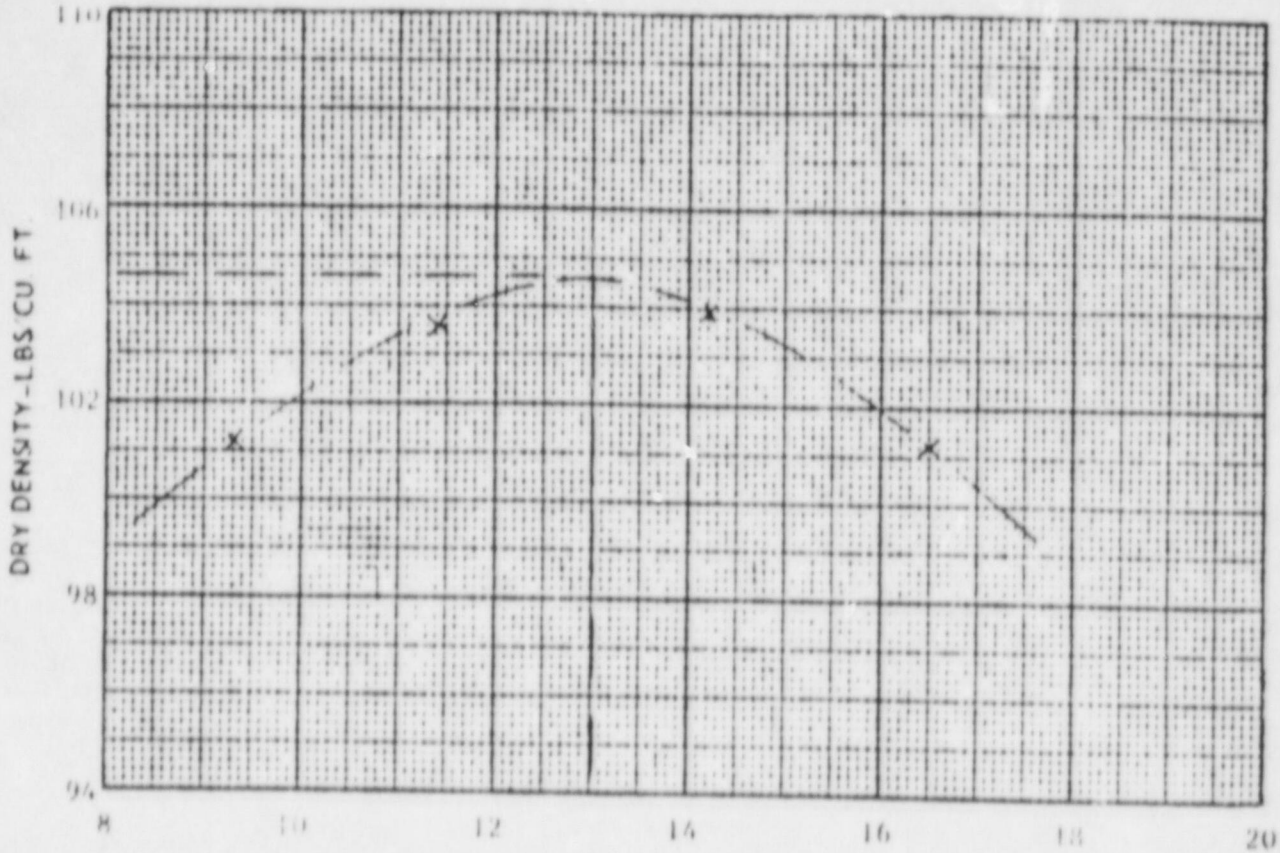
AASHTO T180 and ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT-LBS/CU FT
A	#4	4	4.58	5	25	10.0 LBS	18	56,250
B	#4	4	4.58	5	56	10.0 LBS	18	56,250
C	3/4	6	4.58	5	56	10.0 LBS	18	56,250
D	3/4	6	4.58	5	56	10.0 LBS	18	56,250

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SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Shiprock Site, New Mexico **JOB NO.** LT83-2604



CURVE	SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT	MAXIMUM DRY DENSITY LBS/CU FT	TEST DESIGNATION	TEST METHOD	LAB NO
2	TP-2, Sand, 3'6"	13.0	104.6	D698	A	2604-2

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

AASHTO T99 and ASTM D698 Standard Proctor

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT LBS/CU FT
A	"	4	4.58	3	25	5.5 LBS	12"	12,375
B	"	6	4.58	3	56	5.5 LBS	12"	12,375
C	"	4	4.58	3	56	5.5 LBS	12"	12,375
D	"	6	4.58	3	56	5.5 LBS	12"	12,375

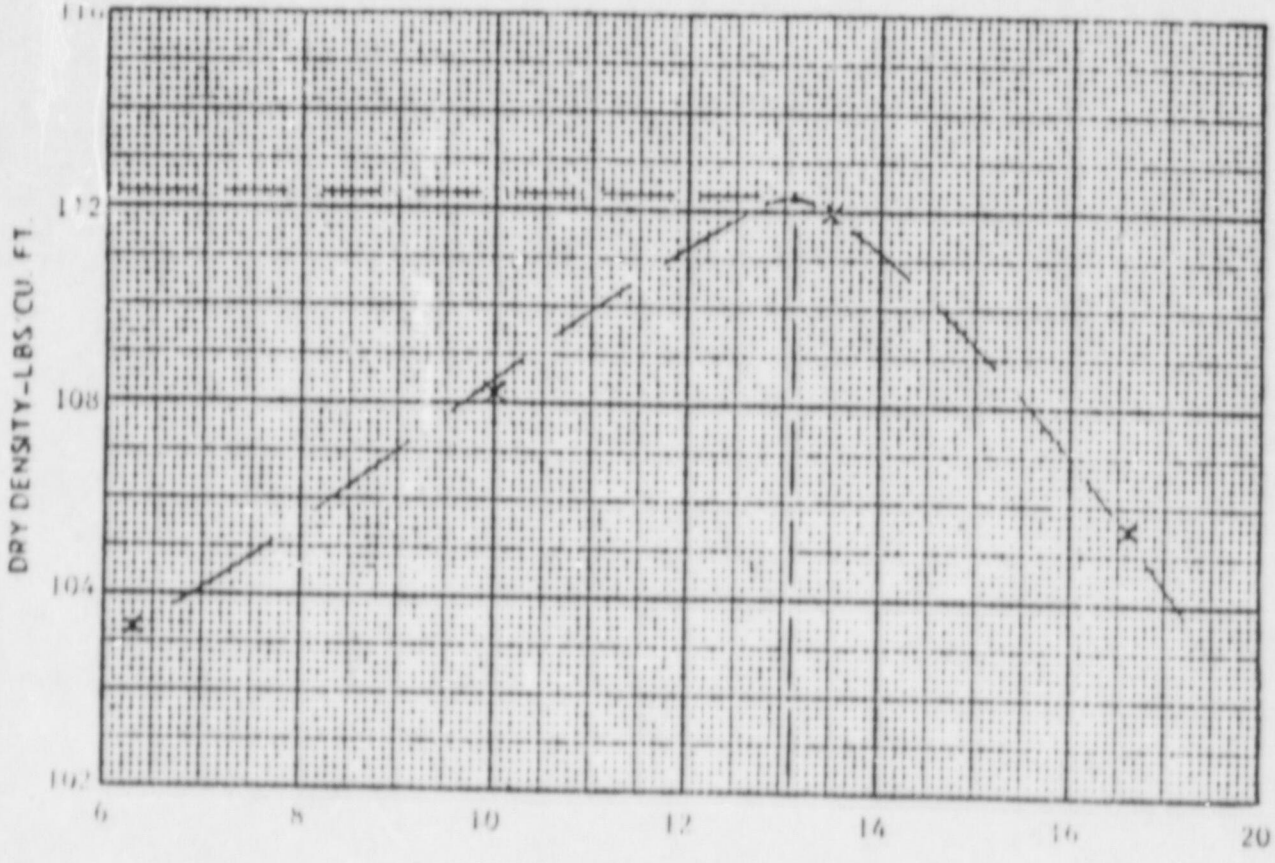
AASHTO T180 and ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT LBS/CU FT
A	"	4	4.58	5	25	10 LBS	18"	56,250
B	"	6	4.58	5	56	10 LBS	18"	56,250
C	"	4	4.58	5	56	10 LBS	18"	56,250
D	"	6	4.58	5	56	10 LBS	18"	56,250

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SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Shiprock Site, New Mexico **JOB NO.** LTR3-2604



CURVE	SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DENSITY LBS./CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
1	TP-2, Sandy Silt, 6'6"	13.1	112.3	D698	A	2604-3

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

AASHTO T99 and ASTM D698 Standard Proctor

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT LBS/CU FT
A	#4	4"	4.58"	3	25	5.5 LBS	12"	12,375
B	#4	6"	4.58"	3	56	5.5 LBS	12"	12,375
C	3/4"	6"	4.58"	3	56	5.5 LBS	12"	12,375
D	3/4"	6"	4.58"	3	56	5.5 LBS	12"	12,375

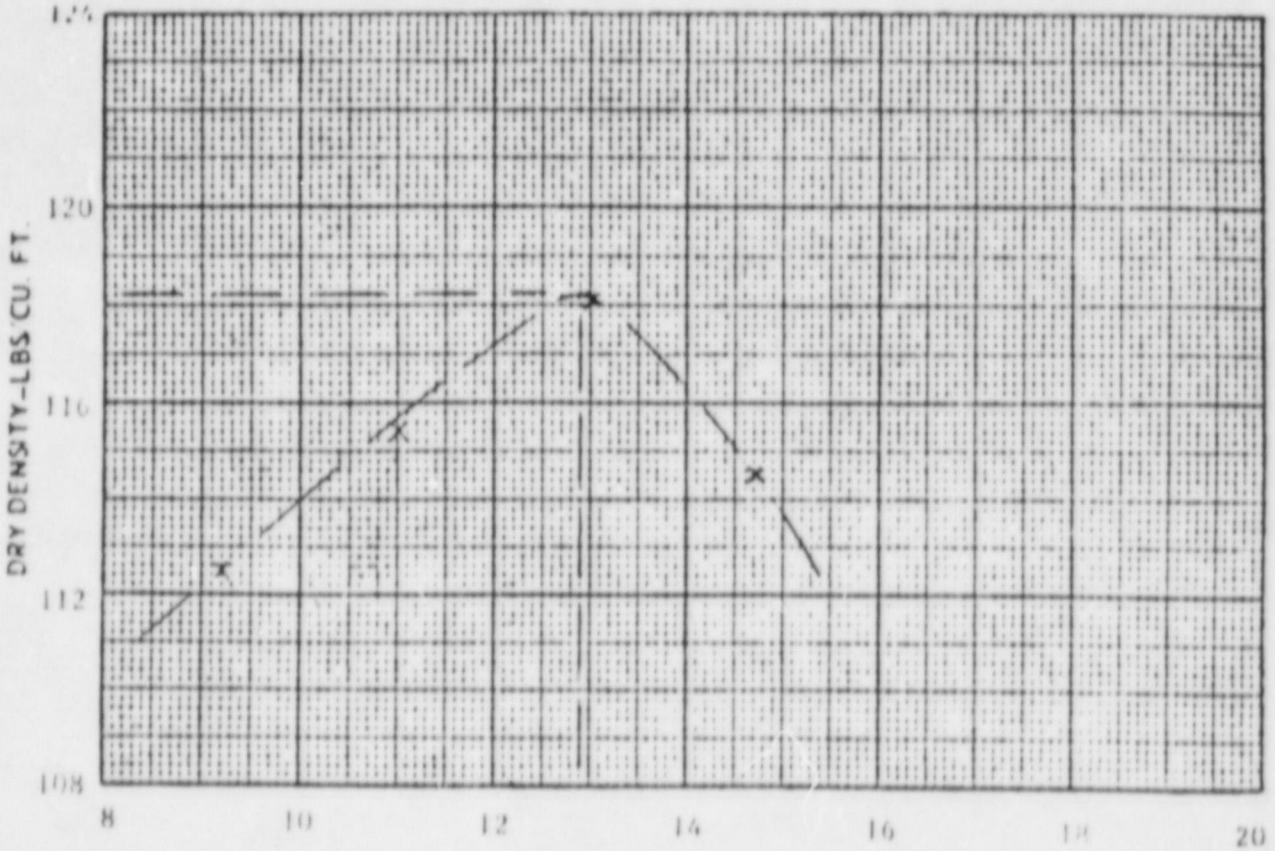
AASHTO T180 and ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT LBS/CU FT.
A	#4	4"	4.58"	5	25	10.0 LBS	18"	56,250
B	#4	6"	4.58"	5	56	10.0 LBS	18"	56,250
C	3/4"	6"	4.58"	5	56	10.0 LBS	18"	56,250
D	3/4"	6"	4.58"	5	56	10.0 LBS	18"	56,250

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SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Shiprock Site, New Mexico **JOB NO.** LT83-2604



CURVE	SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
4	TP-3, Sand/Slime	12.9	118.2	D698	A	2604-4

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

AASHTO T99 and ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT LBS/CU FT
A	#4	4"	4.58"	3	25	5.5 LBS	12"	12,375
B	#4	6"	4.58"	3	56	5.5 LBS	12"	12,417
C	3/4	4"	4.58"	3	56	5.5 LBS	12"	12,417
D	3/4	6"	4.58"	3	56	5.5 LBS	12"	12,417

AASHTO T180 and ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT LBS/CU FT
A	#4	4"	4.58"	5	25	10 LBS	18"	56,250
B	#4	6"	4.58"	5	56	10 LBS	18"	55,000
C	3/4	4"	4.58"	5	56	10 LBS	18"	55,000
D	3/4	6"	4.58"	5	56	10 LBS	18"	55,000

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CONSULTING GEOTECHNICAL ENGINEERS

Rogers & Associates Engineering Corporation

REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS
(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #4 1'-10'	3.0	1.71	4.2×10^{-2}	0.15	
TP #4 1'-10'	3.2	1.77	2.1×10^{-2}	0.18	
TP #4 1'-10'	6.5	1.77	1.3×10^{-2}	0.36	
TP #4 1'-10'	5.5	1.77	2.4×10^{-2}	0.30	
TP #4 1'-10'	12.8	1.77	6.1×10^{-3}	0.70	
TP #4 1'-10'	13.2	1.77	4.0×10^{-3}	0.72	
TP #4 1'-10'	3.5	1.66	2.7×10^{-2}	0.16	

[a]BASED ON A SPECIFIC GRAVITY OF 2.617 g/cm^3.

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CONTRACT C 46-1a

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SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #1 0'-2.5'	1.6	1.74	4.5×10^{-2}	0.09	
TP #1 0'-2.5'	3.5	1.74	3.7×10^{-2}	0.20	
TP #1 0'-2.5'	6.6	1.74	3.6×10^{-2}	0.38	
TP #1 0'-2.5'	6.7	1.73	4.3×10^{-2}	0.38	
TP #1 0'-2.5'	12.8	1.75	4.3×10^{-3}	0.75	
TP #1 0'-2.5'	12.5	1.75	2.9×10^{-3}	0.73	

[a]BASED ON A SPECIFIC GRAVITY OF 2.498 g/cm^3.

RAE

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Rogers & Associates Engineering Corporation

REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS (TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #3, 7'-11'	2.6	1.82	2.2×10^{-2}	0.14	
TP #3, 7'-11'	3.8	1.82	2.0×10^{-2}	0.20	
TP #3, 7'-11'	5.6	1.82	2.2×10^{-2}	0.29	
TP #3, 7'-11'	5.1	1.82	2.1×10^{-2}	0.27	
TP #3, 7'-11'	12.7	1.82	8.9×10^{-4}	0.66	
TP #3, 7'-11'	12.6	1.82	4.6×10^{-3}	0.66	

[a]BASED ON A SPECIFIC GRAVITY OF 2.796 g/cm^3.

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SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #2, 2'-7.5'	2.3	1.75	3.0×10^{-2}	0.12	
TP #2, 2'-7.5'	3.0	1.74	1.9×10^{-2}	0.15	
TP #2, 2'-7.5'	7.6	1.71	2.9×10^{-2}	0.37	
TP #2, 2'-7.5'	7.6	1.71	3.0×10^{-2}	0.37	
TP #2, 2'-7.5'	13.0	1.74	9.9×10^{-3}	0.66	
TP #2, 2'-7.5'	13.6	1.73	4.2×10^{-3}	0.68	
					"

[a]BASED ON A SPECIFIC GRAVITY OF 2.654 g/cm^3.

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(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46 - 1a

BY KMH/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #2 9.5'-11' + 67-10 Dev.W.	2.4	1.75	3.9×10^{-2}	0.12	50/50 mixed by dry weight
"	3.8	1.74	2.9×10^{-2}	0.19	"
"	5.3	1.76	1.7×10^{-2}	0.30	"
"	6.6	1.74	3.0×10^{-2}	0.33	"
"	12.5	1.76	1.5×10^{-3}	0.65	"
"	13.6	1.74	1.0×10^{-3}	0.68	"

[a]BASED ON A SPECIFIC GRAVITY OF 2.67 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS
(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/DJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Gorup, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #8 (Shale)	3.4	1.85	2.0×10^{-2}	0.18	
TP #8 (Shale)	3.5	1.84	1.8×10^{-2}	0.19	
TP #8 (Shale)	6.1	1.84	1.6×10^{-2}	0.32	
TP #8 (Shale)	5.4	1.85	2.2×10^{-2}	0.29	
TP #8 (Shale)	13.0	1.85	9.8×10^{-4}	0.70	
TP #8 (Shale)	12.2	1.85	8.0×10^{-4}	0.66	

[a]BASED ON A SPECIFIC GRAVITY OF 2.82 g/cm^3.

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(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #3, 11'-15'	2.6	1.79	4.1×10^{-2}	0.17	
TP #3, 11'-15'	3.4	1.79	3.5×10^{-2}	0.22	
TP #3, 11'-15'	7.1	1.79	3.4×10^{-2}	0.46	
TP #3, 11'-15'	7.6	1.78	2.8×10^{-2}	0.48	
TP #3, 11'-15'	10.9	1.79	1.2×10^{-2}	0.70	
TP #3, 11'-15'	11.1	1.79	1.6×10^{-2}	0.72	

[a] BASED ON A SPECIFIC GRAVITY OF 2.478 g/cm^3.

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REPORT DATE 3 Oct 83

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SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #3, 11'-15'	2.6	1.79	4.1×10^{-2}	0.17	
TP #3, 11'-15'	3.4	1.79	3.5×10^{-2}	0.22	
TP #3, 11'-15'	7.1	1.79	3.4×10^{-2}	0.46	
TP #3, 11'-15'	7.6	1.78	2.8×10^{-2}	0.48	
TP #3, 11'-15'	10.9	1.79	1.2×10^{-2}	0.70	
TP #3, 11'-15'	11.1	1.79	1.6×10^{-2}	0.72	

[a] BASED ON A SPECIFIC GRAVITY OF 2.478 g/cm^3.

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RAE

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

5301 CENTRAL AVENUE N.E. — SUITE 1700. ALBUQUERQUE. NEW MEXICO 87108
TELEPHONE (505) 846-4030

TO D J Smith

August 31, 1983

Mr. Kirk Neilson
Rogers and Associates Engineering Corp.
P. O. Box 330
Salt Lake City, UT 84110

Dear Kirk:

This letter is to confirm the test parameters we discussed by phone, August 30, 1983. Two corrections must be made to my letter of August 26, 1983. The sample listed as TP#3 9½'-11' should be TP#2 9½'-11', also add sample TP#3 7'-11' to the list. Following is a list of test parameters for the samples.

TP#2 2'-7.5'
Standard Proctor Density = 114.6 pcf
Optimum Moisture = 13.6%
Specific Gravity = 2.654

Test @ 95% of Proctor = 108.9 pcf = 1.745
and Moisture Contents of 3%, 6%, 13%

TP#3 7'-11'
Standard Proctor Density = 118.8 pcf
Optimum Moisture = 12.3%
Specific Gravity = 2.796

Test @ 95% of Proctor = 112.9 pcf 1.81
and Moisture Contents of 3%, 6%, 13%

TP#1 0'-2½'
Standard Proctor Density = 114 pcf
Optimum Moisture = 13%
Specific Gravity - 2.498

Test @ 95% of Proctor = 108.3 pcf 1.736
and Moisture Contents of 3%, 6%, 13%

TP#4 1'-10'
Standard Proctor Density = 116 pcf
Optimum Moisture = 13.7%
Specific Gravity = 2.617

Test @ 95% of Proctor = 110.2 pcf 1.77
and Moisture Contents of 3%, 6%, 13%

TP#2 9½'-11' + 67-10 Devils Wash (50%/50% mixed by dry weight) 1.75
Standard Proctor Density = 115 pcf approx.
Optimum Moisture = 13%
Specific Gravity = 2.67 approx.

Test @ 95% of Proctor - 109.2 pcf
and Moisture Contents of 3%, 6%, 13%

TH#8 (Shale)
Standard Proctor Density = 121.3 pcf
Optimum Moisture = 12.8%
Specific Gravity = 2.82

Test @ 95% of Proctor = 115.2 pcf 1.85
and Moisture Contents of 3%, 6%, 13%

1.79

TP#3 11'-15'
Standard Proctor Density = 117.9 pcf
Optimum Moisture = 12.1%
Specific Gravity = 2.478

Test @ 95% of Proctor = 112 pcf
and Moisture Contents of 2%, 7%, 11%

If you have any questions or problems, please contact me.

Very truly yours,
JACOBS ENGINEERING GROUP INC.

Mark A. Jackson
Project Engineer

MJ:sd

cc: KBaker
WEricson
TSchruben
LStepp

S14B log

Shiprock Samples

E83-1067

		Condition
TP # 1		
0-2.5' SM	2 Bags	bulk
7½	1 Bag	+ 3/8 to 6"
	1 Bag	- 3/8
TP # 2		
2-7.5' ML	1 Cyl Mold	Reduced to - #4
2-7.5'	1 Bag	Proctor Residue
9½-11 SM	1 Bag	Bulk
TP # 3		
7-11	1 Small Bag (Rocks)	+ #4
SM	1 L. Bag	Bulk
TP # 4 ML		
1-10'	2 Bag	Proctor
TP # 5 5-13½	1 Bag	Screened + Recomb
Boulders 5-13½ SM	2 Bags	+ #4
	1 Bag	- #4
TH # 7 small sample	Bag	Bulk (wet)
TH # 8	1 Bag	Screened + Recombined?
67-6 ML TP#3 11-15'	1 Bag	Proctor
	1 Bag	-4
67-10 ML	1 Bag	Proctor

COMPANY : Jacobs Engineering
AREA : Shiprock
PROPERTY: N.E.C.A.
STATE : New Mexico
COUNTY : San Juan

OPERATOR : Privette
UNIT : 1912
LOG TYPE : KRT
PROBE MODEL: 231
SERIAL NO. : 031

EQUIPMENT DATA

DETECTOR : NaI
K-FACTOR : 0.1478 pCi/gm/cps

DETECTOR SIZE : 2"x5"
CALIB.DATE : 11-AUG-83

BOREHOLE RECORD

CASING:

SIZE (OD)	TOP	BASE	THICK	TYPE
3.75	0.0	T.D.	.250(a)	STEEL AUGER

BIT SIZE:

SIZE	TOP	BASE
6.625	0.0	T.D.

FLUID TYPE: None

Hole	Coordinates North	Coordinates East	Elevation Ft	Total Depth Ft (b)	Date	Mean Radium pCi/gm (c)
301	8998.10	10200.18	4947.83	5.5	8-20-83	5.
302	9199.84	10000.00	4946.27	5.0	8-19-83	10. (1)
303	9399.72	9800.12	4945.04	5.0	8-19-83	5.
304	9599.86	9599.98	4937.88	4.5	8-20-83	5.
305	9398.02	9599.93	4944.33	6.0	8-20-83	4.5
306	9199.84	9799.68	4946.59	7.5	8-19-83	5.
307	8998.10	9999.85	4947.63	7.5	8-19-83	4.5
308	8797.85	10200.10	4960.26	11.5	8-19-83	12. (2)
309	8800.11	10000.00	4951.51	8.5	8-18-83	5.
310	8998.10	9799.59	4948.24	6.0	8-19-83	5.
311	9199.84	9579.80	4947.08	5.0	8-20-83	4.5
312	9297.37	9248.55	4946.78	9.5	8-19-83	5.5
313	9199.84	9399.60	4936.40	4.5	8-20-83	5.
314	8998.10	9599.84	4944.34	5.0	8-20-83	5.
315	8800.51	9797.64	4953.84	5.5	8-19-83	5.
316	8600.06	10000.00	4955.63	10.0	8-18-83	6.5
317	8600.23	9797.64	4956.53	9.5	8-17-83	6.
318	8400.49	9997.36	4955.49	11.5	8-18-83	10. (3)
320	8200.47	9987.67	4957.95	8.0	8-18-83	10. (4)
321	8200.30	9797.64	4956.49	5.0	8-17-83	5.
322	8000.31	9792.92	4956.08	8.0	8-17-83	4.
323	8000.31	9592.88	4957.60	10.0	8-17-83	5.
324	7819.91	9767.64	4959.96	9.5	8-17-83	5.
325	8000.31	9357.36	4958.35	9.5	8-17-83	5.
326	7800.33	9572.94	4962.59	12.0	8-23-83	5.

Hole	Coordinates North	East	Elevation Ft	Total Depth Ft	Date	Mean Radium pCi/gm	
327	8000.31	9192.61	4955.63	6.5	8-23-83	5.	
329	7624.29	9583.22	4965.14	12.0	8-23-83	5.	
331	7904.29	9393.22	4964.76	13.5	8-23-83	4.5	
332	7603.22	9172.13	4962.57	11.5	8-23-83	5.	
333	8004.33	8993.18	4953.24	10.4	8-16-83	5.	(d)
334	8000.31	8792.99	4956.86	4.6	8-16-83	5.	(d)
335	8204.41	8592.97	4954.34	6.4	8-16-83	5.	(d)
336	8204.41	8793.10	4953.12	8.6	8-16-83	5.	(d)
337	8204.26	8993.18	4948.12	11.2	8-16-83	5.	(d)
338	8404.29	8993.18	4945.01	8.8	8-16-83	5.	(d)
339	8404.35	8793.10	4950.45	11.2	8-16-83	5.	(d)
340	8404.26	8593.25	4951.56	6.5	8-17-83	4.5	
341	8604.56	8793.10	4945.71	4.5	8-20-83	4.	
342	8604.56	8993.18	4943.98	9.5	8-20-83	4.5	
343	8804.36	8993.18	4942.12	7.0	8-20-83	5.	
344	8804.32	8793.10	4941.26	7.5	8-20-83	4.5	
345	7403.62	9190.64	4966.37	10.0	8-23-83	5.	
346	7373.14	9392.21	4965.82	12.0	8-23-83	5.	
347	7203.61	9390.65	4968.64	8.0	8-23-83	4.5	
348	7173.15	9592.20	4968.86	10.5	8-23-83	4.5	
349	7003.57	9590.69	4970.88	5.5	8-22-83	5.	
350	6973.39	9791.76	4971.83	5.0	8-22-83	5.	
351	6803.62	9790.64	4973.63	5.5	8-22-83	5.5	
352	6778.42	9991.93	4974.53	5.0	8-22-83	5.0	
353	6603.59	9990.67	4976.50	6.0	8-22-83	5.	
354	6603.14	10142.21	4976.07	5.0	8-22-83	4.5	
355	6403.63	10190.63	4978.91	5.5	8-22-83	5.	
356	6424.15	10392.20	4977.95	3.5	8-22-83	5.	
357	6200.33	10387.31	4980.79	5.5	8-22-83	5.	
358	6200.33	10587.33	4980.14	5.5	8-21-83	5.	
359	6003.23	10792.12	4981.67	5.5	8-21-83	5.	
360	6400.57	10587.55	4978.19	5.0	8-21-83	5.5	(5)
361	6200.33	10787.45	4980.52	5.5	8-21-83	5.5	
362	6000.36	10987.42	4981.04	5.0	8-21-83	5.	(6)
363	6400.57	10787.55	4981.93	6.0	8-21-83	4.5	(7)
364	6200.33	10987.52	4984.14	5.0	8-21-83	5.	
365	6000.36	11167.42	4979.46	5.5	8-21-83	5.	
366	6600.14	10811.12	4974.93	5.5	8-21-83	5.	(8)
367	6400.57	10987.55	4985.36	4.5	8-21-83	4.5	
368	6200.33	11187.21	4986.02	5.0	8-21-83	5.	
369	6600.39	10987.37	4972.32	5.0	8-21-83	5.	
370	6400.57	11187.55	4984.75	5.5	8-21-83	5.	
371	6200.33	11264.52	4977.19	5.0	8-21-83	5.	
372	6800.52	11020.50	4970.78	4.5	8-21-83	5.	
373	6600.39	11187.37	4970.31	5.0	8-21-83	5.	
374	6397.02	11390.41	4980.07	5.5	8-21-83	5.5	
375	6800.39	11187.37	4968.73	4.0	8-21-83	4.5	
376	6596.94	11390.41	4970.80	5.5	8-21-83	5.	
377	6373.87	11591.67	4974.53	6.0	8-21-83	5.	
378	7000.39	11225.37	4968.60	4.5	8-22-83	4.5	
379	6796.98	11390.41	4969.51	4.5	8-21-83	5.	(9)

Hole	Coordinates North	East	Elevation Ft	Total Depth Ft	Date	Mean Radium pCi/gm	
380	6597.87	11591.67	4972.75	5.5	8-21-83	5.	
381	6996.78	11390.41	4969.66	5.5	8-22-83	7.5	(10)
382	6797.87	11591.67	4965.58	4.5	8-22-83	4.5	
383	7196.95	11390.41	4965.40	3.5	8-22-83	7.	(11)
384	6997.87	11591.67	4966.55	5.0	8-22-83	4.5	
385	7196.95	11590.57	4962.15	4.5	8-22-83	5.	
386	6998.78	11790.97	4965.71	4.5	8-22-83	5.	
387	7400.28	11587.26	4957.93	5.0	8-22-83	5.	
388	7196.95	11790.49	4962.97	4.0	8-22-83	5.	
389	7396.95	11790.49	4956.60	5.0	8-22-83	5.	
390	7196.95	11990.59	4963.25	5.0	8-22-83	4.5	
391	8199.62	11800.37	4959.91	10.0	8-24-83	4.5	
392	8400.20	11599.79	4963.70	11.5	8-24-83	15.	(12)
393	8600.27	11599.81	4964.32	11.0	8-24-83	6.	
395	8800.06	11199.94	4962.03	14.5	8-24-83	5.	

COMMENTS:

A deconvolution alpha factor of 2.349 ft-1 for a 6.5 inch air-filled hole is applied to the apparent Ra226 concentration. The eRa226 concentration is calculated from the total gamma-ray energy window (1050-3000 Kev). A 3.0 pCi/gm bias should be subtracted from the reported eRa226 concentrations. The average potassium content of 2% contributes 2 pCi/gm and the average thorium content of 8 ppm contributes 1 pCi/gm to the reported eRa226 concentrations.

(a)- A constant correction (CFAC=1.278) is applied for the hollow- stem auger. A separate correction factor for the auger joints is not incorporated.

(b)- The data collection interval is 0.5 ft. The depth recorded is the top of the logged interval. The center of the NaI detector is 0.9 ft. above the bottom of the tool. A logging speed of 2 ft/min is used.

(c)- Mean Radium content is the observed "eyeball" average eRa226 concentration of the depth zone logged. Zones that approach or exceed 15 pCi/gm are footnoted.

(d)- Data collection interval is 0.2 ft. Radium data are not deconvolved.

(1) - Contamination is possibly displaced uphole.
(2) - 15 pCi/gm from 0.0-7.5 ft.
(3) - Contamination is possibly displaced uphole. 25pCi/gm @ 0.5 ft.; 28 pCi/gm @ 3.5 ft.
(4) - Contamination is possibly displaced uphole. 34 pCi/gm @ 5.5 ft.

COMMENTS:

(5) - 17 pCi/gm @ surface : no contamination with depth.
(6) - 10 pCi/gm @ 0.5-1.0 ft
(7) - 8 pCi/gm @ T.D.; possibly >15 pCi/gm below T.D.
(8) - 18 pCi/gm @ 0.5-1.0 ft.
(9) - 8 pCi/gm @ 0.0-1.0 ft.
(10)- 13 pCi/gm @ 1.5-2.5 ft.
(11)- 11 pCI/gm @ 0.5-1.0 ft.
(12)- 120 pCi/gm @ 4.5 ft.

Manual check of calculations

plot printout values		eRa^{226}
5.5	27.6	5.2 —
5.0	25.3	4.8 —
4.5	26.8	5.0 —
4.0	27.0	5.1 —

computer calculation

eRa^{226} = TCOUNTS * KFAC * CFAC

$-5.2 = 27.6 * .1978 * 1.278$

$-4.8 = 25.3 * .1978 * 1.278$

$-5.0 = 26.8 * .1978 * 1.278$

$-5.1 = 27.0 * .1978 * 1.278$

Plot deconvolved value			
DEPTH	TOTAL	eRa^{226}	$eRa^{226}(d)$
5.5	27.6	5.2	5.2
5.0	25.3	4.8	4.4
4.5	26.8	5.0	(5.1)
4.0	27.0	5.1	5.3

DECONVOLVED CALCULATION

NEW = A * 1ST + B * MID + A * LAST

A = $-1.0/(\alpha * DINC)^2 = -0.72$

B = $1.0 + 2/(\alpha * DINC)^2 = 2.44$

$\alpha = 2.349$

DINC = 0.5

CDC Print Deconvolved

	TOTAL	eRa^{226} deconvolv.
5.5	27.6	5.2
5.0	25.3	4.9
-	26.8	(5.1)
4.0	27.0	5.3

DECONVOLUTION CALCULATION CHECK

DEPTH		eRa	dRa
5.0	25.3	4.8	4.4
4.5	26.8	5.0	(5.1)
4.0	27.0	5.1	5.3

1ST = 4.8

MID = 5.0

LAST = 5.1

$\therefore A(4.8 + 5.1) + B(5.0) = R_A(NEW)$

$-0.72(4.8 + 5.1) + 2.44(5.0) = NEW$

$-7.13 + 12.20 = 5.07 = (5.1)$

HOLE 308

AREA SHIPROCK

OPER J.PRIVETTE

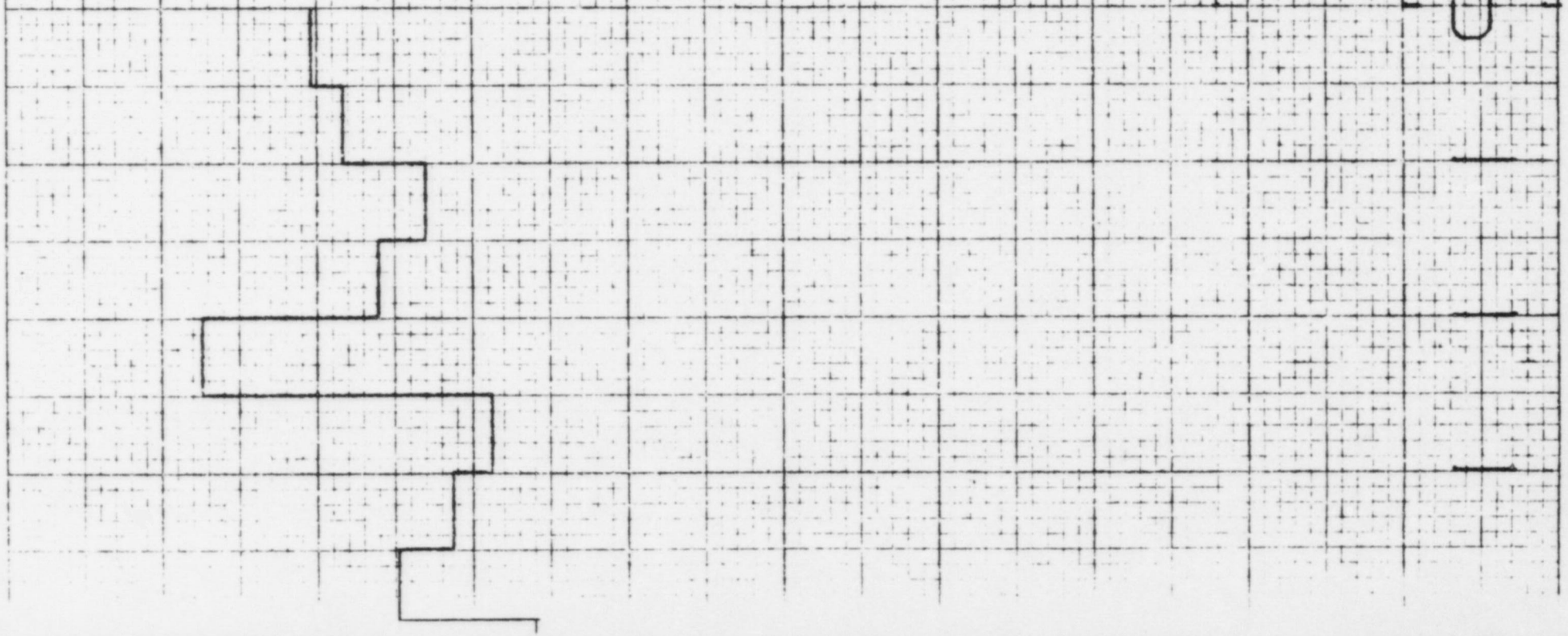
TRUCK 1912

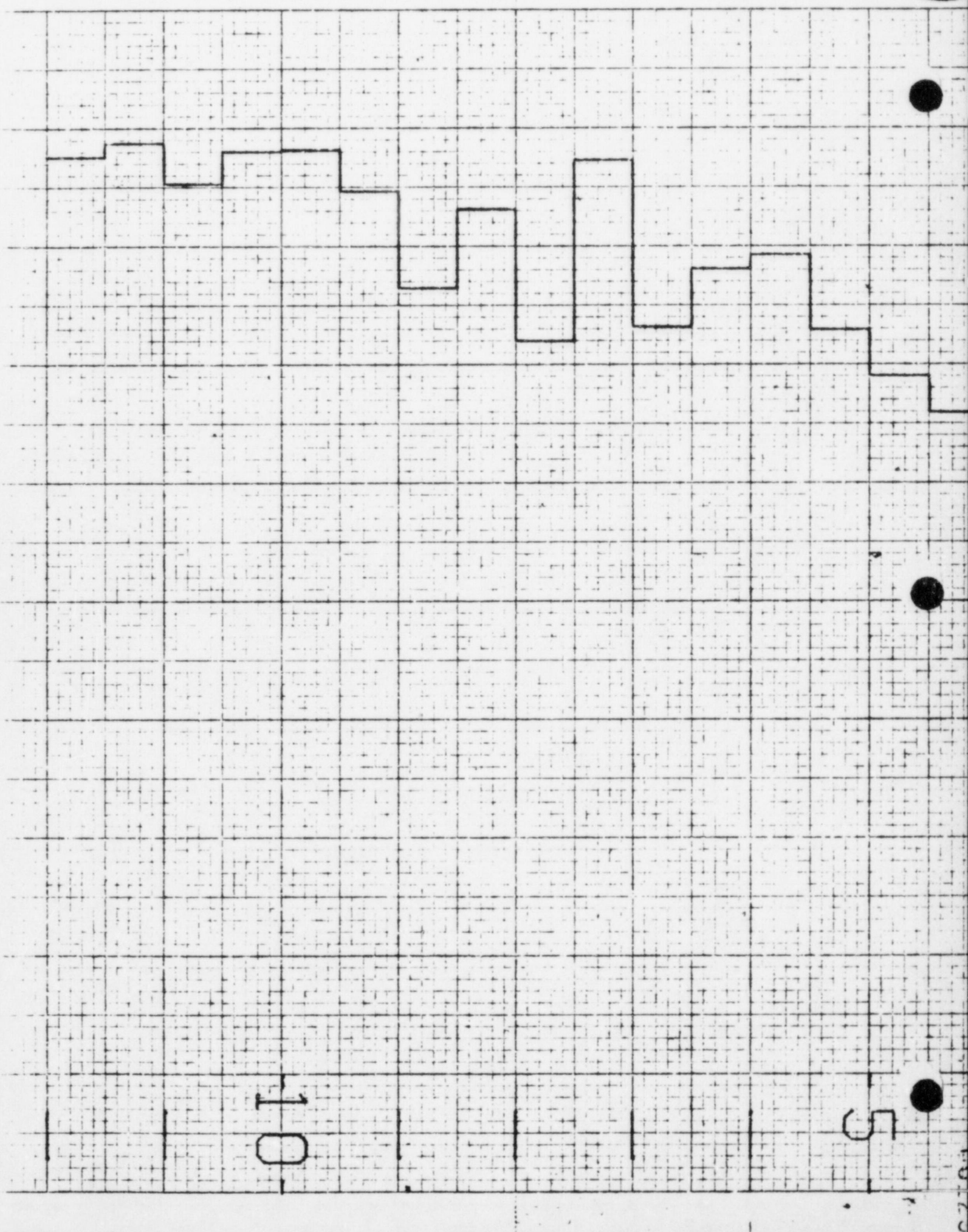
SER # 31

DATE 08-19-83

RADIUM P-CI/GM

0 — 5.0 — 50





REPEAT SECTION

HOLE 308

AREA SHIPROCK

OPER J.PRIVETTE

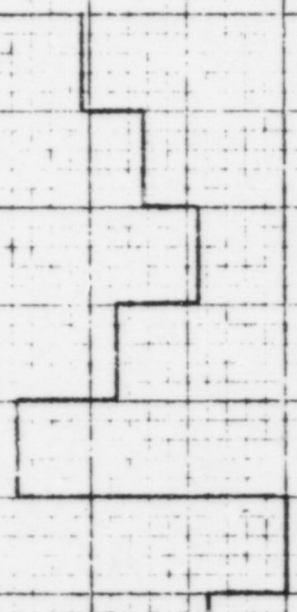
TRUCK 1912

SER # 31

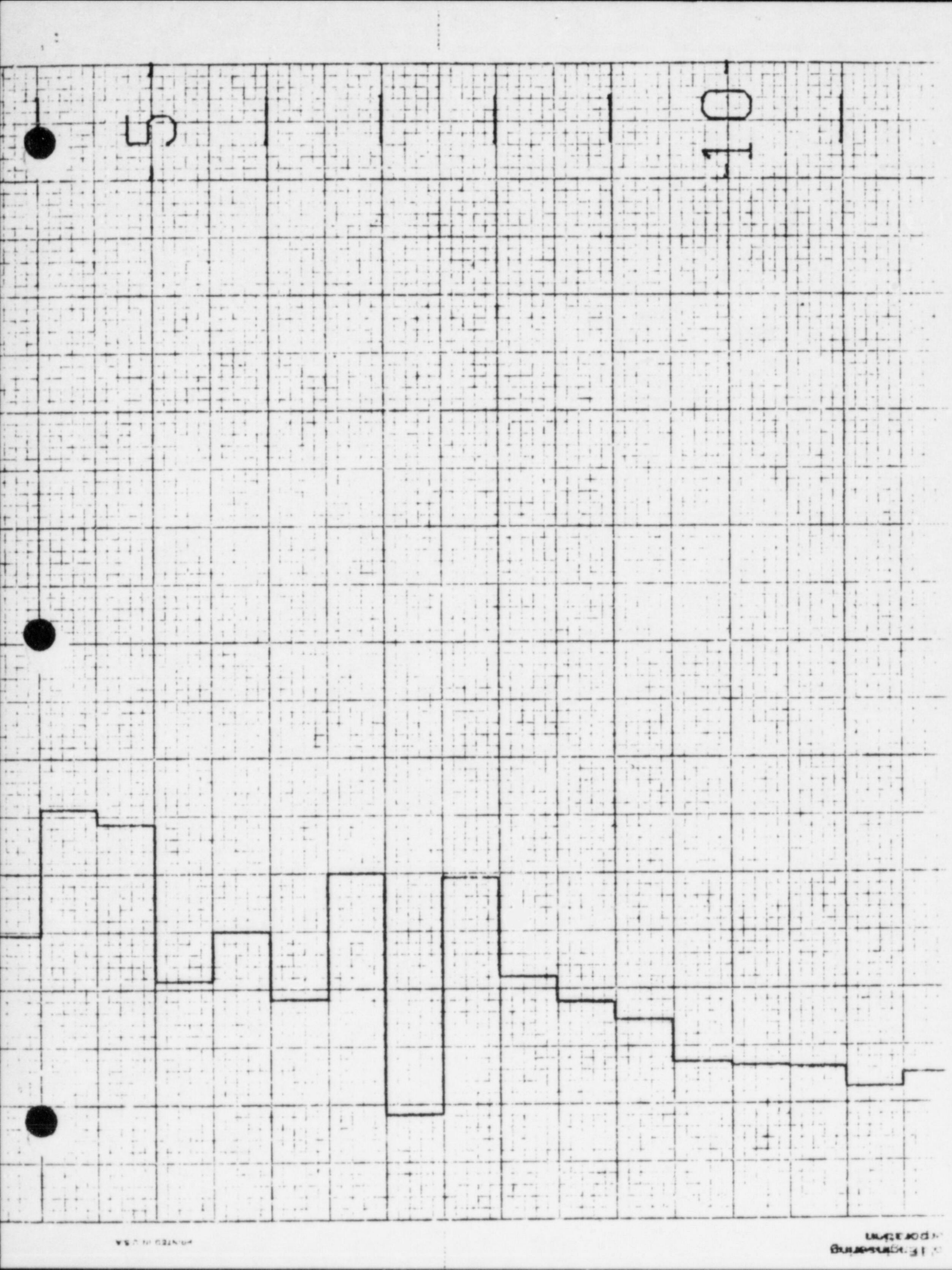
DATE 08-19-83

RADIUM P-CI/GM

0 — 5.0 — 50



No. GC GC-36100



TAPE #2

RADIUM-226 ANALYSIS FOR SHIPROCK SITE TAILINGS SAMPLES

CHEMISTRY LABORATORY
GEOCHEMICAL SUPPORT DEPARTMENT
BENDIX FIELD ENGINEERING CORPORATION
Grand Junction, Colorado

August 9, 1983

Prepared for U.S. Department of Energy
Uranium Mill Tailings Remedial
Action Project Office
Alburquerque Operations Office

1.0 Introduction

A laboratory radiometric analysis for radium-226 of Shiprock site tailings was requested by the Uranium Mill Tailings Project Office, Albuquerque. From the supplied lists a total of 360 samples were found in sufficient quantity for analysis. From the 360 samples, 29 sample splits were prepared as blind duplicates for quality control giving a total of 389 samples to be analyzed.

Of the 360 samples, 115 were of sufficient size to fill the standard 441 cc sample cans. Three duplicates were prepared from these 115 samples. The remainder of the samples and duplicates was analyzed in 22 cc sample containers.

2.0 Analytical Procedure

The determination of radium-226 content was performed using high resolution gamma-ray spectroscopy. The gamma detectors were calibrated with New Brunswick Laboratory (NBL) 100-A series certified gamma-ray standards. Amplifier gain and baseline were manually checked daily and two known controls analyzed daily.

2.1 Sample Preparation

After the samples, together with a request for analytical services, were received, they were logged in and an in-house number was assigned to each. The 115 samples were blended in a Patterson-Kelly cross-flow blender, packed, and sealed in the 441 cc sample cans. The remainder of the samples was packed and sealed in the 22 cc sample cans. The date and time of sealing were recorded on the can after which the samples were forwarded to the laboratory for Ra-226 determination. All samples were allowed to equilibrate for 21 days before analysis.

2.2 Data Handling

All raw data were transferred from a Canberra Series 80 MCA to a PDP 11/34 computer. The raw data were evaluated by GAMCAL V 1.0, a computer program which locates and quantifies the gamma-ray peaks.

2.3 Ra-226 Calculations

A linear least-squares fit of the count rates and the NBL certified values of the standards were used for the working curve. Intercepts for the working curve represent the expected environmental and constant system background as determined from analysis of an empty cave over a 3-day period. Gamma-ray attenuation corrections are applied to the samples of the 441 cc sample size.

The Ra-226 content for each sample was determined using the Bi-214 609 keV gamma ray for the 22 cc sample size and the Bi-214 1765 keV gamma ray for the 441 cc sample size. The 609 keV gamma ray was chosen over the 1765 keV gamma ray for the small sample sizes because the higher detector efficiency and greater intensity were needed to obtain the desired minimum detection limits.

Although use of the 609 keV [illegible] improved [illegible] detection limits considerably, samples with concentrations below 10 [illegible] pCi (eRa-226)/g have a greater variance than that estimated using normal error calculations. This occurs primarily because the calculated error is based on the assumption of a constant background. At concentrations below 10 pCi/gm and sample sizes less than 30 g, the fluctuations in environmental background, although small, can produce a statistically significant influence of up to 20 percent on the results. Because the actual variance cannot be calculated, these results are considered semi-quantitative.

2.4 Reported Error

The error reported with each Ra-226 determination is the total error of two sigma calculated as the square root of the sum of the squares of the relative errors. Errors include random (counting, sample weight, and sample positioning) and systematic (NBL-certified values, working curve and attenuation correction where applicable).

3.0 Results

The assay value of each sample, together with the uncertainty at two sigma, is reported in Table 1 in pCi (eRa-226)/g.

4.0 Duplicate

The assay value of the sample splits, together with the uncertainty, is reported in Table 2 in pCi (eRa-226)/g. Included is a repeat analysis of both duplicates for the duplicate sets whose values do not overlap at two sigma. Although the repeat analyses agree very well, the duplicates do not overlap at two sigma. These duplicates, therefore, are probably not homogeneous. All results, however, agree to better than the 30% required in the Statement of Work.

5.0 Data Tape

A supplementary data tape was created containing the analytical results. The data tape contains Table 1 in one file with the following characteristics:

- 800 bpi
- 9 track
- EBCDIC
- Unlabelled
- RECL = 40
- BLKL = 40

The record format is:

Customer ID - 12A1
Bendix ID - 9A1
Detection Code -A1
Radium Concentration - F10.0
Uncertainty - F6.0

TABLE

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R | 09-AUG-83 | GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-001-01	MAX 001	? 7.	+/-	1.
B-002-04C	MAX 3	355.	+/-	30.
B-003-03	MAX 5	32.	+/-	3.
B-004-01	MAX 7	498.	+/-	42.
B-010-02	MAX 9	404.	+/-	34.
B-010-06	MAX 11	978.	+/-	45.
B-011-02C	MAX 13	623.	+/-	29.
B-012-04	MAX 15	910.	+/-	42.
B-013-01	MAX 17	315.	+/-	15.
B-013-03	MAX 19	284.	+/-	14.
B-013-05C	MAX 21	433.	+/-	20.
B-014-03	MAX 23	299.	+/-	14.
B-014-06	MAX 25	725.	+/-	34.
B-014-08	MAX 27	359.	+/-	30.
B-014-10	MAX 29	401.	+/-	34.
B-015-04	MAX 31	24.	+/-	3.
B-015-06	MAX 33	16.	+/-	2.
A-016-01	MAX 35	392.	+/-	33.
A-016-05	MAX 37	302.	+/-	15.
A-016-07	MAX 39	370.	+/-	18.
A-016-09	MAX 41	362.	+/-	31.
A-016-11	MAX 43	453.	+/-	38.
A-016-13	MAX 45	331.	+/-	28.
A-016-16	MAX 47	319.	+/-	15.
B-017-01	MAX 49	679.	+/-	31.
B-017-03	MAX 051	291.	+/-	14.
B-017-05	MAX 53	421.	+/-	20.
B-018-03	MAX 55	377.	+/-	18.
B-018-05	MAX 57	411.	+/-	34.
B-019-01	MAX 59	313.	+/-	26.
B-019-03	MAX 61	281.	+/-	24.
B-019-05	MAX 63	511.	+/-	43.
A-020-01	MAX 65	423.	+/-	35.
A-020-05	MAX 67	522.	+/-	25.
A-020-08	MAX 69	893.	+/-	42.
A-020-10	MAX 71	959.	+/-	80.
B-021-01	MAX 74	363.	+/-	31.
B-021-04	MAX 76	402.	+/-	34.
B-021-06	MAX 78	489.	+/-	41.
B-023-05	MAX 80	1000.	+/-	83.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-001-04	MAX 2	469.	+/-	39.
B-003-02C	MAX 4	523.	+/-	44.
B-003-04	MAX 6	81.	+/-	7.
B-008-04CP	MAX 8	1463.	+/-	121.
B-010-05	MAX 10	453.	+/-	38.
B-010-11C	MAX 12	940.	+/-	43.
B-011-03	MAX 14	261.	+/-	14.
B-012-06	MAX 16	409.	+/-	19.
B-013-02	MAX 18	58.	+/-	3.
B-013-04	MAX 20	341.	+/-	16.
B-014-01	MAX 22	230.	+/-	11.
B-014-05	MAX 24	296.	+/-	14.
B-014-07	MAX 26	380.	+/-	32.
B-014-09	MAX 28	338.	+/-	28.
B-015-03	MAX 30	136.	+/-	12.
B-015-05	MAX 32	17.	+/-	2.
B-015-07	MAX 34	13.	+/-	2.
A-016-04	MAX 36	430.	+/-	20.
A-016-06	MAX 38	242.	+/-	12.
A-016-08	MAX 40	483.	+/-	23.
A-016-10	MAX 42	502.	+/-	42.
A-016-12	MAX 44	219.	+/-	19.
A-016-14	MAX 46	375.	+/-	18.
A-016-17	MAX 48	478.	+/-	23.
B-017-02	MAX 50	308.	+/-	15.
B-017-04	MAX 52	425.	+/-	20.
B-018-02	MAX 54	435.	+/-	21.
B-018-04	MAX 56	291.	+/-	25.
B-018-06	MAX 58	340.	+/-	29.
B-019-02	MAX 60	444.	+/-	37.
B-019-04	MAX 62	504.	+/-	42.
B-019-06	MAX 64	541.	+/-	45.
A-020-04	MAX 66	817.	+/-	38.
A-020-07	MAX 68	377.	+/-	18.
A-020-09	MAX 70	770.	+/-	36.
A-020-12	MAX 72	1222.	+/-	101.
B-021-02	MAX 75	401.	+/-	34.
B-021-05	MAX 77	259.	+/-	22.
B-023-04	MAX 79	432.	+/-	36.
B-023-06	MAX 81	754.	+/-	35.

< : MINIMUM DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
! : USE OF A SECONDARY PEAK TO CALCULATE CONCENTRATION.
? : INSUFFICIENT COUNTRATE,ANALYSIS IS SEMIQUANTATIVE.
RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

C = composite
CP = composite pulp

SENIOR ANALYST Harold F. Dunlap

Table

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R | 09-AUG-83 | GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-023-07	MAX 82	1247.	+/-	58.
B-023-10	MAX 84	888.	+/-	41.
A-024-01	MAX 86	196.	+/-	10.
A-024-06	MAX 89	252.	+/-	12.
B-025-01	MAX 92	131.	+/-	7.
B-025-03	MAX 94	499.	+/-	23.
B-025-07	MAX 96	453.	+/-	21.
B-025-09	MAX 98	1444.	+/-	67.
B-025-11	MAX 100	985.	+/-	46.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-023-08	MAX 83	1160.	+/-	54.
B-023-51	MAX 85	49.	+/-	3.
A-024-03	MAX 87	445.	+/-	21.
A-024-08	MAX 91	383.	+/-	18.
B-025-02	MAX 93	279.	+/-	14.
B-025-06	MAX 95	638.	+/-	30.
B-025-08	MAX 97	649.	+/-	31.
B-025-10	MAX 99	1586.	+/-	73.

< : MINIMUM DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
! : USE OF A SECONDARY PEAK TO CALCULATE CONCENTRATION.
? : INSUFFICIENT COUNTRATE.ANALYSIS IS SEMIQUANTATIVE.
RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

SENIOR ANALYST Gerald L Dunbar

C = composite
CP = composite pulp

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R

09-AUG-83

GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-[illegible]-05	MAX 88	459.	+/-	31.
B-[illegible]-03	MAX 101	748.	+/-	62.
A-[illegible]-03	MAX 103	654.	+/-	52.
A-[illegible]-05	MAX 105	685.	+/-	43.
[illegible]-07	MAX 107	838.	+/-	60.
[illegible]	MAX 109	442.	+/-	29.
A-[illegible]-12	MAX 111	841.	+/-	39.
A-[illegible]-14	MAX 113	490.	+/-	41.
B-[illegible]-01	MAX 115	470.	+/-	39.
[illegible]-04	MAX 117	337.	+/-	28.
B-[illegible]-05	MAX 119	356.	+/-	17.
B-[illegible]-08	MAX 121	314.	+/-	27.
B-[illegible]-04	MAX 123	568.	+/-	47.
[illegible]	MAX 125	331.	+/-	28.
[illegible]	MAX 127	262.	+/-	22.
A-[illegible]	MAX 129	358.	+/-	30.
A-[illegible]	MAX 131	936.	+/-	46.
[illegible]-11	MAX 133	369.	+/-	18.
[illegible]	MAX 135	294.	+/-	24.
[illegible]-03	MAX 137	356.	+/-	28.
A-[illegible]	MAX 139	413.	+/-	29.
[illegible]-07	MAX 141	528.	+/-	35.
A-[illegible]	MAX 143	382.	+/-	18.
A-[illegible]	MAX 145	466.	+/-	37.
A-[illegible]	MAX 147	2084.	+/-	276.
[illegible]-01	MAX 149	361.	+/-	17.
[illegible]	MAX 151	318.	+/-	15.
[illegible]	MAX 153	366.	+/-	17.
[illegible]	MAX 155	297.	+/-	19.
[illegible]	MAX 157	243.	+/-	19.
[illegible]	MAX 159	443.	+/-	30.
[illegible]	MAX 161	252.	+/-	22.
[illegible]	MAX 163	813.	+/-	38.
[illegible]	MAX 165	439.	+/-	28.
[illegible]	MAX 167	305.	+/-	15.
[illegible]	MAX 169	484.	+/-	23.
[illegible]	MAX 171	326.	+/-	16.
[illegible]	MAX 173	264.	+/-	13.
[illegible]	MAX 175	276.	+/-	22.
[illegible]	MAX 177	388.	+/-	30.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-024-07	MAX 90	552.	+/-	39.
A-026-01	MAX 102	390.	+/-	33.
A-026-04	MAX 104	1413.	+/-	117.
A-026-06	MAX 106	1528.	+/-	126.
A-026-08	MAX 108	1040.	+/-	86.
A-026-11	MAX 110	398.	+/-	25.
A-026-13	MAX 112	388.	+/-	28.
A-026-15	MAX 114	1642.	+/-	146.
B-027-03	MAX 116	364.	+/-	31.
B-027-05	MAX 118	286.	+/-	14.
B-027-07	MAX 120	373.	+/-	31.
A-028-03	MAX 122	849.	+/-	70.
A-028-05	MAX 124	342.	+/-	29.
A-028-07	MAX 126	316.	+/-	27.
A-029-05	MAX 128	403.	+/-	34.
A-029-07	MAX 130	494.	+/-	23.
A-029-10	MAX 132	968.	+/-	45.
A-029-13	MAX 134	830.	+/-	38.
A-030-02	MAX 136	313.	+/-	15.
A-030-04	MAX 138	496.	+/-	25.
A-030-06	MAX 140	629.	+/-	30.
A-030-08	MAX 142	239.	+/-	12.
A-031-05	MAX 144	333.	+/-	30.
A-032-03	MAX 146	2420.	+/-	316.
A-032-05	MAX 148	1696.	+/-	198.
A-033-02	MAX 150	353.	+/-	24.
A-033-04	MAX 152	409.	+/-	29.
A-033-06	MAX 154	249.	+/-	12.
A-033-08	MAX 156	327.	+/-	16.
A-034-02	MAX 158	580.	+/-	27.
A-034-04	MAX 160	215.	+/-	11.
A-034-06	MAX 162	680.	+/-	32.
A-034-08	MAX 164	636.	+/-	30.
A-034-10	MAX 166	318.	+/-	15.
A-034-12	MAX 168	349.	+/-	17.
A-034-14	MAX 170	321.	+/-	15.
A-034-16	MAX 172	2161.	+/-	99.
A-035-02	MAX 174	258.	+/-	13.
A-035-04A	MAX 176	398.	+/-	30.
A-035-05	MAX 178	409.	+/-	29.

< [illegible] DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
[illegible] PRIMARY PEAK TO CALCULATE CONCENTRATION.
? [illegible] CONCENTRATE, ANALYSIS IS SEMIQUANTATIVE.
[illegible] BASED ON BI-214 GAMMA MEASUREMENT

C [illegible] composite
CP = composite pulp

SENIOR ANALYST Donald L Dudat

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PRO[illegible]-100-R 09-AUG-83 GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
[illegible]	MAX 179	471.	+/-	36.
[illegible]	MAX 181	512.	+/-	35.
[illegible]	MAX 183	410.	+/-	30.
[illegible]	MAX 185	372.	+/-	29.
[illegible]	MAX 187	205.	+/-	19.
[illegible]	MAX 189	295.	+/-	15.
[illegible]	MAX 191	109.	+/-	10.
[illegible]	MAX 193	606.	+/-	50.
[illegible]	MAX 195	500.	+/-	42.
[illegible]	MAX 197	12.	+/-	1.
[illegible]	MAX 199	23.	+/-	2.
[illegible]	MAX 201	742.	+/-	62.
[illegible]	MAX 203	48.	+/-	5.
[illegible]	MAX 205	183.	+/-	16.
[illegible]	MAX 207	103.	+/-	9.
[illegible]	MAX 209	82.	+/-	7
[illegible]	MAX 211	38.	+/-	5.
[illegible]	MAX 213	18.	+/-	3.
[illegible]	MAX 215	54.	+/-	6.
[illegible]	MAX 217	14.	+/-	2.
[illegible]	MAX 219	118.	+/-	14.
[illegible]	MAX 221	68.	+/-	6.
[illegible]	MAX 223	390.	+/-	33.
[illegible]	MAX 225	357.	+/-	53.
[illegible]	MAX 227	407.	+/-	60.
[illegible]	MAX 229	249.	+/-	32.
[illegible]	MAX 231	353.	+/-	67.
[illegible]	MAX 235	405.	+/-	34.
[illegible]	MAX 237	419.	+/-	37.
[illegible]	MAX 239	507.	+/-	57.
[illegible]	MAX 241	70.	+/-	7.
[illegible]	MAX 243	103.	+/-	11.
[illegible]	MAX 250	58.	+/-	6.
[illegible]	MAX 253	35.	+/-	4.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-035-07	MAX 180	324.	+/-	25.
B-036-03	MAX 182	223.	+/-	11.
B-036-05	MAX 184	220.	+/-	19.
B-036-07	MAX 186	251.	+/-	20.
D-042-02	MAX 188	272.	+/-	23.
D-044-02	MAX 190	6.	+/-	1.
D-046-01	MAX 192	993.	+/-	82.
D-055-02	MAX 194	66.	+/-	6.
D-055-04	MAX 196	1674.	+/-	125.
D-057-04	MAX 198	440.	+/-	21.
D-059-03	MAX 200	13.	+/-	1.
D-061-01	MAX 202	44.	+/-	4.
D-061-03	MAX 204	237.	+/-	20.
D-063-01	MAX 206	329.	+/-	27.
D-064-02	MAX 208	167.	+/-	15.
D-064-04	MAX 210	23.	+/-	2.
D-065-02	MAX 212	67.	+/-	6.
D-068-01	MAX 214	73.	+/-	7.
D-068-04	MAX 216	303.	+/-	35.
D-069-02	MAX 218	8.	+/-	1.
C-072-01	MAX 220	104.	+/-	9.
C-072-03	MAX 222	268.	+/-	23.
C-074-01	MAX 224	145.	+/-	17.
C-074-03	MAX 226	495.	+/-	71.
C-075-01	MAX 228	33.	+/-	6.
C-075-03	MAX 230	150.	+/-	25.
C-077-03	MAX 234	47.	+/-	9.
C-078-04	MAX 236	687.	+/-	51.
C-080-02	MAX 238	228.	+/-	27.
C-080-04	MAX 240	1001.	+/-	52.
C-081-04	MAX 242	114.	+/-	9.
C-083-03	MAX 248	93.	+/-	12.
C-084-03	MAX 251	30.	+/-	3.
C-086-01	MAX 254	30.	+/-	4.

< : [illegible] DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
! : [illegible] OF 3 SECONDARY PEAK TO CALCULATE CONCENTRATION.
? : [illegible]FICIENT COUNTRATE,ANALYSIS IS SEMIQUANTATIVE.
RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

C = composite
CP = composite pulp

SENIOR ANALYST Donald L. Dulat

Table

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R

09-AUG-83

GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-020-13	MAX 073	1301.	+/-	59.
C-076-03	MAX 232	81.	+/-	5.
C-082-03	MAX 244	60.	+/-	7.
C-083-01	MAX 246	154.	+/-	22.
C-084-01	MAX 249	248.	+/-	36.
C-086-04	MAX 255	102.	+/-	14.
C-087-02	MAX 257	30.	+/-	3.
C-087-04	MAX 259	420.	+/-	67.
C-088-04	MAX 261	651.	+/-	54.
C-089-01	MAX 263	30.	+/-	4.
C-089-03	MAX 265	9.	+/-	2.
C-090-01	MAX 267	8.	+/-	1.
C-091-01	MAX 269	17.	+/-	2.
C-091-03	MAX 271	245.	+/-	23.
C-092-01	MAX 273	4.	+/-	1.
C-092-04	MAX 275	468.	+/-	75.
C-093-02	MAX 277	35.	+/-	2.
C-094-03	MAX 279	208.	+/-	22.
C-095-01	MAX 281	72.	+/-	15.
C-095-04	MAX 283	331.	+/-	16.
C-096-02	MAX 285	30.	+/-	5.
C-096-04	MAX 287	2.	+/-	1.
C-097-02	MAX 289	582.	+/-	37.
C-098-01	MAX 291	407.	+/-	53.
C-098-03	MAX 293	366.	+/-	27.
C-099-01	MAX 295	21.	+/-	2.
C-099-04	MAX 297	1254.	+/-	66.
C-100-03	MAX 299	169.	+/-	16.
C-101-01	MAX 301	10.	+/-	2.
C-101-03	MAX 303	13.	+/-	2.
D-102-01	MAX 305	276.	+/-	23.
D-102-03	MAX 307	249.	+/-	18.
D-103-01	MAX 309	27.	+/-	3.
D-103-03	MAX 311	23.	+/-	3.
D-105-02	MAX 313	704.	+/-	59.
D-105-04	MAX 315	1884.	+/-	117.
A-020-S1	MAX 317	899.	+/-	74.
A-022-10	MAX 319	225.	+/-	19.
A-022-12	MAX 321	414.	+/-	35.
A-022-15	MAX 323	1223.	+/-	101.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-036-04	MAX 183	408.	+/-	39.
C-076-04	MAX 233	337.	+/-	28.
C-082-04	MAX 245	61.	+/-	6.
C-083-02	MAX 247	41.	+/-	4.
C-085-01	MAX 252	69.	+/-	7.
C-087-01	MAX 256	92.	+/-	8.
C-087-03	MAX 258	365.	+/-	56.
C-088-03	MAX 260	412.	+/-	20.
C-088-05	MAX 262	619.	+/-	50.
C-089-02	MAX 264	53.	+/-	5.
C-089-04	MAX 266	124.	+/-	16.
C-090-04	MAX 268	32.	+/-	7.
C-091-02	MAX 270	834.	+/-	70.
C-091-04	MAX 272	7.	+/-	1.
C-092-03	MAX 274	640.	+/-	75.
C-093-01	MAX 276	18.	+/-	4.
C-093-03	MAX 278	4.	+/-	1.
C-094-04	MAX 280	276.	+/-	28.
C-095-03	MAX 282	83.	+/-	5.
C-096-01	MAX 284	44.	+/-	10.
C-096-03	MAX 286	6.	+/-	1.
C-097-01	MAX 288	587.	+/-	56.
C-097-03	MAX 290	510.	+/-	46.
C-098-02	MAX 292	431.	+/-	20.
C-098-04	MAX 294	261.	+/-	13.
C-099-03	MAX 296	45.	+/-	7.
C-100-01	MAX 298	34.	+/-	2.
C-100-04	MAX 300	14.	+/-	1.
C-101-02	MAX 302	17.	+/-	2.
C-101-04	MAX 304	494.	+/-	45.
D-102-02	MAX 306	439.	+/-	31.
D-102-04	MAX 308	397.	+/-	30.
D-103-02	MAX 310	39.	+/-	4.
D-105-01	MAX 312	742.	+/-	64.
D-105-03	MAX 314	1838.	+/-	153.
D-106-03	MAX 316	17.	+/-	2.
A-020-S2	MAX 318	173.	+/-	15.
A-022-11	MAX 320	237.	+/-	20.
A-022-13	MAX 322	412.	+/-	35.
A-029-S1	MAX 324	40.	+/-	4.

< : MINIMUM DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
! : USE OF A SECONDARY PEAK TO CALCULATE CONCENTRATION.
? : INSUFFICIENT COUNTRATE,ANALYSIS IS SEMIQUANTATIVE.
RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

C = composite
CP = composite pulp

SENIOR ANALYST Donald L. Duliat

Table

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R

09-AUG-83

GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-029-S2	MAX 325	776.	+/-	64.
A-031-08	MAX 327	566.	+/-	26.
A-031-11	MAX 329	231.	+/-	11.
A-031-13	MAX 331	1409.	+/-	65.
B-005-S1	MAX 333	1272.	+/-	58.
B-007-S1	MAX 335	125.	+/-	7.
B-009-S1	MAX 337	529.	+/-	44.
B-010-09	MAX 339	1451.	+/-	120.
B-012-S2	MAX 341	102.	+/-	5.
B-021-10	MAX 343	487.	+/-	23.
B-021-12	MAX 345	490.	+/-	23.
B-027-09	MAX 347	427.	+/-	20.
B-027-11	MAX 349	419.	+/-	20.
B-027-13	MAX 351	882.	+/-	41.
B-027-S1	MAX 353	201.	+/-	10.
QUAD A COM	MAX 355	440.	+/-	30.
QUAD B COM	MAX 357	554.	+/-	38.
QUAD D COM	MAX 359	551.	+/-	26.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-031-07	MAX 326	224.	+/-	11.
A-031-10	MAX 328	602.	+/-	28.
A-031-12	MAX 330	395.	+/-	19.
A-031-S1	MAX 332	349.	+/-	17.
B-005-S2	MAX 334	37.	+/-	2.
B-009-06	MAX 336	1218.	+/-	101.
B-010-07	MAX 338	1354.	+/-	112.
B-012-S1	MAX 340	72.	+/-	7.
B-021-09	MAX 342	367.	+/-	17.
B-021-11	MAX 344	378.	+/-	16.
B-021-S1	MAX 346	201.	+/-	10.
B-027-10	MAX 348	680.	+/-	32.
B-027-12	MAX 350	374.	+/-	18.
B-027-14	MAX 352	425.	+/-	20.
D-070-04	MAX 354	283.	+/-	28.
QUAD A TC	MAX 356	514.	+/-	37.
QUAD C COM	MAX 358	394.	+/-	34.
QUAD D TC	MAX 360	451.	+/-	31.

< : MINIMUM DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
I : USE OF A SECONDARY PEAK TO CALCULATE CONCENTRATION.
? : INSUFFICIENT COUNTRATE,ANALYSIS IS SEMIQUANTATIVE.
RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

SENIOR ANALYST Donald L Dalton

C = composite
CP = composite pulp

TABLE 2

DUPLICATE ANALYSIS

Sample I.D.	Ticket	Ra-226	Repeat	Ticket	Ra-226	Repeat
B-010-07	MAX-338	1354 ± 112		MAX-361	1444 ± 119	
B-014-05	MAX-024	296 ± 14		MAX-362	289 ± 24	
B-015-06	MAX-033	16 ± 2		MAX-363	16 ± 2	
A-016-11	MAX-043	453 ± 38		MAX-364	486 ± 41	
B-017-05	MAX-053	421 ± 20		MAX-365	424 ± 35	
A-020-12	MAX-072	1222 ± 101		MAX-366	1097 ± 50	
B-023-08	MAX-083	1160 ± 54	1191 ± 55	MAX-367	1343 ± 111	1334 ± 110
B-025-01	MAX-092	131 ± 7		MAX-368	121 ± 11	
A-026-04	MAX-104	1413 ± 117		MAX-369	1362 ± 113	
A-026-14	MAX-113	490 ± 41	485 ± 41	MAX-370	543 ± 45	554 ± 46
A-028-04	MAX-123	568 ± 47		MAX-371	551 ± 46	
A-029-11	MAX-133	369 ± 18		MAX-372	338 ± 28	
A-031-04	MAX-143	382 ± 18		MAX-373	339 ± 33	
A-034-07	MAX-163	813 ± 38		MAX-374	827 ± 69	
A-035-01	MAX-173	264 ± 13		MAX-375	274 ± 23	
B-036-04	MAX-183	410 ± 30	408 ± 30	MAX-376	351 ± 45	343 ± 44
D-046-02	MAX-193	606 ± 50		MAX-377	601 ± 28	
D-061-02	MAX-203	48 ± 5		MAX-378	53 ± 3	
D-066-03	MAX-213	18 ± 3		MAX-379	18 ± 4	
C-072-03	MAX-222	268 ± 23	264 ± 23	MAX-380	326 ± 16	327 ± 16
C-076-03	MAX-232	81 ± 5		MAX-381	81 ± 5	
C-100-04	MAX-300	14 ± 1		MAX-382	13 ± 1	
D-103-02	MAX-310	39 ± 4		MAX-383	34 ± 6	
A-022-11	MAX-320	237 ± 20		MAX-384	239 ± 12	
A-031-12	MAX-330	395 ± 19		MAX-385	402 ± 19	
B-021-09	MAX-342	367 ± 17	366 ± 17	MAX-386	467 ± 39	446 ± 37
B-027-14	MAX-352	425 ± 20	428 ± 20	MAX-387	475 ± 40	473 ± 40
B-019-05	MAX-063	511 ± 43		MAX-388	514 ± 24	
A-033-05	MAX-153	366 ± 17		MAX-389	365 ± 17	

RAE-33-2

ESTIMATION OF RADON DIFFUSION FOR COVER MATERIALS SHIPROCK, NEW MEXICO, SITE

by

V.C. Rogers
K.K. Nielson

August 27, 1982

for

Jacobs Engineering Group
Jacobs Weston Team
UMTRA Project
Albuquerque, NM 87108

Rogers and Associates Engineering Corp.
Salt Lake City, UT 87110

ESTIMATE OF RADON DIFFUSION FOR COVER MATERIALS - SHIPROCK, NEW MEXICO, SITE

In the area around the Shiprock site, Mancos Shale is overlain by 10 - 30 ft of a sand-silt material. The radon attenuation characteristics of both materials were estimated.

There appears to be sufficient material on the present site to cover the tailings. Surface expressions of Mancos Shale were examined in Dead Man's Wash, located about 0.5 mi southeast of the tailings. About 10-20 ft of surface material would need to be removed in order to obtain the Mancos in sufficient quantities. The Mancos exhibited excellent compaction and moisture retention properties, but there is some question about the ambient soil moisture that it could sustain when placed over the pile. As shown in Table 1, the D for this material is estimated to be 1×10^{-2} cm^2/sec, mainly based upon a relatively low moisture content. The D for the silty sand, given in Table 2, is about 2.5×10^{-2} cm^2/sec, also based upon its ambient moisture content and upon practical upper limits of D for soils.

The source term for the Shiprock site, given in Table 3, is mainly based upon flux measurements.

Mr. Chris Easton, General Manager of the Navajo Engineering and Construction Authority (505) 368-5151, stated that it would probably be easier, with fewer procedural difficulties to use the material on-site for the cover.

TABLE 1

RADON DIFFUSION COEFFICIENT ESTIMATES
FOR COVER MATERIALS NEAR UMTRAP SITES

Site: Shiprock, New Mexico

Material Location: Between the pile and Dead Man's Wash, 0.5 mi from the pile. The Mancos is also closer to the piles, but is overlain by 10-30 ft of sand-silt material.

Material Type: Mancos Shale

Estimate of D: 1×10^{-2} cm^2/sec

Basis for Estimate:

1. Estimate of moisture content of sample is 7%.
2. Cover material would be placed over the 0.5-2 ft of dry cover presently over the tails. This could remove moisture from below.
3. Hot, dry climate with very little annual precipitation.
4. Simple moisture correlation gave 1×10^{-2} cm^2/s for 9.8% moisture.
5. Precipitation at site comes in a series of heavy storms, so much moisture will run-off a compacted Mancos surface.

TABLE 2

RADON DIFFUSION COEFFICIENT ESTIMATES
FOR COVER MATERIALS NEAR UMTRAP SITES

Site: Shiprock, New Mexico

Material Location: Adjacent to the pile in the southeast direction. Borrow pit where cover material has been obtained previously.

Material Type: Brown, silty-sand.

Estimate of D: 2.5×10^{-2} cm^2/sec

Basis for Estimate:

1. Estimate of ambient moisture of about 7%.
2. Hot, dry climate.
3. Cover material would be placed over the present dry cover on the pile. This could remove moisture.
4. Moisture correlation at 6% moisture gives 2.5×10^{-2} cm^2/sec.
5. Value is just less than half the D value for oven-dried sand.

TABLE 3

RADON SOURCE TERM ESTIMATES
FOR UMTRAP SITES

Site: Shiprock, New Mexico

Source Term:

$RE_{p\lambda}$ = 3.2×10^{-4} pCi/cm^{3}s ? = $J_o\left(\frac{\lambda}{D_o}\right)^{1/2}$

J_0 = 110 pCi/m^{2}sec

D_0 = 8×10^{-3} cm^2/sec

Basis For Estimate:
1. FBDU bare flux measurements during a warm, dry period.
2. Some potential for moisture going into the tailings from aquifers.

$$RE_{e\lambda} = J_o\left(\frac{\lambda}{D_o}\right)^{1/2}$$

$J_0 = 0.011$ pCi/cm^2·sec

$D_0 = .008$ cm^2/sec

$$0.011 \text{ pCi/cm}^2\text{·sec}\left(\frac{2.1\times10^{-6}/\text{sec}}{.008\text{cm}^2/\text{sec}}\right)^{1/2}$$

$$0.011 \text{ pCi/cm}^2\text{·sec}\left(1.62\times10^{-2}/\text{cm}\right)$$

$RE_{e\lambda} = 0.0001782$ pCi/cm^3·sec

$= Q$

$= 1.782 \times 10^{-4}$ pCi/cm^3·sec NOT 3.2×10^{-4} ?!!

TAPE #3

Bendix

Field Engineering Corporation

Grand Junction Operations

P.O. Box 1569
Grand Junction, CO 81502
Tel (303) 242-8621

A Subsidiary of
The Bendix Corporation

October 25, 1983

Dr. Ken Baker
Jacobs Engineering Group, Inc.
5301 Central Ave., NE
Suite 1700
Albuquerque, NM 87108

Dear Ken:

We are herewith transmitting a preliminary copy of the Exposure rate results for the Shiprock site radiologic characterization project. The accompanying 9 track magnetic tape also contains these data. The final data presentation will be part of the final report.

Sincerely,

David A. Emilia
Director
Remedial Action Projects Division

DOE/GJAO Concurrence:

L. Ball

Enclosure

Table 6.3

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
5998	10185	14	14
6003	10792	20	17
6021	10208	14	14
6021	10208	14	14
6033	10220	14	14
6033	10220	14	14
6033	10220	14	14
6069	10256	14	14
6069	10256	14	14
6069	10256	14	14
6104	10291	15	15
6104	10291	15	15
6104	10291	15	15
6121	10108	15	15
6129	10316	15	14
6129	10316	15	16
6133	10120	14	15
6163	10350	16	16
6165	10352	16	15
6165	10352	15	16
6169	10156	14	14
6198	10385	16	16
6200	10387	16	16
6200	10387	16	16
6200	11187	14	14
6204	10191	15	16
6221	10008	14	14
6227	10214	16	16
6233	10020	14	15
6233	10420	16	17
6233	10420	16	17
6233	10420	16	17
6263	10250	16	16
6269	10056	15	15
6269	10456	17	18
6269	10456	18	17
6269	10456	18	18
6298	10285	16	16
6304	10091	15	15
6304	10091	16	16
6304	10491	18	17
6304	10491	18	17
6304	10491	18	19
6321	9908	15	14
6333	9920	15	14
6333	10120	15	16

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
6333	10320	17	18
6369	9956	15	15
6369	10156	16	16
6369	10356	20	20
6397	11390	14	14
6401	10988	16	16
6404	9991	15	15
6404	10191	16	17
6404	10391	20	19
6421	9808	14	14
6433	9820	14	14
6433	10220	18	18
6463	10050	15	15
6469	9856	15	16
6469	10256	19	20
6498	10085	18	17
6504	9891	15	15
6504	10291	21	21
6521	9708	15	14
6533	9720	14	14
6533	9920	16	16
6533	10120	20	19
6560	9547	14	15
6569	9756	14	15
6569	9956	16	17
6569	10156	19	20
6597	11390	16	16
6604	9791	15	15
6604	9991	17	17
6604	10191	21	21
6627	9814	16	15
6633	9620	14	15
6633	10020	18	18
6663	9850	16	17
6669	9656	15	14
6669	10056	19	20
6696	9556	15	14
6698	9885	18	17
6704	9691	15	16
6704	10091	19	19
6721	9508	14	14
6733	9520	14	14
6733	9720	15	15
6733	9920	16	19
6769	9556	14	14

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
6769	9756	15	16
6769	9956	19	19
6797	11390	17	20
6798	9385	14	14
6804	9591	14	14
6804	9791	16	17
6804	9991	18	20
6827	9614	15	15
6833	9420	14	14
6833	9820	16	17
6863	9650	15	15
6869	9456	14	14
6869	9856	17	18
6898	9285	14	14
6898	9685	16	16
6904	9491	14	15
6904	9891	18	19
6933	9320	14	14
6933	9520	15	15
6933	9720	16	17
6969	9356	14	14
6969	9756	18	18
6998	11592	16	16
7004	9391	14	15
7004	9591	16	16
7004	9791	18	18
7020	9208	14	14
7033	9220	14	14
7033	9620	17	16
7063	9450	15	15
7069	9256	14	14
7069	9656	17	18
7104	9291	15	15
7104	9691	18	18
7121	9108	14	14
7129	9329	14	15
7133	9120	13	13
7133	9520	15	16
7165	9365	15	15
7169	9156	14	14
7169	9556	16	16
7197	11591	18	18
7197	11991	14	14
7204	9191	14	14
7204	9191	14	15
7204	9241	15	14

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
7204	9291	15	15
7204	9341	16	15
7204	9391	15	16
7204	9391	15	15
7204	9441	16	17
7204	9491	18	17
7204	9591	17	18
7204	9591	16	17
7204	9641	21	20
7204	9661	21	21
7227	9214	15	14
7233	9420	16	16
7263	9250	15	15
7269	9456	15	16
7298	9285	15	15
7304	9491	15	16
7333	9320	14	15
7369	9356	15	16
7397	11790	17	17
7400	11587	20	19
7400	11687	19	18
7400	11890	16	16
7400	11990	20	20
7404	9191	14	14
7404	9241	16	15
7404	9291	15	15
7404	9341	16	15
7404	9391	16	16
7404	9391	15	16
7404	9441	16	16
7404	9491	19	18
7603	9192	14	14
7603	9242	15	15
7604	9293	16	17
7604	9343	16	17
7604	9393	16	17
7604	9443	20	18
7604	9493	18	19
7604	9543	19	20
7624	9583	19	20
7624	9593	21	25
7803	9192	16	15
7803	9242	18	16
7803	9292	16	15
7803	9342	15	15
7803	9392	16	15

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
7803	9442	16	16
7803	9493	19	18
7803	9543	18	17
7803	9593	17	18
7803	9643	17	18
7803	9693	20	20
7803	9743	22	22
7803	9763	24	26
7803	9783	30	30
7850	11850	85	49
7850	11950	30	26
7900	8993	15	14
7950	8993	14	13
7997	11991	21	21
7997	12001	22	21
8000	8793	13	13
8000	8843	14	14
8000	8893	14	14
8000	8943	15	14
8000	8993	12	13
8000	8993	14	14
8000	9043	14	14
8000	9093	14	14
8000	9143	14	14
8000	9193	14	14
8000	9243	14	14
8000	9292	14	13
8000	9341	14	14
8000	9356	15	15
8000	9391	14	14
8000	9442	15	14
8000	9492	15	15
8000	9543	15	16
8000	9593	17	17
8000	9643	18	18
8000	9693	18	16
8000	9743	19	20
8000	9793	19	20
8000	11950	26	26
8054	8993	15	14
8104	8993	14	15
8154	8993	14	14
8180	9808	53	38
8184	12006	20	20
8200	9392	14	14
8200	9492	13	14

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
8200	9542	14	15
8200	9642	18	17
8200	9692	15	15
8200	9742	18	18
8200	9798	19	20
8200	9798	19	20
8200	9848	22	21
8200	9988	28	28
8200	9998	28	34
8200	12100	16	17
8204	8593	13	14
8204	8643	14	14
8204	8693	13	14
8204	8743	13	14
8204	8793	14	14
8204	8843	13	14
8204	8893	14	14
8204	8943	14	14
8204	8993	14	14
8204	8993	14	14
8204	9043	13	13
8204	9093	14	13
8204	9193	14	13
8204	9243	13	13
8204	9293	12	12
8204	9343	13	13
8254	8993	14	14
8260	11940	29	26
8304	8993	14	14
8354	8993	14	14
8400	9620	15	15
8400	9665	15	14
8400	9709	17	16
8400	9754	17	15
8400	9798	18	18
8400	9798	18	19
8400	9798	6	6
8400	9848	19	19
8400	9898	21	21
8400	9947	26	28
8400	9997	44	46
8400	10050	69	69
8400	11995	18	18
8403	9142	13	13
8403	9192	13	13
8404	8593	13	13

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
8404	8643	16	14
8404	8693	14	14
8404	8743	13	13
8404	8793	13	14
8404	8843	15	14
8404	8893	15	14
8404	8943	16	16
8404	8993	15	14
8404	8993	15	15
8404	9043	13	13
8404	9093	13	13
8454	8993	13	13
8496	11896	19	19
8500	11850	20	20
8504	8993	16	16
8521	11853	36	24
8529	11929	20	20
8535	11885	19	20
8554	8973	15	15
8565	11965	20	20
8600	11600	30	30
8600	12000	18	19
8603	9192	14	13
8603	9192	13	13
8603	9242	13	12
8603	9292	13	14
8603	9342	14	14
8603	9392	14	14
8603	9442	14	13
8603	9542	14	13
8603	9572	12	14
8604	9093	14	14
8604	9142	15	14
8605	8793	14	14
8605	8843	13	14
8605	8893	13	13
8605	8943	15	14
8605	8993	14	14
8605	9043	14	14
8629	11629	26	32
8654	8973	16	15
8700	11700	30	34
8704	8973	15	14
8726	8674	17	16
8729	11529	26	30
8731	11736	22	22

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
8733	8664	15	15
8754	8973	13	14
8761	11771	30	28
8765	11565	38	38
8769	8628	13	14
8798	9850	20	23
8798	9900	23	23
8798	9950	25	24
8798	10200	38	42
8800	9798	18	20
8800	9798	6	6
8800	10000	25	25
8800	10050	30	30
8800	10100	34	34
8800	10150	34	30
8800	11200	46	42
8800	11400	30	30
8800	11600	30	30
8800	11800	20	20
8801	9397	13	12
8801	9447	13	13
8801	9498	14	14
8801	9548	15	16
8801	9598	15	15
8801	9648	16	16
8801	9698	19	18
8801	9748	19	19
8802	9295	14	13
8802	9295	12	12
8802	9346	13	12
8802	9346	13	14
8803	9142	17	16
8803	9192	15	15
8803	9243	15	16
8804	8593	13	13
8804	8593	13	12
8804	8743	15	15
8804	8793	14	15
8804	8843	14	14
8804	8893	13	14
8804	8943	14	14
8804	8943	14	14
8804	8993	14	14
8804	8993	14	15
8804	9043	13	14
8804	9093	15	16

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
8831	8765	20	16
8833	8763	19	16
8835	11435	49	46
8835	11635	26	26
8839	8558	15	14
8854	8943	14	14
8869	8728	15	16
8871	11471	32	34
8871	11671	28	28
8879	11279	34	34
8900	11300	46	46
8900	11500	63	57
8900	11700	28	28
8904	8943	12	15
8904	8993	15	16
8904	8993	6	16
8922	8876	15	15
8933	8864	16	15
8934	8868	13	15
8935	11335	34	38
8935	11535	44	42
8935	11735	20	21
8939	8658	15	15
8965	11165	42	42
8969	8828	17	16
8971	11371	38	40
8971	11571	30	34
8971	11771	20	20
8998	9590	15	15
8998	9600	16	16
8998	9650	21	19
8998	9700	18	17
8998	9750	21	20
8998	9800	17	18
8998	9850	17	18
8998	9900	17	18
8998	9950	18	19
8998	10000	20	20
8998	10050	23	23
8998	10100	22	22
8998	10150	22	26
8998	10200	26	30
8998	10250	26	30
8998	10300	26	30
8998	10375	38	38
8999	11598	36	34

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
9000	9180	12	13
9000	9250	14	13
9000	9300	13	13
9000	9350	13	13
9000	9400	12	12
9000	9450	14	13
9000	9500	14	14
9000	9500	14	14
9000	11200	61	59
9000	11200	79	61
9000	11400	30	34
9004	8793	16	15
9004	8793	16	15
9006	11806	20	19
9008	8992	23	18
9026	11624	30	26
9029	8971	17	16
9035	11235	71	61
9037	11434	46	49
9039	8758	15	15
9057	11654	22	24
9065	8935	15	14
9065	11065	49	51
9071	11271	57	48
9074	11468	38	38
9088	11683	22	22
9098	9485	16	15
9100	8900	6	15
9100	8900	15	15
9100	11100	81	81
9100	11300	53	53
9109	11501	34	36
9122	9078	13	13
9123	11718	18	18
9129	9071	18	17
9132	11332	28	36
9135	8865	15	16
9135	8865	15	16
9135	11135	46	48
9143	11533	30	30
9163	11364	38	42
9165	9035	19	18
9165	10965	69	77
9171	11171	48	46
9175	11563	20	22
9194	11393	49	38

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
9200	9000	16	16
9200	9000	16	17
9200	9325	14	14
9200	9350	16	16
9200	9400	16	16
9200	9442	14	14
9200	9450	17	17
9200	9500	18	16
9200	9550	16	15
9200	9600	15	15
9200	9600	16	16
9200	9650	15	15
9200	9700	15	15
9200	9750	14	15
9200	9800	16	17
9200	9850	20	18
9200	9900	16	16
9200	9950	16	18
9200	10000	21	21
9200	10000	20	20
9200	10050	20	20
9200	10100	19	20
9200	10150	22	23
9200	10200	30	26
9200	10250	25	25
9200	10300	23	24
9200	10350	21	22
9200	10375	23	26
9200	11000	85	79
9200	11200	48	46
9204	9143	14	14
9206	11592	26	25
9220	9180	15	17
9224	11422	57	40
9226	11225	42	42
9229	9171	23	20
9235	8965	16	16
9235	11035	65	65
9239	11624	21	22
9248	10848	42	46
9251	11249	32	30
9262	11454	46	40
9265	9135	23	20
9265	10865	61	65
9271	11071	65	57
9272	11656	18	18

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
9279	11277	32	30
9284	11485	34	30
9297	9249	28	26
9300	9100	16	16
9300	9100	16	16
9300	10900	57	59
9300	11100	67	53
9308	11304	38	34
9311	9282	65	42
9320	11515	24	26
9329	9271	21	21
9331	11130	57	48
9335	9065	19	17
9335	10935	67	65
9336	11332	30	30
9337	10737	46	46
9355	11545	24	22
9362	11160	38	32
9364	11359	30	30
9365	9235	21	20
9371	10971	49	53
9372	10772	61	57
9381	11577	24	22
9388	9550	22	20
9393	11190	30	28
9398	9500	19	20
9398	9550	30	34
9398	9600	16	16
9400	9200	19	19
9400	9200	19	18
9400	9650	17	16
9400	9700	16	16
9400	9750	15	14
9400	9800	14	15
9400	9850	15	15
9400	9900	17	16
9400	9950	16	16
9400	10000	16	16
9400	10050	17	17
9400	10100	19	18
9400	10150	20	19
9400	10200	105	18
9400	10250	20	19
9400	10300	19	20
9400	10350	20	21
9400	10400	20	21

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
9400	10450	20	21
9400	10500	22	22
9400	10550	22	22
9400	10600	21	23
9400	10800	57	53
9400	11000	49	53
9400	11000	49	46
9400	11393	24	24
9406	11006	53	49
9407	11608	22	21
9408	9600	19	20
9411	9386	18	19
9424	11219	38	32
9429	9365	49	30
9432	11033	44	42
9435	9165	17	18
9435	10835	57	53
9436	11427	20	21
9441	11638	19	19
9453	11246	28	30
9460	9400	101	46
9463	11065	44	32
9465	9335	21	25
9465	10665	46	46
9468	11459	20	20
9471	10871	34	44
9474	11668	17	18
9475	9400	77	44
9482	11273	28	28
9492	11095	22	26
9500	9300	22	23
9500	9300	22	23
9500	10700	57	49
9500	10900	30	38
9500	10900	34	34
9500	11491	19	18
9511	9490	69	46
9511	11303	34	26
9521	11125	30	30
9529	9471	53	42
9529	10529	38	42
9530	10929	30	30
9532	11491	16	17
9535	9265	25	22
9540	11332	30	30
9550	11155	26	23

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
9560	10958	22	24
9565	9435	30	23
9565	10565	46	42
9574	11363	22	24
9579	11185	21	23
9592	10988	24	26
9600	9400	19	18
9600	9400	19	18
9600	9575	46	30
9600	9600	14	14
9600	9650	14	16
9600	9700	16	16
9600	9750	14	15
9600	9800	15	15
9600	9850	14	15
9600	9900	15	15
9600	9950	15	14
9600	10000	15	16
9600	10050	15	16
9600	10100	19	18
9600	10150	17	17
9600	10200	16	16
9600	10200	16	16
9600	10215	17	16
9600	10265	16	16
9600	10315	16	16
9600	10365	17	16
9600	10600	46	46
9600	10800	30	30
9600	10800	44	34
9600	10800	38	32
9607	11394	22	22
9608	9592	34	26
9623	11017	22	26
9629	9571	16	16
9629	10729	53	46
9631	11216	22	21
9635	9365	16	17
9635	10635	46	44
9636	10837	28	28
9636	10837	23	26
9637	11417	22	23
9638	11246	26	28
9654	11048	20	20
9665	9535	16	15
9665	10465	57	46

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
9665	10765	61	49
9667	11450	20	20
9668	11275	34	30
9671	10671	28	30
9671	10873	26	26
9684	11079	22	25
9696	11479	18	17
9698	11304	23	25
9700	9500	6	14
9700	9500	14	14
9700	10500	23	23
9700	10500	26	26
9700	10700	23	26
9701	10904	23	23
9706	9693	30	24
9715	11109	21	21
9724	11507	18	17
9727	11333	23	23
9729	9671	15	16
9729	10529	32	32
9731	10935	25	25
9733	10741	28	30
9735	9465	15	16
9735	10535	23	33
9743	10343	38	38
9745	11139	23	20
9755	11362	20	21
9761	10966	30	23
9765	9635	14	14
9765	10365	26	30
9765	10565	32	28
9766	10782	23	24
9771	10571	21	23
9777	11169	18	18
9789	11395	19	19
9791	10997	20	20
9791	10997	20	20
9796	10822	25	25
9800	9600	15	15
9800	9600	15	16
9800	9800	25	20
9800	9850	13	15
9800	9900	14	15
9800	9950	14	14
9800	10000	14	16
9800	10050	14	14

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
9800	10100	14	14
9800	10150	15	15
9800	10200	19	16
9800	10400	67	59
9800	10600	20	22
9800	10600	21	22
9801	9799	32	21
9806	10606	29	30
9808	11199	28	25
9821	11028	18	18
9822	11428	16	16
9823	9823	15	14
9826	10861	20	24
9829	9771	15	15
9835	9565	16	15
9835	10435	24	22
9837	11229	25	25
9840	10632	31	24
9851	11059	18	19
9855	11461	16	16
9856	10900	21	23
9859	9859	14	14
9865	9735	15	16
9865	10265	20	19
9865	11258	23	20
9871	10471	21	20
9880	10674	24	28
9886	10939	23	22
9896	9896	14	15
9896	11287	23	21
9900	9700	6	15
9900	9700	14	15
9900	10300	30	26
9900	10500	20	20
9900	10500	22	22
9900	10500	21	22
9906	9894	28	21
9917	10978	19	20
9920	10716	22	22
9927	11315	18	18
9929	9871	15	15
9929	9929	14	14
9929	10129	14	14
9929	10329	16	16
9935	9665	14	15
9940	10534	20	21

PRELIMINARY

Table 6.3 (continued)

EXPOSURE RATE
SHIPROCK SITE

NORTH	EAST	EXPOSURE RATE (uR/h) SURFACE	3 FEET
9947	11017	18	18
9950	10758	16	19
9958	11350	16	16
9965	9835	15	14
9965	9965	15	16
9965	10165	14	14
9965	10365	18	17
9976	10570	22	19
9979	11062	23	20
9988	11384	15	15
9991	10798	17	20
10000	9800	15	15
10000	9800	15	16
10004	9996	24	21
10000	10000	17	18
10000	10200	14	14
10000	10400	18	16
10011	10605	16	16
10011	11106	19	18
10013	11409	15	14
10029	9971	22	18
10029	10029	15	15
10031	10837	23	19
10035	9765	15	15
10035	10235	14	14
10041	11145	19	18
10046	10640	16	16
10065	9935	17	16
10065	10065	14	14
10070	11183	19	18
10071	10271	14	15
10072	10877	16	16
10100	9900	25	16
10100	10100	15	16
10100	10300	16	16
10100	10300	16	15
10129	10129	15	15
10165	10165	18	16
10200	10200	14	14

PRELIMINARY

#3

Rogers & Associates Engineering Corporation

POST OFFICE BOX 330
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(801) 263-1600

SHP

November 11, 1983

Mr. Daniel D. Dzaack
Manager Contracts
Jacobs Engineering Croup, Inc.
5301 Central Avenue, N.E., Suite 1700
Albuquerque, New Mexico 87108

C-46-3a

Dear Mr. Dzaack:

Attached are three copies of the results of the radium and radon emanation coefficient tests on the four uranium tailings samples received September 16, 1983. These samples were from the Shiprock, New Mexico site. These results constitute the complete contract deliverables for Task 3a of our contract ASD-34-6702-S-83.

The laboratory test procedure for these tests was described in our memorandum TIM-36-4 dated June 3, 1983.

Please call me if you have any questions regarding these tests or the results.

Sincerely,

Kirk K. Nielson

KKN/ljp
Enclosures
cc: V.C. Rogers

Rogers & Associates Engineering Corporation

REPORT OF RADIUM AND EMANATION COEFFICIENT MEASUREMENTS

(LAB PROCEDURE RAE-SQAP-3.1)

REPORT DATE 11-Nov-83

CONTRACT C-46-3a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering, Albuquerque DATE RECEIVED Samples 16-Sept-83 Parameters 4-Oct-83

SAMPLE NUMBER	MOISTURE (DRY WT. %)	RADON EMANATION COEFFICIENT [a]	RADIUM [a] (pCi/gram)	COMMENTS
TP-3 Mixed	7.0	0.28±0.01	405±2	
TP-3 Mixed	7.0	.30±.01	421±2	
TP-3 Mixed	8.2	.28±.01	405±2	
TP-3 Mixed	8.5	.28±.01	410±2	
TP-3 Mixed	14.7	.29±.01	432±3	
TP-3 Mixed	15.0	.27±.01	388±2	
TP-2 Mixed	10.6	.15±.01	312±2	
TP-2 Mixed	10.8	.15±.01	319±2	

[a] UNCERTAINTIES BASED ON GAMMA-RAY COUNTING STATISTICS ONLY.

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REPORT OF RADIUM AND EMANATION COEFFICIENT MEASUREMENTS
(LAB PROCEDURE RAE-SQAP-3.1)

REPORT DATE 11-Nov-83

CONTRACT C-46-3a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering, Albuquerque DATE RECEIVED Samples 16-Sep-83 Parameters 4-Oct-83

SAMPLE NUMBER	MOISTURE (DRY WT. %)	RADON EMANATION COEFFICIENT [a]	RADIUM [a] (pCi/gram)	COMMENTS
TP-1 Slimes	12.2	0.16±0.01	1444±5	
TP-1 Slimes	12.7	.16± .01	1515±5	
TP-1 Slimes	17.9	.17±.01	1473±5	
TP-1 Slimes	19.8	.17±.01	1527±5	
TP-1 Slimes	46.4	.13±.01	1529±5	
TP-1 Slimes	48.3	.15±.01	1614±6	
TP-1 Slimes	49.8	.16±.01	1634±6	
TP-1 Slimes	50.2	.15±.01	1670±6	

[a] UNCERTAINTIES BASED ON GAMMA-RAY COUNTING STATISTICS ONLY.

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REPORT OF RADIUM AND EMANATION COEFFICIENT MEASUREMENTS
(LAB PROCEDURE RAE-SQAP-3.1)

REPORT DATE 11-Nov-83

CONTRACT C-46-3a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering, Albuquerque DATE RECEIVED Samples 16-Sep-83 Parameters 4-Oct-83

SAMPLE NUMBER	MOISTURE (DRY WT. %)	RADON EMANATION COEFFICIENT [a]	RADIUM [a] (pCi/gram)	COMMENTS
TP-2 Sands	5.2	0.12±0.01	204±2	
TP-2 Sands	5.4	.12±.01	211±2	
TP-2 Sands	5.6	.15±.01	219±2	
TP-2 Sands	5.6	.14±.01	211±2	
TP-2 Sands	9.2	.19±.01	214±2	
TP-2 Sands	9.2	.15±.01	216±2	
TP-2 Sands	12.8	.14±.01	220±2	
TP-2 Sands	13.5	.14±.01	227±2	

[a] UNCERTAINTIES BASED ON GAMMA-RAY COUNTING STATISTICS ONLY.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS (TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 4 Nov 83

CONTRACT C-46-2a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED Samples 16 Sep 83 Parameter 4 Oct 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mρ/P)	COMMENTS
TP-2 Mixed	6.8	1.61	4.8×10^{-2}	0.31	Sands & Slimes
TP-2 Mixed	7.2	1.59	4.3×10^{-2}	0.31	" "
TP-2 Mixed	9.7	1.61	3.0×10^{-2}	0.44	" "
TP-2 Mixed	9.7	1.61	2.1×10^{-2}	0.44	" "
TP-2 Mixed	11.5	1.59	2.7×10^{-2}	0.50	" "
TP-2 Mixed	13.0	1.61	8.3×10^{-3}	0.62	" "

[a]BASED ON A SPECIFIC GRAVITY OF 2.51 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS (TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 4 Nov 83

CONTRACT C-46-2A

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED Samples 16 Sep 83 Parameters 4 Oct 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP-2 Sands	6.0	1.50	4.0×10^{-2}	0.22	
TP-2 Sands	6.8	1.50	3.8×10^{-2}	0.25	
TP-2 Sands	9.3	1.51	3.3×10^{-2}	0.34	
TP-2 Sands	9.4	1.51	1.9×10^{-2}	0.35	
TP-2 Sands	13.3	1.51	1.0×10^{-2}	0.49	
TP-2 Sands	13.5	1.51	9.8×10^{-3}	0.50	

[a]BASED ON A SPECIFIC GRAVITY OF 2.55 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS (TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 4 Nov 83

CONTRACT C-46-2a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED Samples 16 Sep 83 Parameters 4 Oct 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP-3 Mixed	6.5	1.68	4.0×10^{-2}	0.33	Sands & Slimes
TP-3 Mixed	7.2	1.67	4.1×10^{-2}	0.35	" "
TP-3 Mixed	9.7	1.70	2.9×10^{-2}	0.50	" "
TP-3 Mixed	9.9	1.70	1.8×10^{-2}	0.51	" "
TP-3 Mixed	12.9	1.71	7.1×10^{-3}	0.68	" "
TP-3 Mixed	13.4	1.71	5.9×10^{-3}	0.71	" "

[a] BASED ON A SPECIFIC GRAVITY OF 2.53 g/cm^3.

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Rogers & Associates Engineering Corporation

REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS (TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 4 Nov 83

CONTRACT C-46-2a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Uranium Mill Tailings

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED Samples 16 Sep 83 Parameters 4 Oct 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] ($M\rho/P$)	COMMENTS
TP-1 Slimes	11.5	1.38	2.3×10^{-2}	0.36	
TP-1 Slimes	11.7	1.38	2.1×10^{-2}	0.37	
TP-1 Slimes	16.0	1.37	2.5×10^{-2}	0.49	
TP-1 Slimes	16.8	1.39	2.2×10^{-2}	0.54	
TP-1 Slimes	26.7	1.40	6.0×10^{-4}	0.86	
TP-1 Slimes	29.5	1.39	5.1×10^{-4}	0.94	

[a] BASED ON A SPECIFIC GRAVITY OF 2.466 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS
(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SOAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #4 1'-10'	3.0	1.71	4.2×10^{-2}	0.15	
TP #4 1'-10'	3.2	1.77	2.1×10^{-2}	0.18	
TP #4 1'-10'	6.5	1.77	1.3×10^{-2}	0.36	
TP #4 1'-10'	5.5	1.77	2.4×10^{-2}	0.30	
TP #4 1'-10'	12.8	1.77	6.1×10^{-3}	0.70	
TP #4 1'-10'	13.2	1.77	4.0×10^{-3}	0.72	
TP #4 1'-10'	3.5	1.66	2.7×10^{-2}	0.16	

[a]BASED ON A SPECIFIC GRAVITY OF 2.617 g/cm^3.

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REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #1 0'-2.5'	1.6	1.74	4.5×10^{-2}	0.09	
TP #1 0'-2.5'	3.5	1.74	3.7×10^{-2}	0.20	
TP #1 0'-2.5'	6.6	1.74	3.6×10^{-2}	0.38	
TP #1 0'-2.5'	6.7	1.73	4.3×10^{-2}	0.38	
TP #1 0'-2.5'	12.8	1.75	4.3×10^{-3}	0.75	
TP #1 0'-2.5'	12.5	1.75	2.9×10^{-3}	0.73	

[a]BASED ON A SPECIFIC GRAVITY OF 2.498 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS
(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #3, 7'-11'	2.6	1.82	2.2×10^{-2}	0.14	
TP #3, 7'-11'	3.8	1.82	2.0×10^{-2}	0.20	
TP #3, 7'-11'	5.6	1.82	2.2×10^{-2}	0.29	
TP #3, 7'-11'	5.1	1.82	2.1×10^{-2}	0.27	
TP #3, 7'-11'	12.7	1.82	8.9×10^{-4}	0.66	
TP #3, 7'-11'	12.6	1.82	4.6×10^{-3}	0.66	

[a]BASED ON A SPECIFIC GRAVITY OF 2.796 g/cm^3.

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(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SOAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C-46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] ($M\rho/P$)	COMMENTS
TP #2, 2'-7.5'	2.3	1.75	3.0×10^{-2}	0.12	
TP #2, 2'-7.5'	3.0	1.74	1.9×10^{-2}	0.15	
TP #2, 2'-7.5'	7.6	1.71	2.9×10^{-2}	0.37	
TP #2, 2'-7.5'	7.6	1.71	3.0×10^{-2}	0.37	
TP #2, 2'-7.5'	13.0	1.74	9.9×10^{-3}	0.66	
TP #2, 2'-7.5'	13.6	1.73	4.2×10^{-3}	0.68	

[a]BASED ON A SPECIFIC GRAVITY OF 2.654 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS
(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46 - 1a

BY KKH/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] (Mp/P)	COMMENTS
TP #2 9.5'-11' + 67-10 Dev. W	2.4	1.75	3.9×10^{-2}	0.12	50%/50% mixed by dry weight
"	3.8	1.74	2.9×10^{-2}	0.19	"
"	5.3	1.76	1.7×10^{-2}	0.30	"
"	6.6	1.74	3.0×10^{-2}	0.33	"
"	12.5	1.76	1.5×10^{-3}	0.65	"
"	13.6	1.74	1.0×10^{-3}	0.68	"

[a] BASED ON A SPECIFIC GRAVITY OF 2.67 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS
(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SOAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Gorup, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] ($M\rho/P$)	COMMENTS
TP #8 (Shale)	3.4	1.85	2.0×10^{-2}	0.18	
TP #8 (Shale)	3.5	1.84	1.8×10^{-2}	0.19	
TP #8 (Shale)	6.1	1.84	1.6×10^{-2}	0.32	
TP #8 (Shale)	5.4	1.85	2.2×10^{-2}	0.29	
TP #8 (Shale)	13.0	1.85	9.8×10^{-4}	0.70	
TP #8 (Shale)	12.2	1.85	8.0×10^{-4}	0.66	

[a] BASED ON A SPECIFIC GRAVITY OF 2.82 g/cm^3.

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REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS (TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

REPORT DATE 3 Oct 83

CONTRACT C 46-1a

BY KKN/BJB

SAMPLE IDENTIFICATION Shiprock Cover Soils

SUBMITTED BY Jacobs Engineering Group, Albuquerque DATE RECEIVED 29 Aug 83

SAMPLE NUMBER	MOISTURE (DRY WT.%)	DENSITY (g/cm^3)	RADON DIFFUSION COEFF. (cm^2/s)	SATURATION[a] ($M\rho/P$)	COMMENTS
TP #3, 11'-15'	2.6	1.79	4.1×10^{-2}	0.17	
TP #3, 11'-15'	3.4	1.79	3.5×10^{-2}	0.22	
TP #3, 11'-15'	7.1	1.79	3.4×10^{-2}	0.46	
TP #3, 11'-15'	7.6	1.78	2.8×10^{-2}	0.48	
TP #3, 11'-15'	10.9	1.79	1.2×10^{-2}	0.70	
TP #3, 11'-15'	11.1	1.79	1.6×10^{-2}	0.72	

[a] BASED ON A SPECIFIC GRAVITY OF 2.478 g/cm^3.

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2A

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APPLIED SOIL MECHANICS • ENGINEERING GEOLOGY • MATERIALS ENGINEERING

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DONALD L. CURRAN, P.E. | ALLON C. OWEN, JR., P.E.

October 10, 1983

Rogers & Associates Engineering Corp.
515 East 4500 South
Suite G-100
Salt Lake City, Utah 84110

SHB Job No. LT83-2604

Attention: Kirk K. Nielson, Ph.D.

Re: Shiprock Site
Shiprock, New Mexico

Gentlemen,

Please find attached the results of laboratory tests performed on samples of tailings from the above referenced project. The samples were delivered to our office on September 28. 1983.

The samples used in our testing program were returned to your representative on October 3, 1983.

If you have any questions concerning the test results, procedures or if we can be of further service, please contact us at your convenience.

Respectfully submitted,
Sergent, Hauskins & Beckwith Engineers

By Donald L. Curran
Donald L. Curran, P.E.

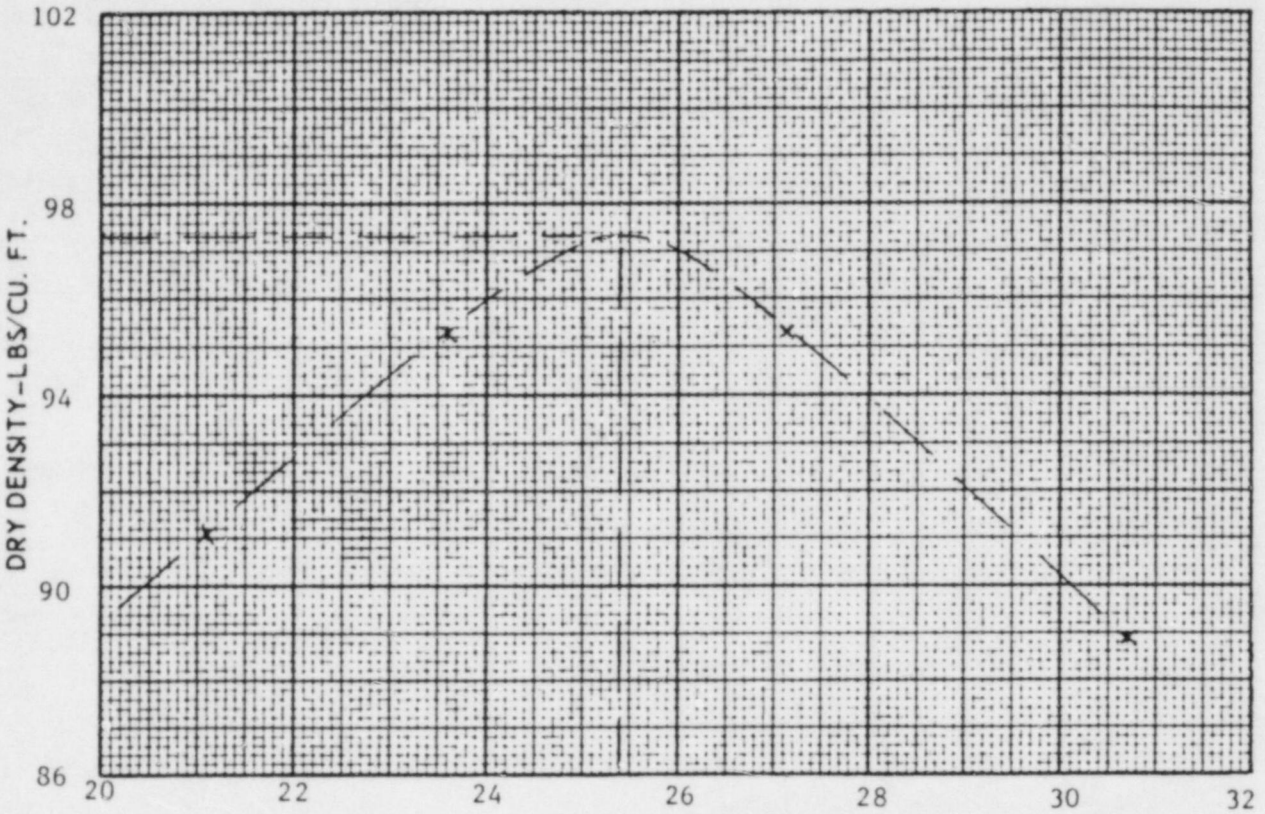
DLC/clc

Copies: Addressee (2)

Enclosures.

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Shiprock Site, New Mexico **JOB NO.** LT83-2604



CURVE	SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS./CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
1	TP-1, Slimes	25.4	97.3	D698	A	2604-1

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

AASHTO T99 and ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 LBS.	12"	12,375
B	-#4	6"	4.58"	3	56	5.5 LBS.	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 LBS.	12"	12,317
D	-3/4	6"	4.58"	3	56	5.5 LBS.	12"	12,317

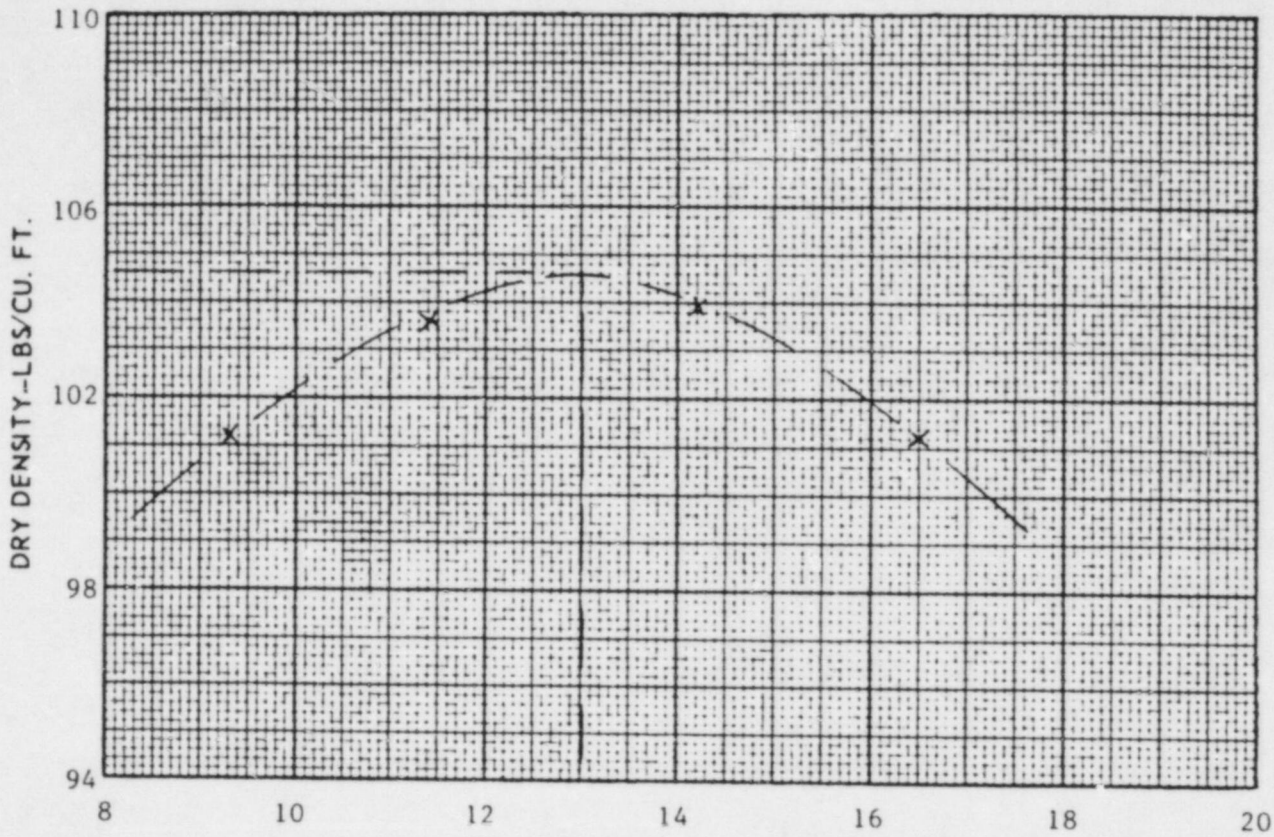
AASHTO T180 and ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 LBS.	18"	56,250
B	-#4	6"	4.58"	5	56	10.0 LBS.	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 LBS.	18"	55,986
D	-3/4	6"	4.58"	5	56	10.0 LBS.	18"	55,986

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SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Shiprock Site, New Mexico **JOB NO.** LT83-2604



CURVE	SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS./CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
2	TP-2, Sands, 3'6"	13.0	104.6	D698	A	2604-2

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

AASHTO T99 and ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 LBS.	12"	12,375
B	-#4	6"	4.58"	3	56	5.5 LBS.	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 LBS.	12"	12,317
D	-3/4	6"	4.58"	3	56	5.5 LBS.	12"	12,317

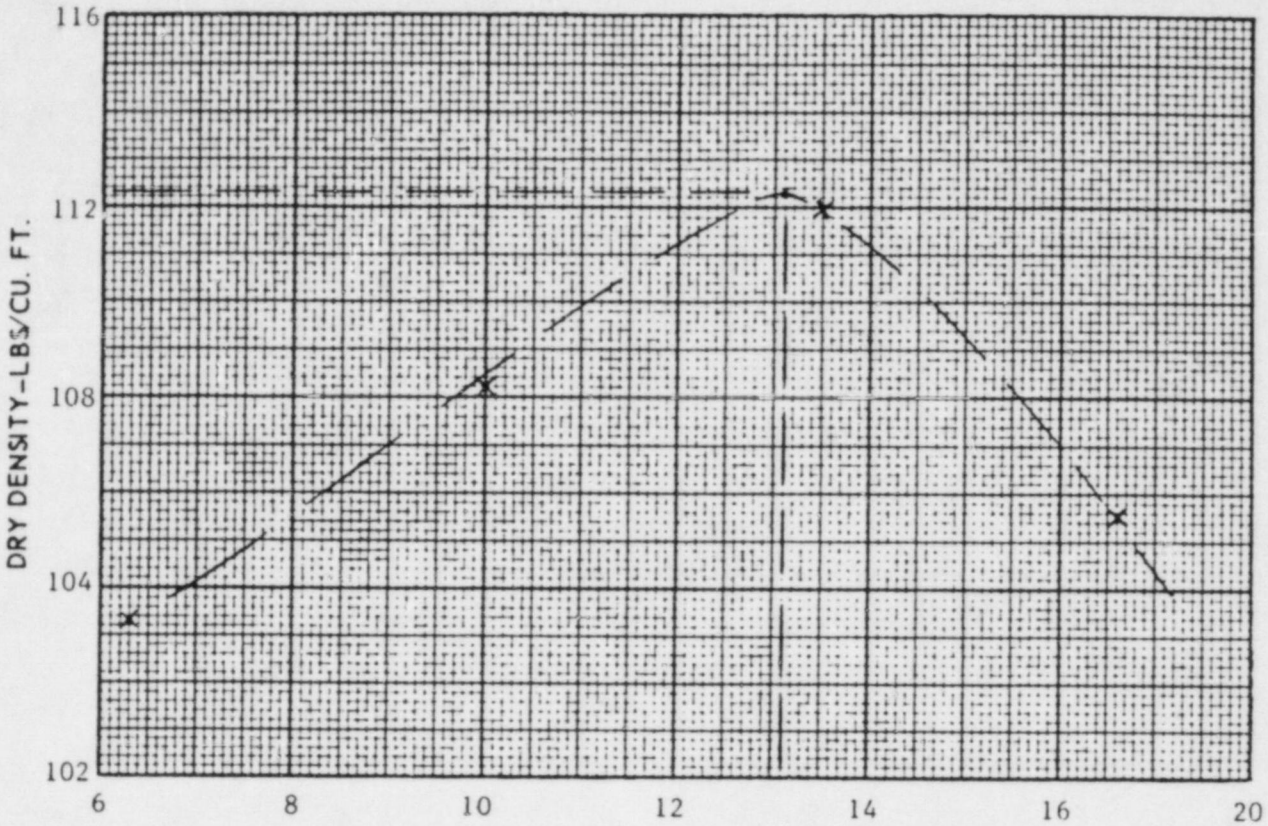
AASHTO T180 and ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 LBS.	18"	56,250
B	-#4	6"	4.58"	5	56	10.0 LBS.	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 LBS.	18"	55,986
D	-3/4	6"	4.58"	5	56	10.0 LBS.	18"	55,986

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SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Shiprock Site, New Mexico **JOB NO.** LT83-2604



CURVE	SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
3	TP-2, Sand/Slime, 6'6"	13.1	112.3	D698	A	2604-3

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

AASHTO T99 and ASTM D598 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 LBS.	12"	12,375
B	-#4	6"	4.58"	3	56	5.5 LBS.	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 LBS.	12"	12,317
D	-3/4	6"	4.58"	3	56	5.5 LBS.	12"	12,317

AASHTO T180 and ASTM D1557 (Modified Proctor)

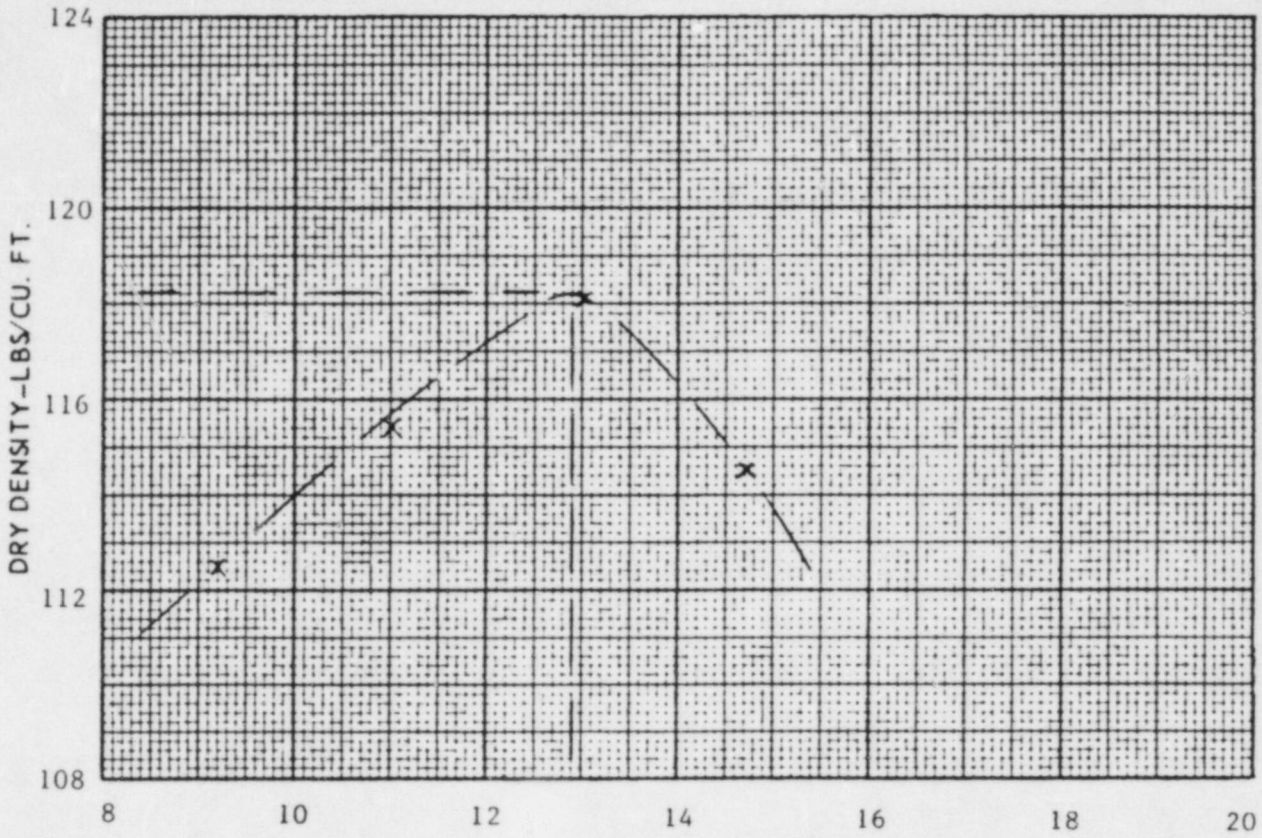
METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 LBS.	18"	56,250
B	-#4	6"	4.58"	5	56	10.0 LBS.	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 LBS.	18"	55,986
D	-3/4	6"	4.58"	5	56	10.0 LBS.	18"	55,986

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SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Shiprock Site, New Mexico **JOB NO.** LT83-2604



CURVE	SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS./CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
4	TP-3, Sand/Slime	12.9	118.2	D698	A	2604-4

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

AASHTO T99 and ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 LBS.	12"	12,375
B	-#4	6"	4.58"	3	56	5.5 LBS.	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 LBS.	12"	12,317
D	-3/4	6"	4.58"	3	56	5.5 LBS.	12"	12,317

AASHTO T180 and ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 LBS.	18"	56,250
B	-#4	6"	4.58"	5	56	10.0 LBS.	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 LBS.	18"	55,986
D	-3/4	6"	4.58"	5	56	10.0 LBS.	18"	55,986

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Bendix

Field Engineering Corporation

Grand Junction Operations

P.O. Box 1569
Grand Junction, CO 81502
Tel (303) 242-8621

A Subsidiary of
The Bendix Corporation

October 3, 1983

Dr. Ken Baker
Jacobs Engineering Group, Inc.
5301 Central Ave., NE
Suite 1700
Albuquerque, NM 87108

Dear Ken:

We are herewith transmitting a preliminary copy of the delta gamma, in-situ radium measurement data and the soil sample analysis results for the Shiprock site radiologic characterization project. The accompanying 9 track magnetic tape also contains these data. The final data presentation will be part of the final report.

The exposure rate and building survey information will be included in the final report, which is expected to follow in about two weeks.

Sincerely,

Dave

David A. Emilia
Director
Remedial Action Projects Division

DOE/GJAO Concurrence:

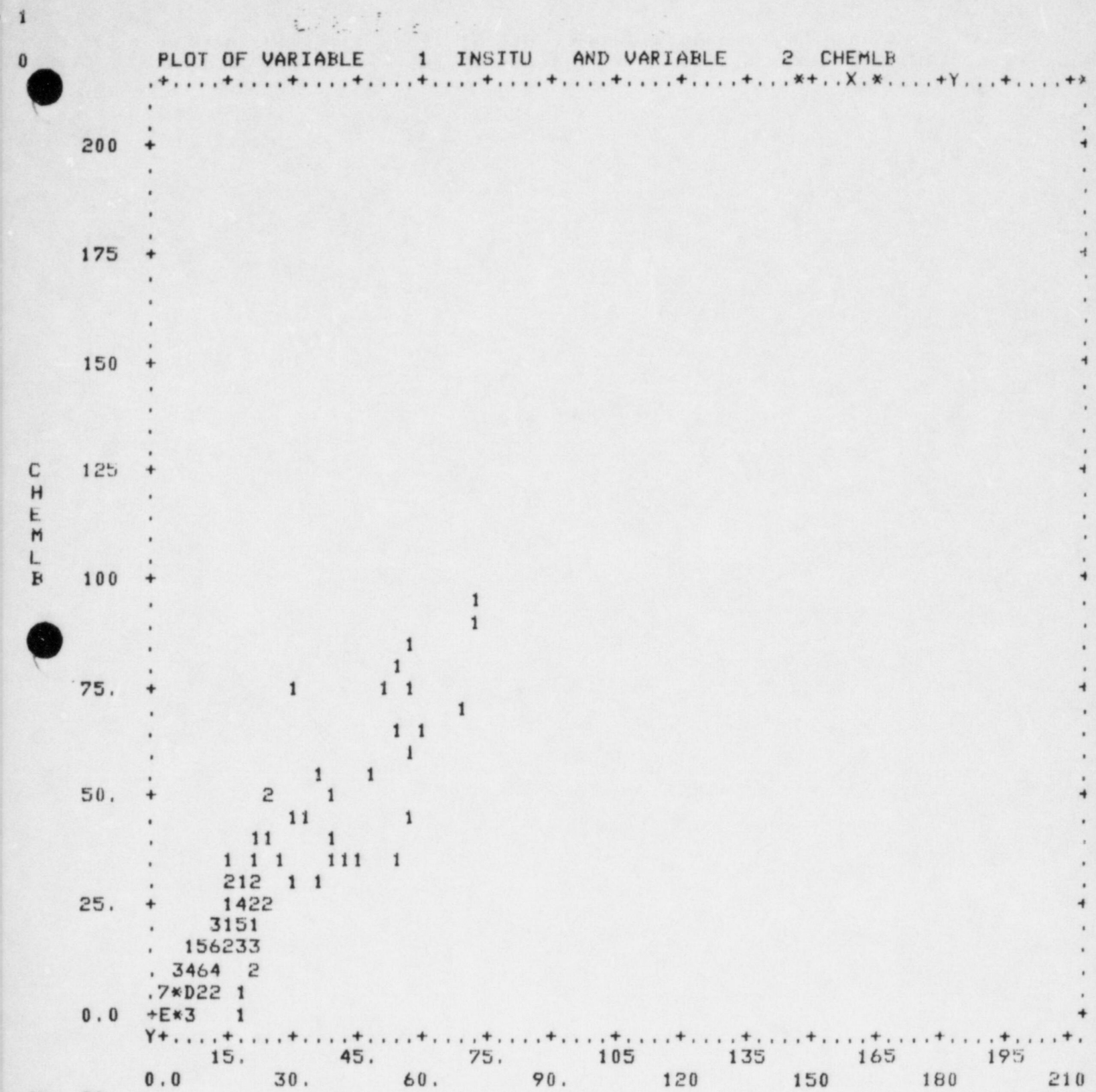
L. Ball Kenneth E. Campbell for

Enclosures

N= 211
COR= .953

	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	17.305	36.499	X= .57208*Y+ 3.9681	121.79
Y	23.313	60.829	Y= 1.5890*X-4.1839	338.28

PRELIMINARY



N= 206
COR= .930

	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	12.349	15.233	X= .73814*Y+ 1.3523	31.478
Y	14.898	19.194	Y= 1.1719*X+ .42636	49.975

PRELIMINARY

SHIPROCK SITE

	NORTH	EAST	DEPTH	DELTA ASSAY pCi(eRa-226)/g	LAB ASSAY
BACKGROUND	1.00	1.00	0	1.9 +/- .6	2.0 +/- 1.0
"	1.00	1.00	0		1.0 +/- 1.0
"	1.00	2.00	0	1.6 +/- .5	2.0 +/- 1.0
"	1.00	2.00	0	1.9 +/- .6	1.0 +/- 1.0
"	1.00	3.00	0	1.7 +/- .6	2.0 +/- 1.0
"	1.00	3.00	0	1.8 +/- .6	2.0 +/- 1.0
"	2.00	1.00	0	2.6 +/- .6	1.0 +/- 1.0
"	2.00	1.00	0	2.7 +/- .6	
"	2.00	2.00	0	2.4 +/- .5	1.0 +/- 1.0
"	2.00	2.00	0	1.0 +/- .6	
"	2.00	3.00	0	2.1 +/- .5	1.0 +/- 1.0
"	2.00	3.00	0	1.5 +/- .5	
"	3.00	1.00	0	1.5 +/- .5	2.0 +/- 1.0
"	3.00	1.00	0	1.3 +/- .6	
"	3.00	2.00	0	1.4 +/- .6	2.0 +/- 1.0
"	3.00	2.00	0	2.8 +/- .6	
"	3.00	3.00	0	2.1 +/- .5	1.0 +/- 1.0
"	3.00	3.00	0	2.2 +/- .6	
"	4.00	1.00	0	3.3 +/- .6	2.0 +/- 1.0
"	4.00	1.00	0	3.5 +/- .6	2.0 +/- 1.0
"	4.00	2.00	0	2.2 +/- .6	2.0 +/- 1.0
"	4.00	2.00	0	1.9 +/- .6	
"	4.00	3.00	0	2.4 +/- .6	1.0 +/- 1.0
BACKGROUND	4.00	3.00	0	1.7 +/- .6	
	6000.00	10987.00	0	4.7 +/- .6	2.0 +/- 1.0
	6000.00	11167.00	0	2.5 +/- .5	
	6003.00	10792.00	0	4.4 +/- .6	4.0 +/- 1.0
	6004.00	10792.00	0	7.4 +/- .7	
	6005.00	9991.00	0	1.8 +/- .6	
	6200.00	10387.00	0	1.6 +/- .6	1.0 +/- 1.0
	6200.00	10587.00	0	3.1 +/- .6	
	6200.00	10787.00	0	1.6 +/- .6	2.0 +/- 1.0
	6200.00	10988.00	0	1.8 +/- .6	
	6200.00	11187.00	0	1.3 +/- .5	1.0 +/- 1.0
	6200.00	11187.00	0		1.0 +/- 1.0
	6200.00	11365.00	0	3.6 +/- .6	
	6200.00	11388.00	0	3.0 +/- .5	
	6374.00	11592.00	0	1.9 +/- .6	
	6397.00	11390.00	0	-.2 +/- .5	
	6401.00	10588.00	0	14.1 +/- 1.0	
	6401.00	10788.00	0	2.7 +/- .6	1.0 +/- 1.0
	6401.00	10988.00	0	1.4 +/- .6	
	6401.00	11188.00	0	1.5 +/- .5	1.0 +/- 1.0
	6402.00	11591.00	0	2.6 +/- .6	2.0 +/- 1.0
	6404.00	10191.00	0	2.7 +/- .6	
	6424.00	10392.00	0	1.6 +/- .6	2.0 +/- 1.0
	6597.00	11390.00	0	2.8 +/- .6	
	6598.00	11592.00	0	3.0 +/- .6	4.0 +/- 1.0
	6600.00	10798.00	0	20.0 +/- 1.3	
	6600.00	10811.00	0	24.9 +/- 1.1	25.0 +/- ?.0

PRELIMINARY

SHIPROCK SITE

NORTH	EAST	DEPTH	DELTA ASSAY pCi(eRa-226)/g	LAB ASSAY
6600.00	10811.00	0		23.0 +/- 1.0
6600.00	10811.00	6	20.6 +/- 1.1	14.0 +/- 1.0
6600.00	10987.00	0	4.6 +/- .7	
6600.00	11187.00	0	1.3 +/- .6	3.0 +/- 1.0
6601.00	10798.00	0	21.8 +/- 1.3	
6603.00	10142.00	0	2.9 +/- .6	
6604.00	9991.00	0	1.7 +/- .6	2.0 +/- 1.0
6778.00	9992.00	0	1.8 +/- .6	2.0 +/- 1.0
6778.00	9992.00	0		2.0 +/- 1.0
6797.00	11390.00	0	3.7 +/- .6	1.0 +/- 1.0
6798.00	11592.00	0	1.7 +/- .5	
6800.00	11187.00	0	2.0 +/- .6	
6801.00	10988.00	0	13.1 +/- 1.2	11.0 +/- 1.0
6801.00	11021.00	0	12.2 +/- .9	
6804.00	9791.00	0	1.5 +/- .6	
6973.00	9792.00	0	1.6 +/- .6	
6997.00	11390.00	0	4.3 +/- .7	5.0 +/- 1.0
6998.00	11592.00	0	1.5 +/- .5	
6999.00	11791.00	0	.8 +/- .5	1.0 +/- 1.0
7000.00	11187.00	0	3.6 +/- .6	
7000.00	11187.00	0	2.3 +/- .6	
7000.00	11225.00	0	5.9 +/- .8	9.0 +/- 1.0
7004.00	9391.00	0	2.1 +/- .5	
7004.00	9591.00	0	1.6 +/- .6	1.0 +/- 1.0
7104.00	9291.00	0	1.8 +/- .6	
7173.00	9592.00	0	3.0 +/- .6	2.0 +/- 1.0
7174.00	9592.00	0	2.0 +/- .6	
7197.00	11390.00	0	19.5 +/- 1.1	23.0 +/- 1.0
7197.00	11390.00	0	23.4 +/- 1.2	
7197.00	11591.00	0	1.9 +/- .6	
7197.00	11790.00	0	1.3 +/- .5	2.0 +/- 1.0
7197.00	11991.00	0	.6 +/- .5	
7204.00	9391.00	0	1.6 +/- .6	
7373.00	9392.00	0	1.4 +/- .6	
7397.00	11790.00	0	1.8 +/- .6	2.0 +/- 1.0
7397.00	11790.00	0		2.0 +/- 1.0
7400.00	11587.00	0	2.8 +/- .6	
7404.00	9191.00	0	2.4 +/- .4	3.0 +/- 1.0
7404.00	9191.00	0		1.0 +/- 1.0
7603.00	9172.00	0	3.8 +/- .6	2.0 +/- 1.0
7603.00	9172.00	0	.8 +/- .6	2.0 +/- 1.0
7603.00	9192.00	0	2.2 +/- .4	
7604.00	9393.00	0	2.5 +/- .6	
7605.00	9393.00	0	2.3 +/- .6	
7624.00	9583.00	0	3.2 +/- .6	2.0 +/- 1.0
7800.00	9573.00	0	1.2 +/- .6	2.0 +/- 1.0
7800.00	9593.00	0	1.5 +/- .6	2.0 +/- 1.0
7800.00	9593.00	0		1.0 +/- 1.0
7803.00	9192.00	0	.7 +/- .6	2.0 +/- 1.0
7803.00	9392.00	0	1.0 +/- .6	

PRELIMINARY

SHIPROCK SITE

NORTH	EAST	DEPTH	DELTA ASSAY pCi(eRa-226)/g	LAB ASSAY
7803.00	9392.00	0	1.6 +/- .5	
7804.00	9192.00	0	2.3 +/- .5	
7820.00	9768.00	0	8.9 +/- .7	
7850.00	11850.00	0	56.1 +/- 1.6	45.0 +/- 2.0
7850.00	11850.00	6	6.8 +/- 1.2	
7997.00	11991.00	0	8.0 +/- 1.8	
8000.00	8793.00	0	.6 +/- .5	
8000.00	9193.00	0	.5 +/- .5	
8000.00	9357.00	0	1.0 +/- .6	
8000.00	9593.00	0	2.2 +/- .6	3.0 +/- 1.0
8000.00	9793.00	0	1.3 +/- .6	
8001.00	9793.00	0	1.0 +/- .6	
8004.00	8993.00	0	2.3 +/- .6	1.0 +/- 1.0
8075.00	9720.00	0		129.0 +/- 7.0
8075.00	9720.00	6		47.0 +/- 2.0
8075.00	9720.00	(24) 127.		8.0 +/- 1.0
8200.00	9392.00	0	1.1 +/- .5	
8200.00	9798.00	0 — 6"	43.8 +/- 1.2	
8200.00	9798.00	(0)	2.2 +/- .6	
8200.00	9798.00	0	2.4 +/- .6	
8200.00	9988.00	0	3.0 +/- .7	5.0 +/- 1.0
8200.00	11800.00	0	.3 +/- .6	2.0 +/- 1.0
8204.00	8593.00	0	1.9 +/- .5	1.0 +/- 1.0
8204.00	8793.00	0	2.7 +/- .6	2.0 +/- 1.0
8204.00	8993.00	0	2.3 +/- .6	1.0 +/- 1.0
8204.00	9193.00	0	.9 +/- .5	
8205.00	8993.00	0	2.1 +/- .6	
8205.00	9593.00	0	2.8 +/- .5	
8205.00	9793.00	0	1.5 +/- .6	
8260.00	11940.00	0	13.4 +/- .9	
8260.00	11940.00	6		3.0 +/- 1.0
8260.00	11940.00	6		2.0 +/- 1.0
8400.00	9620.00	0	1.1 +/- .6	
8400.00	9798.00	0	.5 +/- .6	
8400.00	9997.00	0	17.4 +/- 1.1	20.0 +/- 1.0
8400.00	11600.00	0	9.6 +/- 1.0	
8403.00	9192.00	0	-.1 +/- .5	
8404.00	8793.00	0	.9 +/- .5	
8404.00	8993.00	0	1.7 +/- .6	2.0 +/- 1.0
8408.00	8593.00	0	1.4 +/- .6	1.0 +/- 1.0
8521.00	11853.00	0	20.4 +/- 1.0	29.0 +/- 2.0
8521.00	11853.00	0		29.0 +/- 1.0
8521.00	11853.00	6	24.1 +/- 1.6	48.0 +/- 2.0
8585.00	9615.00	0	1.4 +/- .5	
8600.00	9798.00	0	7.3 +/- .7	2.0 +/- 1.0
8600.00	10000.00	0	4.3 +/- .7	
8600.00	11400.00	0	8.7 +/- .9	
8600.00	11600.00	0	7.2 +/- .8	9.0 +/- 1.0
8600.00	11600.00	0		9.0 +/- 1.0
8600.00	11800.00	0	18.6 +/- 1.0	29.0 +/- 3.0

PRELIMINARY

SHIPROCK SITE

NORTH	EAST	DEPTH	pCi(eRa-226)/g DELTA ASSAY	LAB ASSAY
8600.00	11800.00	0		25.0 +/- 1.0
8600.00	11800.00	6	5.2 +/- 1.0	7.0 +/- 1.0
8600.00	11800.00	6	5.5 +/- 1.0	
8601.00	9798.00	0	2.5 +/- .6	
8601.00	11600.00	0	6.5 +/- .8	
8603.00	9192.00	0	1.0 +/- .5	
8603.00	9392.00	0	2.1 +/- .5	
8605.00	8793.00	0	-.4 +/- .5	
8605.00	8993.00	0	1.4 +/- .6	3.0 +/- 1.0
8645.00	9843.00	0	300.6 +/-48.4	345.0 +/-17.0
8645.00	9843.00	6		304.0 +/-31.0
8645.00	9843.00	12		224.0 +/-23.0
8645.00	9843.00	24		92.0 +/- 9.0
8675.00	9847.00	0	281.6 +/- 2.9	562.0 +/-57.0
8675.00	9847.00	6	213.2 +/- 3.5	475.0 +/-25.0
8675.00	9847.00	6		477.0 +/-49.0
8675.00	9847.00	12	164.8 +/- 3.4	219.0 +/-22.0
8675.00	9847.00	18	147.2 +/- 3.2	249.0 +/-13.0
8675.00	9847.00	24	101.1 +/- 3.0	
8700.00	11700.00	0	17.2 +/- 1.0	19.0 +/- 2.0
8700.00	11700.00	6	3.4 +/- .8	7.0 +/- 1.0
8710.00	9683.00	0	54.7 +/- 1.4	36.0 +/- 4.0
8710.00	9683.00	6	48.6 +/- 1.6	54.0 +/- 6.0
8710.00	9683.00	12	3.3 +/- .9	
8748.00	9722.00	0	41.1 +/- 1.2	36.0 +/- 4.0
8748.00	9722.00	4	57.2 +/- 2.0	
8748.00	9722.00	6	35.1 +/- 1.5	
8761.00	11771.00	0	10.6 +/- .8	4.0 +/- 1.0
8761.00	11771.00	0		4.0 +/- 1.0
8761.00	11771.00	6	15.3 +/- .9	26.0 +/- 1.0
8798.00	10200.00	0	20.3 +/- 1.1	16.0 +/- 2.0
8798.00	10200.00	0	18.4 +/- 1.0	
8798.00	10200.00	0	16.0 +/- 1.0	
8798.00	10200.00	6	15.2 +/- 1.0	15.0 +/- 1.0
8800.00	10000.00	0	3.1 +/- .7	
8800.00	10000.00	0	4.2 +/- .7	
8800.00	11200.00	0	17.0 +/- .9	20.0 +/- 2.0
8800.00	11200.00	6	15.4 +/- 1.0	
8800.00	11400.00	0	6.3 +/- .8	7.0 +/- 1.0
8800.00	11600.00	0	10.6 +/- .9	15.0 +/- 1.0
8800.00	11600.00	0	8.1 +/- .8	9.0 +/- 1.0
8800.00	11600.00	0		16.0 +/- 1.0
8800.00	11600.00	6	2.8 +/- .8	4.0 +/- 1.0
8800.00	11600.00	6	2.3 +/- .7	
8800.00	11800.00	0	4.5 +/- .7	3.0 +/- 1.0
8801.00	9397.00	0	.5 +/- .5	
8801.00	9598.00	0	1.5 +/- .6	
8801.00	9798.00	0	3.7 +/- .6	3.0 +/- 1.0
8801.00	11200.00	0	11.7 +/- .9	
8803.00	9192.00	0	2.9 +/- .6	

PRELIMINARY

SHIPROCK SITE

pCi(eRa-226)/g

NORTH	EAST	DEPTH	DELTA ASSAY	LAB ASSAY
8803.00	9192.00	0	3.4 +/- .6	
8804.00	8793.00	0	1.4 +/- .5	2.0 +/- 1.0
8804.00	8993.00	0	1.3 +/- .6	3.0 +/- 1.0
8871.00	11671.00	0	11.1 +/- .9	11.0 +/- 1.0
8871.00	11671.00	6	2.3 +/- .7	2.0 +/- 1.0
8871.00	11871.00	0	3.0 +/- .6	
8900.00	11300.00	0	19.8 +/- 1.2	39.0 +/- 4.0
8900.00	11300.00	0	21.9 +/- 1.2	26.0 +/- 1.0
8900.00	11300.00	6	7.5 +/- .9	10.0 +/- 1.0
8900.00	11300.00	6	6.1 +/- .8	
8900.00	11500.00	0	29.3 +/- 1.4	75.0 +/- 3.0
8900.00	11500.00	0		52.0 +/- 5.0
8900.00	11500.00	6	1.9 +/- 1.0	4.0 +/- 1.0
8900.00	11500.00	6	2.7 +/- .9	
8900.00	11700.00	0	15.1 +/- .9	36.0 +/- 4.0
8900.00	11700.00	0		35.0 +/- 2.0
8900.00	11700.00	6	4.2 +/- .9	7.0 +/- 1.0
8906.00	11906.00	0	1.3 +/- .6	
8942.00	11721.00	0	14.2 +/- .9	30.0 +/- 1.0
8942.00	11721.00	0	10.6 +/- .9	
8942.00	11721.00	6	11.4 +/- .9	19.0 +/- 1.0
8969.00	11770.00	0	3.4 +/- .7	
8969.00	11770.00	0	3.5 +/- .7	
8971.00	11571.00	0	16.0 +/- 1.1	19.0 +/- 1.0
8971.00	11571.00	6	4.4 +/- .8	4.0 +/- 1.0
8998.00	9600.00	0	2.6 +/- .6	
8998.00	9800.00	0	2.0 +/- .6	2.0 +/- 1.0
8998.00	10000.00	0	2.2 +/- .6	
8998.00	10200.00	0	5.0 +/- .7	6.0 +/- 1.0
9000.00	9400.00	0	1.9 +/- .5	
9000.00	11200.00	0	38.1 +/- 1.5	39.0 +/- 4.0
9000.00	11200.00	0	48.2 +/- 1.7	
9000.00	11200.00	6	4.2 +/- 1.3	
9000.00	11200.00	6	1.8 +/- .9	
9000.00	11400.00	0	9.5 +/- .8	11.0 +/- 1.0
9000.00	11400.00	6	5.5 +/- .8	7.0 +/- 1.0
9004.00	9192.00	0	1.6 +/- .5	
9016.00	11809.00	0	4.8 +/- .7	
9026.00	11624.00	0	9.1 +/- .8	15.0 +/- 2.0
9026.00	11624.00	0	11.3 +/- .9	
9026.00	11624.00	6		14.0 +/- 1.0
9074.00	11468.00	0	10.8 +/- 1.1	15.0 +/- 2.0
9074.00	11468.00	6	2.5 +/- .8	7.0 +/- 1.0
9088.00	11683.00	0	11.3 +/- .8	4.0 +/- 1.0
9088.00	11683.00	6	18.3 +/- 1.0	17.0 +/- 1.0
9088.00	11683.00	12	3.4 +/- .9	7.0 +/- 1.0
9100.00	11100.00	0	56.4 +/- 1.7	75.0 +/- 8.0
9100.00	11100.00	0	59.4 +/- 1.7	64.0 +/- 3.0
9100.00	11100.00	6	9.8 +/- 1.2	
9100.00	11300.00	0	5.1 +/- 1.0	3.0 +/- 1.0

PRELIMINARY

SHIPROCK SITE

NORTH	EAST	DEPTH	DELTA ASSAY pCi(eRa-226)/g	LAB ASSAY
9143.00	11533.00	0	19.7 +/- 1.1	21.0 +/- 2.0
9143.00	11533.00	6	2.7 +/- .8	2.0 +/- 1.0
9154.00	11746.00	0	4.0 +/- .7	
9154.00	11746.00	0	4.2 +/- .7	
9163.00	11364.00	0	18.9 +/- 1.2	25.0 +/- 1.0
9163.00	11364.00	6	3.8 +/- .9	5.0 +/- 1.0
9163.00	11364.00	6		6.0 +/- 1.0
9200.00	9400.00	0	2.1 +/- .6	3.0 +/- 1.0
9200.00	9600.00	0	.4 +/- .5	
9200.00	9800.00	0	2.3 +/- .6	2.0 +/- 1.0
9200.00	9800.00	0		2.0 +/- 1.0
9200.00	10000.00	0	4.9 +/- .7	
9200.00	10000.00	0	6.1 +/- .7	
9200.00	11000.00	0	55.9 +/- 1.7	59.0 +/- 3.0
9200.00	11000.00	0	59.8 +/- 1.8	
9200.00	11000.00	6	2.8 +/- 1.1	
9200.00	11200.00	0	20.6 +/- 1.2	37.0 +/- 2.0
9200.00	11200.00	0		34.0 +/- 2.0
9200.00	11200.00	6	1.0 +/- .8	
9200.00	11203.00	0	19.9 +/- 1.2	
9201.00	9600.00	0	1.6 +/- .6	
9206.00	11592.00	0	7.8 +/- .8	11.0 +/- 1.0
9206.00	11592.00	6	3.0 +/- .7	3.0 +/- 1.0
9206.00	11593.00	0	9.4 +/- .8	
9206.00	11593.00	6		5.0 +/- 1.0
9224.00	9808.00	0	9.2 +/- .8	
9224.00	11422.00	0	9.6 +/- 1.0	17.0 +/- 1.0
9224.00	11422.00	0	10.7 +/- 1.0	
9251.00	11249.00	0	18.0 +/- 1.1	26.0 +/- 3.0
9251.00	11249.00	6	5.8 +/- .8	14.0 +/- 2.0
9272.00	11656.00	0	3.4 +/- .7	
9284.00	11485.00	0	18.4 +/- 1.0	19.0 +/- 2.0
9284.00	11485.00	0	20.2 +/- 1.0	
9284.00	11485.00	6	5.6 +/- .9	12.0 +/- 1.0
9284.00	11485.00	6		4.0 +/- 1.0
9297.00	9249.00	0	16.5 +/- 1.0	27.0 +/- 3.0
9297.00	9249.00	0	16.6 +/- 1.0	13.0 +/- 1.0
9298.00	11684.00	0	2.1 +/- .6	
9300.00	10900.00	0	44.2 +/- 1.6	36.0 +/- 4.0
9300.00	10900.00	0	30.0 +/- 1.5	46.0 +/- 2.0
9300.00	11100.00	0	38.3 +/- 1.5	33.0 +/- 3.0
9300.00	11100.00	0	23.0 +/- 1.4	52.0 +/- 5.0
9300.00	11100.00	6	3.0 +/- .9	5.0 +/- 1.0
9300.00	11100.00	6	2.6 +/- .9	
9307.00	11303.00	0	11.6 +/- .9	13.0 +/- 1.0
9307.00	11303.00	6	2.7 +/- .7	9.0 +/- 1.0
9317.00	9294.00	0	54.6 +/- 1.5	80.0 +/- 8.0
9317.00	9294.00	0	54.8 +/- 1.5	63.0 +/- 3.0
9317.00	9294.00	6	3.5 +/- 1.1	
9317.00	9294.00	6	2.7 +/- 1.0	

PRELIMINARY

SHIPROCK SITE

NORTH	EAST	DEPTH	DELTA ASSAY pCi(eRa-226)/g	LAB ASSAY
9325.00	9001.00	0	192.9 +/- 2.2	
9334.00	11720.00	0	.6 +/- .6	
9337.00	11716.00	0	3.3 +/- .6	
9355.00	11545.00	0	6.6 +/- .8	
9355.00	11545.00	0	5.3 +/- .7	
9362.00	11160.00	0	6.7 +/- .9	6.0 +/- 1.0
9362.00	11160.00	6	1.3 +/- .7	4.0 +/- 1.0
9362.00	11160.00	6		4.0 +/- 1.0
9364.00	11359.00	0	12.0 +/- .9	20.0 +/- 2.0
9364.00	11359.00	6	1.7 +/- .7	6.0 +/- 1.0
9397.00	9369.00	0	7.7 +/- .7	
9397.00	9414.00	0	3.2 +/- .7	
9398.00	9600.00	0	2.0 +/- .6	3.0 +/- 1.0
9400.00	9800.00	0	.2 +/- .5	
9400.00	10800.00	0	16.8 +/- 1.3	17.0 +/- 1.0
9400.00	10800.00	0	18.1 +/- 1.3	
9400.00	10800.00	6	3.7 +/- .9	
9400.00	11000.00	0	35.5 +/- 1.5	30.0 +/- 2.0
9400.00	11000.00	0	23.5 +/- 1.2	
9400.00	11000.00	6	1.4 +/- .9	
9407.00	11608.00	0	4.6 +/- .7	4.0 +/- 1.0
9407.00	11608.00	0	5.5 +/- .7	7.0 +/- 1.0
9424.00	11219.00	0	8.3 +/- .9	13.0 +/- 1.0
9424.00	11219.00	6	3.5 +/- .7	8.0 +/- 1.0
9436.00	11427.00	0	11.2 +/- 1.0	11.0 +/- 1.0
9436.00	11427.00	6	2.5 +/- .8	5.0 +/- 1.0
9455.00	9350.00	0	70.8 +/- 1.7	92.0 +/- 9.0
9455.00	9350.00	0	72.4 +/- 1.7	93.0 +/- 9.0
9455.00	9350.00	6		8.0 +/- 1.0
9463.00	11065.00	0	12.8 +/- .9	16.0 +/- 2.0
9463.00	11065.00	6	3.0 +/- .7	
9474.00	11668.00	0	5.6 +/- .7	
9474.00	11668.00	0	6.4 +/- .7	
9482.00	11273.00	0	11.6 +/- .9	14.0 +/- 1.0
9482.00	11273.00	6	4.0 +/- .7	5.0 +/- 1.0
9500.00	10700.00	0	27.8 +/- 1.4	35.0 +/- 2.0
9500.00	10700.00	0	22.3 +/- 1.3	9.0 +/- 1.0
9500.00	10700.00	6	2.7 +/- .8	
9500.00	10900.00	0	14.9 +/- 1.0	
9500.00	11491.00	0	6.1 +/- .8	
9501.00	10900.00	0	9.1 +/- .9	
9506.00	9461.00	0	78.5 +/- 1.8	
9506.00	9461.00	6		2.0 +/- 1.0
9521.00	11125.00	0	12.3 +/- .9	
9540.00	11332.00	0	10.0 +/- .9	15.0 +/- 2.0
9540.00	11332.00	6	1.5 +/- .7	7.0 +/- 1.0
9560.00	10958.00	0	10.5 +/- .9	
9573.00	11555.00	0	5.7 +/- .7	
9579.00	11185.00	0	4.5 +/- .7	4.0 +/- 1.0
9600.00	9600.00	0	.5 +/- .6	3.0 +/- 1.0

PRELIMINARY

SHIPROCK SITE

NORTH	EAST	DEPTH	DELTA ASSAY pCi(eRa-226)/g	LAB ASSAY
9600.00	10596.00	0	10.4 +/- .9	
9600.00	10600.00	0	10.6 +/- .9	17.0 +/- 1.0
9600.00	10799.00	0	30.2 +/- 1.3	
9600.00	10799.00	0	32.3 +/- 1.3	
9600.00	10800.00	0	10.2 +/- 1.0	
9600.00	10800.00	6		4.0 +/- 1.0
9600.00	10800.00	6		4.0 +/- 1.0
9607.00	11394.00	0	6.5 +/- .8	7.0 +/- 1.0
9607.00	11394.00	6	1.6 +/- .7	1.0 +/- 1.0
9618.00	9269.00	0	38.0 +/- 1.2	48.0 +/- 2.0
9618.00	9269.00	6	50.6 +/- 1.6	77.0 +/- 4.0
9618.00	9269.00	12		21.0 +/- 1.0
9623.00	11017.00	0	3.4 +/- .7	
9630.00	9600.00	0	16.9 +/- 1.1	21.0 +/- 1.0
9630.00	9600.00	0		30.0 +/- 1.0
9630.00	9600.00	6		14.0 +/- 1.0
9633.00	11612.00	0	5.9 +/- .7	
9638.00	11246.00	0	5.0 +/- .8	
9667.00	11450.00	0	8.6 +/- .9	
9667.00	11450.00	6	1.0 +/- .7	4.0 +/- 1.0
9671.00	10873.00	0	2.7 +/- .6	1.0 +/- 1.0
9684.00	11079.00	0	4.0 +/- .6	
9698.00	11304.00	0	9.8 +/- .9	16.0 +/- 1.0
9698.00	11304.00	6	1.7 +/- .7	5.0 +/- 1.0
9700.00	10500.00	0	4.2 +/- .8	8.0 +/- 1.0
9700.00	10500.00	0	5.4 +/- .8	
9700.00	10700.00	0	19.9 +/- 1.0	10.0 +/- 1.0
9700.00	10700.00	0	10.5 +/- .8	4.0 +/- 1.0
9700.00	10700.00	6	11.0 +/- .9	
9712.00	9231.00	0	34.7 +/- 1.1	53.0 +/- 3.0
9712.00	9231.00	0	34.3 +/- 1.1	47.0 +/- 2.0
9712.00	9231.00	0		47.0 +/- 2.0
9712.00	9231.00	6	29.8 +/- 1.3	31.0 +/- 3.0
9712.00	9231.00	6		50.0 +/- 2.0
9712.00	9231.00	12		39.0 +/- 2.0
9724.00	11507.00	0	4.9 +/- .7	
9731.00	10935.00	0	17.8 +/- 1.0	7.0 +/- 1.0
9731.00	10935.00	0		22.0 +/- 1.0
9731.00	10935.00	6	5.0 +/- .8	
9745.00	11139.00	0	4.9 +/- .7	
9750.00	10500.00	0	13.4 +/- .9	
9755.00	11362.00	0	8.1 +/- .9	9.0 +/- 1.0
9766.00	10782.00	0	19.3 +/- 1.0	1.0 +/- 1.0
9766.00	10782.00	6	.7 +/- .6	1.0 +/- 1.0
9777.00	11564.00	0	4.4 +/- .7	
9791.00	10997.00	0	5.8 +/- .7	
9791.00	10997.00	6	3.9 +/- .7	
9800.00	9600.00	0	1.4 +/- .6	2.0 +/- 1.0
9800.00	10400.00	0	57.7 +/- 1.5	84.0 +/- 9.0
9800.00	10400.00	0	69.9 +/- 1.6	71.0 +/- 3.0

PRELIMINARY

NORTH	EAST	DEPTH	DELTA ASSAY pCi(eRa-226)/g	LAB ASSAY
9800.00	10400.00	6	25.2 +/- 1.5	42.0 +/- 2.0
9800.00	10400.00	12	4.5 +/- 1.1	
9800.00	10600.00	0	4.5 +/- .7	
9801.00	10400.00	0	67.6 +/- 1.6	
9808.00	11199.00	0	1.7 +/- .6	
9822.00	11428.00	0	6.0 +/- .8	5.0 +/- 1.0
9826.00	10861.00	0	2.7 +/- .7	
9850.00	10350.00	0	73.9 +/- 1.8	
9850.00	10360.00	0	1.0 +/- .6	
9851.00	11059.00	0	4.9 +/- .8	8.0 +/- 1.0
9851.00	11059.00	6	2.5 +/- .6	
9865.00	11258.00	0	10.2 +/- .9	
9880.00	10674.00	0	10.6 +/- .9	12.0 +/- 1.0
9880.00	10674.00	0		11.0 +/- 1.0
9880.00	10674.00	6	3.8 +/- .8	5.0 +/- 1.0
9881.00	11479.00	0	1.8 +/- .6	
9886.00	10939.00	0	3.5 +/- .6	
9900.00	10300.00	0	14.1 +/- .9	14.0 +/- 1.0
9900.00	10500.00	0	8.5 +/- .8	8.0 +/- 1.0
9900.00	10500.00	6		3.0 +/- 1.0
9913.00	11120.00	0	10.9 +/- .9	18.0 +/- 1.0
9913.00	11120.00	6	4.4 +/- .7	
9927.00	11315.00	0	10.4 +/- .8	
9940.00	10534.00	0	1.7 +/- .6	
9942.00	11563.00	0	3.4 +/- .6	7.0 +/- 1.0
9947.00	11017.00	0	7.2 +/- .8	
9950.00	10758.00	0	4.1 +/- .7	3.0 +/- 1.0
9967.00	9266.00	0	23.0 +/- 1.0	25.0 +/- 1.0
9967.00	9266.00	0	31.3 +/- 1.3	
9972.00	11179.00	0	4.2 +/- .7	7.0 +/- 1.0
9972.00	11179.00	6	3.5 +/- .7	
9988.00	11384.00	0	6.0 +/- .7	
10000.00	10200.00	0	2.8 +/- .6	
10000.00	10400.00	0	4.7 +/- .7	
10011.00	10605.00	0	2.2 +/- .6	
10011.00	11106.00	0	4.5 +/- .7	
10030.00	11226.00	0	7.8 +/- .8	5.0 +/- 1.0
10031.00	10837.00	0	7.0 +/- .7	7.0 +/- 1.0
10031.00	10837.00	6	5.3 +/- .7	
10037.00	11443.00	0	3.6 +/- .6	
10070.00	11183.00	0	7.0 +/- .8	
10092.00	11301.00	0	6.1 +/- .7	3.0 +/- 1.0
10092.00	11301.00	0		2.0 +/- 1.0
10100.00	10100.00	0	2.9 +/- .6	1.0 +/- 1.0
10100.00	10300.00	0	4.7 +/- .6	3.0 +/- 1.0
10100.00	10300.00	0		3.0 +/- 1.0
10105.00	10691.00	0	5.3 +/- .6	
10111.00	10921.00	0	1.3 +/- .6	1.0 +/- 1.0
10120.00	11403.00	0	3.0 +/- .6	5.0 +/- 1.0
10123.00	11260.00	0	7.1 +/- .8	

PRELIMINARY

SHIPROCK SITE

NORTH	EAST	DEPTH	pCi(eRa-226)/g DELTA ASSAY	LAB ASSAY
10147.00	10729.00	0	4.0 +/- .7	
10179.00	11362.00	0	3.5 +/- .6	
10200.00	10200.00	0	3.2 +/- .6	
10331.00	9488.00	0	19.5 +/- 1.0	26.0 +/- 3.0
10331.00	9488.00	0		24.0 +/- 1.0
10331.00	9488.00	6		4.0 +/- 1.0
10452.00	9546.00	0	22.1 +/- 1.0	31.0 +/- 1.0
10452.00	9546.00	0	19.9 +/- 1.0	29.0 +/- 2.0
10452.00	9546.00	0		16.0 +/- 2.0
10452.00	9546.00	6	15.6 +/- 1.1	30.0 +/- 1.0
10452.00	9546.00	6	15.6 +/- 1.1	
10452.00	9546.00	12	4.4 +/- .9	
10558.00	9440.00	0	13.0 +/- .9	
10558.00	9440.00	6	2.8 +/- .8	

37 pCi/g

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PRELIMINARY

TO ~ Smith

SHIPROCK TAILINGS PILE AVERAGE RA-226 FROM BENDIX DATA 12-1-83.

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
A-016	0.0	392	1	392.00	392.00
A-016	7.5	430	2	822.00	411.00
A-016	10.0	302	3	1124.00	374.67
A-016	12.5	242	4	1366.00	341.50
A-016	15.0	370	5	1736.00	347.20
A-016	17.5	483	6	2219.00	369.83
A-016	20.0	362	7	2581.00	368.71
A-016	22.5	502	8	3083.00	385.38
A-016	25.0	453	9	3536.00	392.89
A-016	27.5	219	10	3755.00	375.50
A-016	30.0	331	11	4086.00	371.45
A-016	32.5	375	12	4461.00	371.75
A-016	37.5	319	13	4780.00	367.69
A-016	40.0	478	14	5258.00	375.57
A-020	0.0	423	15	5681.00	378.73
A-020	7.5	817	16	6498.00	406.13
A-020	10.0	522	17	7020.00	412.94
A-020	15.0	377	18	7397.00	410.94
A-020	17.5	893	19	8290.00	436.32
A-020	20.0	770	20	9060.00	453.00
A-020	22.5	959	21	10019.00	477.10
A-020	27.5	1222	22	11241.00	510.95
A-020	30.0	1301	23	12542.00	545.30
A-020	32.5	899	24	13441.00	560.04
A-020	35.0	173	25	13614.00	544.56
A-022	22.5	225	26	13839.00	532.27
A-022	25.0	237	27	14076.00	521.33
A-022	27.5	414	28	14490.00	517.50
A-022	30.0	412	29	14902.00	513.86
A-022	35.0	1223	30	16125.00	537.50
A-024	0.0	196	31	16321.00	526.48
A-024	5.0	445	32	16766.00	523.94
A-024	10.0	459	33	17225.00	521.97
A-024	12.5	252	34	17477.00	514.03
A-024	15.0	552	35	18029.00	515.11
A-024	17.5	383	36	18412.00	511.44
A-026	0.0	390	37	18802.00	508.16
A-026	5.0	854	38	19656.00	517.26
A-026	7.5	1413	39	21069.00	540.23
A-026	10.0	685	40	21754.00	543.85
A-026	12.5	1528	41	23282.00	567.85
A-026	15.0	838	42	24120.00	574.29
A-026	17.5	1040	43	25160.00	585.12
A-026	20.0	442	44	25602.00	581.86
A-026	25.0	398	45	26000.00	577.78
A-026	27.5	841	46	26841.00	583.50
A-026	30.0	388	47	27229.00	579.34
A-026	32.5	490	48	27719.00	577.48
A-026	35.0	1642	49	29361.00	599.20
A-028	5.0	849	50	30210.00	604.20
A-028	7.5	568	51	30778.00	603.49
A-028	10.0	342	52	31120.00	598.46
A-028	12.5	331	53	31451.00	593.42
A-028	15.0	316	54	31767.00	588.28

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
A-028	17.5	262	55	32029.00	582.35
A-029	10.0	403	56	32432.00	579.14
A-029	12.5	358	57	32790.00	575.26
A-029	15.0	494	58	33284.00	573.86
A-029	17.5	986	59	34270.00	580.85
A-029	22.5	968	60	35238.00	587.30
A-029	25.0	369	61	35607.00	583.72
A-029	30.0	830	62	36437.00	587.69
A-029	32.5	40	63	36477.00	579.00
A-029	35.0	776	64	37253.00	582.08
A-030	0.0	294	65	37547.00	577.65
A-030	2.5	313	66	37860.00	573.64
A-030	5.0	356	67	38216.00	570.39
A-030	7.5	496	68	38712.00	569.29
A-030	10.0	413	69	39125.00	567.03
A-030	12.5	629	70	39754.00	567.91
A-030	15.0	528	71	40282.00	567.35
A-030	17.5	239	72	40521.00	562.79
A-031	7.5	382	73	40903.00	560.32
A-031	10.0	333	74	41236.00	557.24
A-031	12.5	466	75	41702.00	556.03
A-031	15.0	224	76	41926.00	551.66
A-031	17.5	566	77	42492.00	551.84
A-031	22.5	602	78	43094.00	552.49
A-031	25.0	231	79	43325.00	548.42
A-031	27.5	395	80	43720.00	546.50
A-031	30.0	1409	81	45129.00	557.15
A-031	35.0	349	82	45478.00	554.61
A-032	5.0	2420	83	47898.00	577.08
A-032	7.5	2084	84	49982.00	595.02
A-032	10.0	1696	85	51678.00	607.98
A-033	0.0	361	86	52039.00	605.10
A-033	2.5	353	87	52392.00	602.21
A-033	5.0	318	88	52710.00	598.98
A-033	7.5	439	89	53149.00	597.18
A-033	10.0	366	90	53515.00	594.61
A-033	12.5	249	91	53764.00	590.81
A-033	15.0	297	92	54061.00	587.62
A-033	17.5	327	93	54388.00	584.82
A-034	0.0	243	94	54631.00	581.18
A-034	2.5	580	95	55211.00	581.17
A-034	5.0	443	96	55654.00	579.73
A-034	7.5	215	97	55869.00	575.97
A-034	10.0	252	98	56121.00	572.66
A-034	12.5	680	99	56801.00	573.75
A-034	15.0	813	100	57614.00	576.14
A-034	17.5	636	101	58250.00	576.73
A-034	20.0	439	102	58689.00	575.38
A-034	22.5	318	103	59007.00	572.88
A-034	25.0	305	104	59312.00	570.31
A-034	27.5	349	105	59661.00	568.20
A-034	30.0	484	106	60145.00	567.41
A-034	32.5	321	107	60466.00	565.10
A-034	35.0	326	108	60792.00	562.89

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
A-034	37.5	2161	109	62953.00	577.55
A-035	0.0	264	110	63217.00	574.70
A-035	2.5	258	111	63475.00	571.85
A-035	5.0	276	112	63751.00	569.21
A-035	7.5	398	113	64149.00	567.69
A-035	10.0	388	114	64537.00	566.11
A-035	12.5	471	115	65008.00	565.29
A-035	15.0	324	116	65332.00	563.21
A-035	17.5	512	117	65844.00	562.77
B-001	0.0	7	118	65851.00	558.06
B-001	7.5	469	119	66320.00	557.31
B-002	7.5	355	120	66675.00	555.63
B-003	2.5	523	121	67198.00	555.36
B-003	5.0	32	122	67230.00	551.07
B-003	7.5	81	123	67311.00	547.24
B-004	0.0	498	124	67809.00	546.85
B-008	7.5	1463	125	69272.00	554.18
B-009	12.5	1218	126	70490.00	559.44
B-010	2.5	404	127	70894.00	558.22
B-010	10.0	453	128	71347.00	557.40
B-010	12.5	978	129	72325.00	560.66
B-010	15.0	1354	130	73679.00	566.76
B-010	20.0	1451	131	75130.00	573.51
B-010	25.0	940	132	76070.00	576.29
B-011	2.5	623	133	76693.00	576.64
B-011	5.0	281	134	76974.00	574.43
B-012	7.5	910	135	77884.00	576.92
B-012	12.5	409	136	78293.00	575.68
B-012	22.5	72	137	78365.00	572.01
B-012	25.0	102	138	78467.00	568.60
B-013	0.0	315	139	78782.00	566.78
B-013	2.5	58	140	78840.00	563.14
B-013	5.0	284	141	79124.00	561.16
B-013	7.5	341	142	79465.00	559.61
B-013	10.0	433	143	79898.00	558.73
B-014	0.0	230	144	80128.00	556.44
B-014	5.0	299	145	80427.00	554.67
B-014	10.0	296	146	80723.00	552.90
B-014	12.5	725	147	81448.00	554.07
B-014	15.0	380	148	81828.00	552.89
B-014	17.5	359	149	82187.00	551.59
B-014	20.0	338	150	82525.00	550.17
B-014	22.5	401	151	82926.00	549.18
B-015	5.0	136	152	83062.00	546.46
B-015	7.5	24	153	83086.00	543.05
B-015	10.0	17	154	83103.00	539.63
B-015	12.5	16	155	83119.00	536.25
B-015	15.0	13	156	83132.00	532.90
B-017	0.0	679	157	83811.00	533.83
B-017	2.5	308	158	84119.00	532.40
B-017	5.0	291	159	84410.00	530.88
B-017	7.5	425	160	84835.00	530.22
B-017	10.0	421	161	85256.00	529.54
B-018	2.5	435	162	85691.00	528.96

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
B-018	5.0	377	163	86068.00	528.02
B-018	7.5	291	164	86359.00	526.58
B-018	10.0	411	165	86770.00	525.88
B-018	12.5	340	166	87110.00	524.76
B-019	0.0	313	167	87423.00	523.49
B-019	2.5	444	168	87867.00	523.02
B-019	5.0	281	169	88148.00	521.59
B-019	7.5	504	170	88652.00	521.48
B-019	10.0	511	171	89163.00	521.42
B-019	12.5	541	172	89704.00	521.53
B-021	0.0	363	173	90067.00	520.62
B-021	2.5	401	174	90468.00	519.93
B-021	7.5	402	175	90870.00	519.26
B-021	10.0	259	176	91129.00	517.78
B-021	12.5	489	177	91618.00	517.62
B-021	20.0	367	178	91985.00	516.77
B-021	22.5	487	179	92472.00	516.60
B-021	25.0	378	180	92850.00	515.83
B-021	27.5	490	181	93340.00	515.69
B-023	7.5	432	182	93772.00	515.23
B-023	10.0	1000	183	94772.00	517.88
B-023	12.5	754	184	95526.00	519.16
B-023	15.0	1247	185	96773.00	523.10
B-023	17.5	1160	186	97933.00	526.52
B-023	22.5	888	187	98821.00	528.45
B-023	25.0	49	188	98870.00	525.90
B-025	0.0	131	189	99001.00	523.81
B-025	2.5	279	190	99280.00	522.53
B-025	5.0	499	191	99779.00	522.40
B-025	12.5	638	192	100417.00	523.01
B-025	15.0	453	193	100870.00	522.64
B-025	17.5	649	194	101519.00	523.29
B-025	20.0	1444	195	102963.00	528.02
B-025	22.5	1586	196	104549.00	533.41
B-025	25.0	985	197	105534.00	535.71
B-025	30.0	748	198	106282.00	536.78
B-027	0.0	470	199	106752.00	536.44
B-027	5.0	364	200	107116.00	535.58
B-027	7.5	337	201	107453.00	534.59
B-027	10.0	286	202	107739.00	533.36
B-027	12.5	356	203	108095.00	532.49
B-027	15.0	373	204	108468.00	531.71
B-027	17.5	314	205	108782.00	530.64
B-027	20.0	427	206	109209.00	530.14
B-027	22.5	680	207	109889.00	530.86
B-027	25.0	419	208	110308.00	530.33
B-027	27.5	374	209	110682.00	529.58
B-027	30.0	882	210	111564.00	531.26
B-027	32.5	425	211	111989.00	530.75
B-027	37.5	201	212	112190.00	529.20
B-036	5.0	223	213	112413.00	527.76
B-036	7.5	410	214	112823.00	527.21
B-036	10.0	220	215	113043.00	525.78
B-036	12.5	372	216	113415.00	525.07

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
B-036	15.0	251	217	113666.00	523.81
B-036	17.5	205	218	113871.00	522.34
C-072	0.0	104	219	113975.00	520.43
C-072	2.5	68	220	114043.00	518.38
C-072	5.0	268	221	114311.00	517.24
C-072	7.5	390	222	114701.00	516.67
C-074	0.0	145	223	114846.00	515.00
C-074	2.5	357	224	115203.00	514.30
C-074	5.0	495	225	115698.00	514.21
C-074	7.5	407	226	116105.00	513.74
C-075	0.0	33	227	116138.00	511.62
C-075	2.5	249	228	116387.00	510.47
C-075	5.0	150	229	116537.00	508.90
C-075	7.5	353	230	116890.00	508.22
C-076	5.0	81	231	116971.00	506.37
C-076	7.5	337	232	117308.00	505.64
C-077	5.0	47	233	117355.00	503.67
C-078	5.0	405	234	117760.00	503.25
C-078	7.5	687	235	118447.00	504.03
C-080	0.0	419	236	118866.00	503.67
C-080	2.5	228	237	119094.00	502.51
C-080	5.0	507	238	119601.00	502.53
C-080	7.5	1001	239	120602.00	504.61
C-081	5.0	70	240	120672.00	502.80
C-081	7.5	114	241	120786.00	501.19
C-082	0.0	103	242	120889.00	499.54
C-082	5.0	60	243	120949.00	497.73
C-082	7.5	61	244	121010.00	495.94
C-083	0.0	154	245	121164.00	494.55
C-083	2.5	41	246	121205.00	492.70
C-083	5.0	93	247	121298.00	491.09
C-084	0.0	248	248	121546.00	490.10
C-084	2.5	58	249	121604.00	488.37
C-084	5.0	30	250	121634.00	486.54
C-085	0.0	69	251	121703.00	484.87
C-085	5.0	35	252	121738.00	483.09
C-086	0.0	30	253	121768.00	481.30
C-086	7.5	102	254	121870.00	479.80
C-087	0.0	92	255	121962.00	478.28
C-087	2.5	30	256	121992.00	476.53
C-087	5.0	365	257	122357.00	476.10
C-087	7.5	420	258	122777.00	475.88
C-088	5.0	412	259	123189.00	475.63
C-088	7.5	651	260	123840.00	476.31
C-088	10.0	619	261	124459.00	476.85
C-089	0.0	30	262	124489.00	475.15
C-089	2.5	53	263	124542.00	473.54
C-089	5.0	9	264	124551.00	471.78
C-089	7.5	124	265	124675.00	470.47
C-090	0.0	8	266	124683.00	468.73
C-090	7.5	32	267	124715.00	467.10
C-091	0.0	17	268	124732.00	465.42
C-091	2.5	834	269	125566.00	466.79
C-091	5.0	245	270	125811.00	465.97

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
C-091	7.5	7	271	125818.00	464.27
C-092	0.0	4	272	125822.00	462.58
C-092	5.0	640	273	126462.00	463.23
C-092	7.5	468	274	126930.00	463.25
C-093	0.0	18	275	126948.00	461.63
C-093	2.5	35	276	126983.00	460.08
C-093	5.0	4	277	126987.00	458.44
C-094	5.0	208	278	127195.00	457.54
C-094	7.5	276	279	127471.00	456.89
C-095	0.0	72	280	127543.00	455.51
C-095	5.0	83	281	127626.00	454.19
C-095	7.5	331	282	127957.00	453.75
C-096	0.0	44	283	128001.00	452.30
C-096	2.5	30	284	128031.00	450.81
C-096	5.0	6	285	128037.00	449.25
C-096	7.5	2	286	128039.00	447.69
C-097	0.0	587	287	128626.00	448.17
C-097	2.5	582	288	129208.00	448.64
C-097	5.0	510	289	129718.00	448.85
C-098	0.0	407	290	130125.00	448.71
C-098	2.5	431	291	130556.00	448.65
C-098	5.0	366	292	130922.00	448.36
C-098	7.5	261	293	131183.00	447.72
C-099	0.0	21	294	131204.00	446.27
C-099	5.0	45	295	131249.00	444.91
C-099	7.5	1254	296	132503.00	447.65
C-100	0.0	34	297	132537.00	446.25
C-100	5.0	169	298	132706.00	445.32
C-100	7.5	14	299	132720.00	443.88
C-101	0.0	10	300	132730.00	442.43
C-101	2.5	17	301	132747.00	441.02
C-101	5.0	13	302	132760.00	439.60
C-101	7.5	494	303	133254.00	439.78
D-042	2.5	272	304	133526.00	439.23
D-044	0.0	295	305	133821.00	438.76
D-044	2.5	6	306	133827.00	437.34
D-044	5.0	109	307	133936.00	436.27
D-046	0.0	993	308	134929.00	438.08
D-046	2.5	606	309	135535.00	438.62
D-055	2.5	66	310	135601.00	437.42
D-055	5.0	500	311	136101.00	437.62
D-055	7.5	1674	312	137775.00	441.59
D-057	5.0	12	313	137787.00	440.21
D-057	7.5	440	314	138227.00	440.21
D-059	2.5	23	315	138250.00	438.89
D-059	5.0	13	316	138263.00	437.54
D-059	7.5	742	317	139005.00	438.50
D-061	0.0	44	318	139049.00	437.26
D-061	2.5	48	319	139097.00	436.04
D-061	5.0	237	320	139334.00	435.42
D-061	7.5	183	321	139517.00	434.63
D-063	0.0	320	322	139837.00	434.28
D-064	0.0	103	323	139940.00	433.25
D-064	2.5	167	324	140107.00	432.43

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
D-064	5.0	82	325	140189.00	431.35
D-064	7.5	23	326	140212.00	430.10
D-065	0.0	38	327	140250.00	428.90
D-065	2.5	67	328	140317.00	427.80
D-066	5.0	18	329	140335.00	426.55
D-068	0.0	73	330	140408.00	425.48
D-068	5.0	54	331	140462.00	424.36
D-068	7.5	303	332	140765.00	423.99
D-069	0.0	14	333	140779.00	422.76
D-069	2.5	8	334	140787.00	421.52
D-070	0.0	118	335	140905.00	420.61
D-070	7.5	283	336	141188.00	420.20
D-102	0.0	276	337	141464.00	419.77
D-102	2.5	439	338	141903.00	419.83
D-102	5.0	249	339	142152.00	419.33
D-102	7.5	397	340	142549.00	419.26
D-103	0.0	27	341	142576.00	418.11
D-103	2.5	39	342	142615.00	417.00
D-103	5.0	23	343	142638.00	415.85
D-105	0.0	742	344	143380.00	416.80
D-105	2.5	704	345	144084.00	417.63
D-105	5.0	1838	346	145922.00	421.74
D-105	7.5	1884	347	147806.00	425.95
D-106	5.0	17	348	147823.00	424.78

SHIPROCK TAILINGS PILE AVERAGE RA-226 FROM BENDIX DATA 12-1-83.

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
A-016	0.0	392	1	392.00	392.00
A-016	7.5	430	2	822.00	411.00
A-016	10.0	302	3	1124.00	374.67
A-016	12.5	242	4	1366.00	341.50
A-016	15.0	370	5	1736.00	347.20
A-016	17.5	483	6	2219.00	369.83
A-016	20.0	362	7	2581.00	368.71
A-016	22.5	502	8	3083.00	385.38
A-016	25.0	453	9	3536.00	392.89
A-016	27.5	219	10	3755.00	375.50
A-016	30.0	331	11	4086.00	371.45
A-016	32.5	375	12	4461.00	371.75
A-016	37.5	319	13	4780.00	367.69
A-016	40.0	478	14	5258.00	375.57
A-020	0.0	423	15	5681.00	378.73
A-020	7.5	817	16	6498.00	406.13
A-020	10.0	522	17	7020.00	412.94
A-020	15.0	377	18	7397.00	410.94
A-020	17.5	893	19	8290.00	436.32
A-020	20.0	770	20	9060.00	453.00
A-020	22.5	959	21	10019.00	477.10
A-020	27.5	1222	22	11241.00	510.95
A-020	30.0	1301	23	12542.00	545.30
A-020	32.5	899	24	13441.00	560.04
A-020	35.0	173	25	13614.00	544.56
A-022	22.5	225	26	13839.00	532.27
A-022	25.0	237	27	14076.00	521.33
A-022	27.5	414	28	14490.00	517.50
A-022	30.0	412	29	14902.00	513.86
A-022	35.0	1223	30	16125.00	537.50
A-024	0.0	196	31	16321.00	526.48
A-024	5.0	445	32	16766.00	523.94
A-024	10.0	459	33	17225.00	521.97
A-024	12.5	252	34	17477.00	514.03
A-024	15.0	552	35	18029.00	515.11
A-024	17.5	383	36	18412.00	511.44
A-026	0.0	390	37	18802.00	508.16
A-026	5.0	854	38	19656.00	517.26
A-026	7.5	1413	39	21069.00	540.23
A-026	10.0	685	40	21754.00	543.85
A-026	12.5	1528	41	23282.00	567.85
A-026	15.0	838	42	24120.00	574.29
A-026	17.5	1040	43	25160.00	585.12
A-026	20.0	442	44	25602.00	581.86
A-026	25.0	398	45	26000.00	577.78
A-026	27.5	841	46	26841.00	583.50
A-026	30.0	388	47	27229.00	579.34
A-026	32.5	490	48	27719.00	577.48
A-026	35.0	1642	49	29361.00	599.20
A-028	5.0	849	50	30210.00	604.20
A-028	7.5	568	51	30778.00	603.49
A-028	10.0	342	52	31120.00	598.46
A-028	12.5	331	53	31451.00	593.42
A-028	15.0	316	54	31767.00	588.28

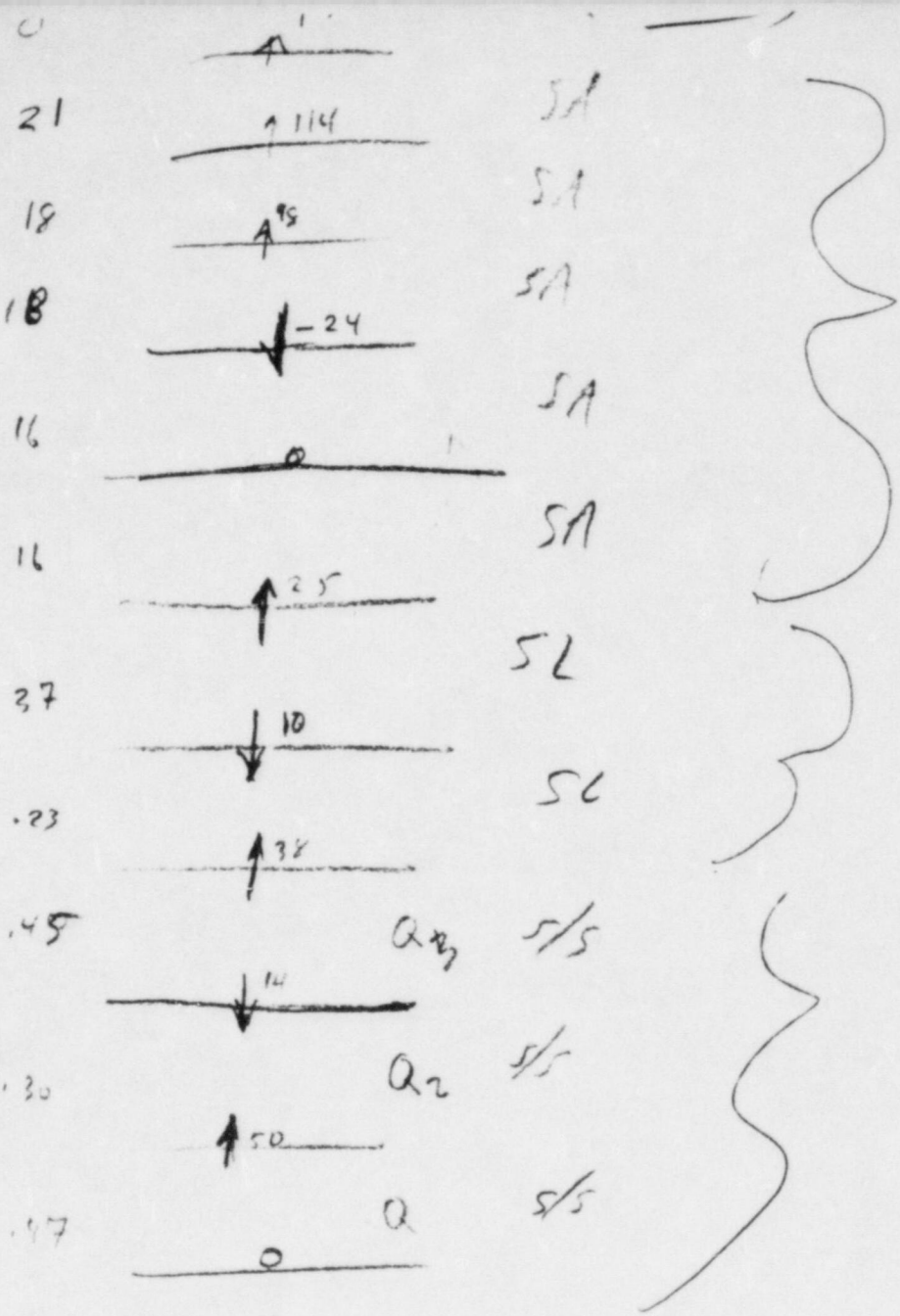
HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
A-028	17.5	262	55	32029.00	582.35
A-029	10.0	403	56	32432.00	579.14
A-029	12.5	358	57	32790.00	575.26
A-029	15.0	494	58	33284.00	573.86
A-029	17.5	986	59	34270.00	580.85
A-029	22.5	968	60	35238.00	587.30
A-029	25.0	369	61	35607.00	583.72
A-029	30.0	830	62	36437.00	587.69
A-029	32.5	40	63	36477.00	579.00
A-029	35.0	776	64	37253.00	582.08
A-030	0.0	294	65	37547.00	577.65
A-030	2.5	313	66	37860.00	573.64
A-030	5.0	356	67	38216.00	570.39
A-030	7.5	496	68	38712.00	569.29
A-030	10.0	413	69	39125.00	567.03
A-030	12.5	629	70	39754.00	567.91
A-030	15.0	528	71	40282.00	567.35
A-030	17.5	239	72	40521.00	562.79
A-031	7.5	382	73	40903.00	560.32
A-031	10.0	333	74	41236.00	557.24
A-031	12.5	466	75	41702.00	556.03
A-031	15.0	224	76	41926.00	551.66
A-031	17.5	566	77	42492.00	551.84
A-031	22.5	602	78	43094.00	552.49
A-031	25.0	231	79	43325.00	548.42
A-031	27.5	395	80	43720.00	546.50
A-031	30.0	1409	81	45129.00	557.15
A-031	35.0	349	82	45478.00	554.61
A-032	5.0	2420	83	47898.00	577.08
A-032	7.5	2084	84	49982.00	595.02
A-032	10.0	1696	85	51678.00	607.98
A-033	0.0	361	86	52039.00	605.10
A-033	2.5	353	87	52392.00	602.21
A-033	5.0	318	88	52710.00	598.98
A-033	7.5	439	89	53149.00	597.18
A-033	10.0	366	90	53515.00	594.61
A-033	12.5	249	91	53764.00	590.81
A-033	15.0	297	92	54061.00	587.62
A-033	17.5	327	93	54388.00	584.82
A-034	0.0	243	94	54631.00	581.18
A-034	2.5	580	95	55211.00	581.17
A-034	5.0	443	96	55654.00	579.73
A-034	7.5	215	97	55869.00	575.97
A-034	10.0	252	98	56121.00	572.66
A-034	12.5	680	99	56801.00	573.75
A-034	15.0	813	100	57614.00	576.14
A-034	17.5	636	101	58250.00	576.73
A-034	20.0	439	102	58689.00	575.38
A-034	22.5	318	103	59007.00	572.88
A-034	25.0	305	104	59312.00	570.31
A-034	27.5	349	105	59661.00	568.20
A-034	30.0	484	106	60145.00	567.41
A-034	32.5	321	107	60466.00	565.10
A-034	35.0	326	108	60792.00	562.89

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
A-034	37.5	2161	109	62953.00	577.55
A-035	0.0	264	110	63217.00	574.70
A-035	2.5	258	111	63475.00	571.85
A-035	5.0	276	112	63751.00	569.21
A-035	7.5	398	113	64149.00	567.69
A-035	10.0	388	114	64537.00	566.11
A-035	12.5	471	115	65008.00	565.29
A-035	15.0	324	116	65332.00	563.21
A-035	17.5	512	117	65844.00	562.77
B-001	0.0	7	118	65851.00	558.06
B-001	7.5	469	119	66320.00	557.31
B-002	7.5	355	120	66675.00	555.63
B-003	2.5	523	121	67198.00	555.36
B-003	5.0	32	122	67230.00	551.07
B-003	7.5	81	123	67311.00	547.24
B-004	0.0	498	124	67809.00	546.85
B-008	7.5	1463	125	69272.00	554.18
B-009	12.5	1218	126	70490.00	559.44
B-010	2.5	404	127	70894.00	558.22
B-010	10.0	453	128	71347.00	557.40
B-010	12.5	978	129	72325.00	560.66
B-010	15.0	1354	130	73679.00	566.76
B-010	20.0	1451	131	75130.00	573.51
B-010	25.0	940	132	76070.00	576.29
B-011	2.5	623	133	76693.00	576.64
B-011	5.0	281	134	76974.00	574.43
B-012	7.5	910	135	77884.00	576.92
B-012	12.5	409	136	78293.00	575.68
B-012	22.5	72	137	78365.00	572.01
B-012	25.0	102	138	78467.00	568.60
B-013	0.0	315	139	78782.00	566.78
B-013	2.5	58	140	78840.00	563.14
B-013	5.0	284	141	79124.00	561.16
B-013	7.5	341	142	79465.00	559.61
B-013	10.0	433	143	79898.00	558.73
B-014	0.0	230	144	80128.00	556.44
B-014	5.0	299	145	80427.00	554.67
B-014	10.0	296	146	80723.00	552.90
B-014	12.5	725	147	81448.00	554.07
B-014	15.0	380	148	81828.00	552.89
B-014	17.5	359	149	82187.00	551.59
B-014	20.0	338	150	82525.00	550.17
B-014	22.5	401	151	82926.00	549.18
B-015	5.0	136	152	83062.00	546.46
B-015	7.5	24	153	83086.00	543.05
B-015	10.0	17	154	83103.00	539.63
B-015	12.5	16	155	83119.00	536.25
B-015	15.0	13	156	83132.00	532.90
B-017	0.0	679	157	83811.00	533.83
B-017	2.5	308	158	84119.00	532.40
B-017	5.0	291	159	84410.00	530.88
B-017	7.5	425	160	84835.00	530.22
B-017	10.0	421	161	85256.00	529.54
B-018	2.5	435	162	85691.00	528.96

DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
5.0	377	163	86068.00	528.02
7.5	291	164	86359.00	526.58
10.0	411	165	86770.00	525.88
12.5	340	166	87110.00	524.76
0.0	313	167	87423.00	523.49
2.5	444	168	87867.00	523.02
5.0	281	169	88148.00	521.59
7.5	504	170	88652.00	521.48
10.0	511	171	89163.00	521.42
12.5	541	172	89704.00	521.53
0.0	363	173	90067.00	520.62
2.5	401	174	90468.00	519.93
7.5	402	175	90870.00	519.26
10.0	259	176	91129.00	517.78
12.5	489	177	91618.00	517.62
20.0	367	178	91985.00	516.77
22.5	487	179	92472.00	516.60
25.0	378	180	92850.00	515.83
27.5	490	181	93340.00	515.69
7.5	432	182	93772.00	515.23
10.0	1000	183	94772.00	517.88
12.5	754	184	95526.00	519.16
15.0	1247	185	96773.00	523.10
17.5	1160	186	97933.00	526.52
[illegible]5	888	187	98821.00	528.45
[illegible].0	49	188	98870.00	525.90
0.0	131	189	99001.00	523.81
2.5	279	190	99280.00	522.53
5.0	499	191	99779.00	522.40
12.5	638	192	100417.00	523.01
15.0	453	193	100870.00	522.64
17.5	649	194	101519.00	523.29
20.0	1444	195	102963.00	528.02
22.5	1586	196	104549.00	533.41
25.0	985	197	105534.00	535.71
30.0	748	198	106282.00	536.78
0.0	470	199	106752.00	536.44
5.0	364	200	107116.00	535.58
7.5	337	201	107453.00	534.59
10.0	286	202	107739.00	533.36
12.5	356	203	108095.00	532.49
15.0	373	204	108468.00	531.71
17.5	314	205	108782.00	530.64
20.0	427	206	109209.00	530.14
22.5	680	207	109889.00	530.86
25.0	419	208	110308.00	530.33
27.5	374	209	110682.00	529.58
30.0	882	210	111564.00	531.26
32.5	425	211	111989.00	530.75
[illegible].5	201	212	112190.00	529.20
[illegible].0	223	213	112413.00	527.76
7.5	410	214	112823.00	527.21
10.0	220	215	113043.00	525.78
12.5	372	216	113415.00	525.07

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
C-091	7.5	7	271	125818.00	464.27
C-092	0.0	4	272	125822.00	462.58
C-092	5.0	640	273	126462.00	463.23
C-092	7.5	468	274	126930.00	463.25
C-093	0.0	18	275	126948.00	461.63
C-093	2.5	35	276	126983.00	460.08
C-093	5.0	4	277	126987.00	458.44
C-094	5.0	208	278	127195.00	457.54
C-094	7.5	276	279	127471.00	456.89
C-095	0.0	72	280	127543.00	455.51
C-095	5.0	83	281	127626.00	454.19
C-095	7.5	331	282	127957.00	453.75
C-096	0.0	44	283	128001.00	452.30
C-096	2.5	30	284	128031.00	450.81
C-096	5.0	6	285	128037.00	449.25
C-096	7.5	2	286	128039.00	447.69
C-097	0.0	587	287	128626.00	448.17
C-097	2.5	582	288	129208.00	448.64
C-097	5.0	510	289	129718.00	448.85
C-098	0.0	407	290	130125.00	448.71
C-098	2.5	431	291	130556.00	448.65
C-098	5.0	366	292	130922.00	448.36
C-098	7.5	261	293	131183.00	447.72
C-099	0.0	21	294	131204.00	446.27
C-099	5.0	45	295	131249.00	444.91
C-099	7.5	1254	296	132503.00	447.65
C-100	0.0	34	297	132537.00	446.25
C-100	5.0	169	298	132706.00	445.32
C-100	7.5	14	299	132720.00	443.88
C-101	0.0	10	300	132730.00	442.43
C-101	2.5	17	301	132747.00	441.02
C-101	5.0	13	302	132760.00	439.60
C-101	7.5	494	303	133254.00	439.78
D-042	2.5	272	304	133526.00	439.23
D-044	0.0	295	305	133821.00	438.76
D-044	2.5	6	306	133827.00	437.34
D-044	5.0	109	307	133936.00	436.27
D-046	0.0	993	308	134929.00	438.08
D-046	2.5	606	309	135535.00	438.62
D-055	2.5	66	310	135601.00	437.42
D-055	5.0	500	311	136101.00	437.62
D-055	7.5	1674	312	137775.00	441.59
D-057	5.0	12	313	137787.00	440.21
D-057	7.5	440	314	138227.00	440.21
D-059	2.5	23	315	138250.00	438.89
D-059	5.0	13	316	138263.00	437.54
D-059	7.5	742	317	139005.00	438.50
D-061	0.0	44	318	139049.00	437.26
D-061	2.5	48	319	139097.00	436.04
D-061	5.0	237	320	139334.00	435.42
D-061	7.5	183	321	139517.00	434.63
D-063	0.0	320	322	139837.00	434.28
D-064	0.0	103	323	139940.00	433.25
D-064	2.5	167	324	140107.00	432.43

HOLE #	DEPTH	PCI/G	SAMPLE #	RUNNING TOTAL	RUNNING AVG.
D-064	5.0	82	325	140189.00	431.35
D-064	7.5	23	326	140212.00	430.10
D-065	0.0	38	327	140250.00	428.90
D-065	2.5	67	328	140317.00	427.80
D-066	5.0	18	329	140335.00	426.55
D-068	0.0	73	330	140408.00	425.48
D-068	5.0	54	331	140462.00	424.36
D-068	7.5	303	332	140765.00	423.99
D-069	0.0	14	333	140779.00	422.76
D-069	2.5	8	334	140787.00	421.52
D-070	0.0	118	335	140905.00	420.61
D-070	7.5	283	336	141188.00	420.20
D-102	0.0	276	337	141464.00	419.77
D-102	2.5	439	338	141903.00	419.83
D-102	5.0	249	339	142152.00	419.33
D-102	7.5	397	340	142549.00	419.26
D-103	0.0	27	341	142576.00	418.11
D-103	2.5	39	342	142615.00	417.00
D-103	5.0	23	343	142638.00	415.85
D-105	0.0	742	344	143380.00	416.80
D-105	2.5	704	345	144084.00	417.63
D-105	5.0	1838	346	145922.00	421.74
D-105	7.5	1884	347	147806.00	425.95
D-106	5.0	17	348	147823.00	424.78


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S/S

SHIPROCK SCD COVER DESIGN

********** I N P U T P A R A M E T E R S **********
NUMBER OF LAYERS =12
INITIAL RADON FLUX = 0.000E+00 PCI/SQM*SEC
SURFACE RADON CONCENTRATION = 8.000E-01 PCI/LITER
OPTIMIZATION FLAG = 1
FLUX CRITERION FOROPTIMIZATION = 2.000E+01 PCI/SQM*SEC
ACC = .0010

LAYER	THICKNESS (CM)	DIFF COEFF (SQCM/SEC)	POROSITY	SOURCE (PCI/CC*SEC)	MOISTURE (DRY WT. FRACTION)
1	76.	2.4000E-02	.3500	4.7000E-04	0.0000
2	76.	2.4000E-02	.3500	3.0000E-04	0.0000
3	76.	2.4000E-02	.3500	4.5000E-04	0.0000
4	76.	5.4500E-04	.4400	2.3000E-04	0.0000
5	76.	5.4500E-04	.4400	3.7000E-04	0.0000
6	76.	3.9000E-02	.4100	1.6000E-04	0.0000
7	76.	3.9000E-02	.4100	1.6000E-04	0.0000
8	76.	3.9000E-02	.4100	1.8000E-04	0.0000
9	76.	3.9000E-02	.4100	1.8000E-04	0.0000
10	16.	3.9000E-02	.4100	2.1000E-05	0.0000
11	162.	1.7000E-02	.3300	0.0000E+00	0.0000
12	30.	2.4800E-02	.3300	0.0000E+00	0.0000

BARE SOURCE FLUX (Jo) FROM LAYER 1 : .00 pCi/m2*sec

***** 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/SQM*SEC)	EXIT CONC. (PCI/L)	MIC
1	76.	1.7014E+01	1.8865E+05	1.0000
2	76.	-6.2379E+00	1.8396E+05	1.0000
3	76.	1.0684E+01	1.8202E+05	1.0000
4	76.	-4.7476E+00	1.4282E+05	1.0000
5	76.	1.3720E+01	8.3574E+04	1.0000
6	76.	1.0876E+01	7.7861E+04	1.0000
7	76.	1.1519E+01	7.2660E+04	1.0000
8	76.	2.2433E+01	6.4774E+04	1.0000
9	76.	4.0538E+01	5.0149E+04	1.0000
10	16.	3.5281E+01	4.6360E+04	1.0000
11	83.	2.0788E+01	7.5511E+03	1.0000
12	30.	1.9996E+01	8.0000E-01	1.0000

SHIPROCK SCD COVER DESIGN

********** I N P U T P A R A M E T E R S **********
NUMBER OF LAYERS =12
INITIAL RADON FLUX = 0.000E+00 PCI/SQM*SEC
SURFACE RADON CONCENTRATION = 8.000E-01 PCI/LITER
OPTIMIZATION FLAG = 1
FLUX CRITERION FOROPTIMIZATION = 2.000E+01 PCI/SQM*SEC
ACC = .0010

LAYER	THICKNESS (CM)	DIFF COEFF (SQCM/SEC)	POROSITY	SOURCE (PCI/CC*SEC)	MOISTURE (DRY WT. FRACTION)
1	76.	2.4000E-02	.3500	1.3400E-03	0.0000
2	76.	2.4000E-02	.3500	8.5700E-04	0.0000
3	76.	2.4000E-02	.3500	1.2950E-03	0.0000
4	76.	5.4500E-04	.4400	5.2200E-04	0.0000
5	76.	5.4500E-04	.4400	8.4000E-04	0.0000
6	76.	3.9000E-02	.4100	3.9000E-04	0.0000
7	76.	3.9000E-02	.4100	3.9000E-04	0.0000
8	76.	3.9000E-02	.4100	4.3900E-04	0.0000
9	76.	3.9000E-02	.4100	4.3900E-04	0.0000
10	16.	3.9000E-02	.4100	5.1000E-05	0.0000
11	162.	1.7000E-02	.3300	0.0000E+00	0.0000
12	30.	2.4800E-02	.3300	0.0000E+00	0.0000

BARE SOURCE FLUX (Jo) FROM LAYER 1 : .00 pCi/m2*sec

***** 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/SQM*SEC)	EXIT CONC. (PCI/L)	MIC
1	76.	4.9757E+01	5.3525E+05	1.0000
2	76.	-1.4139E+01	5.1974E+05	1.0000
3	76.	3.8533E+01	5.0912E+05	1.0000
4	76.	-1.0673E+01	3.2515E+05	1.0000
5	76.	2.9380E+01	2.0162E+05	1.0000
6	76.	2.3239E+01	1.8940E+05	1.0000
7	76.	2.4546E+01	1.7830E+05	1.0000
8	76.	4.9840E+01	1.6103E+05	1.0000
9	76.	9.1110E+01	1.2829E+05	1.0000
10	16.	7.7395E+01	1.1987E+05	1.0000
11	161.	2.0774E+01	7.5459E+03	1.0000
12	30.	1.9982E+01	8.0000E-01	1.0000

Input to SHP PSCR

2/17/84

John Smith

Tailings Emanating Fractions and Diffusion Coefficients.

The emanating fraction ~~for Rn 220~~ and the diffusion coefficient for Rn-220 were measured for samples of Shiprock tailings (Nielson 1983 b, c). One sample each of sand tailings and slime tailings were used, and two samples of sand/slime mixes were analyzed. Based on the optimum moisture for compaction, and the expected in-situ moisture following stabilization, each sample's diffusion coefficient was measured ~~at~~ over a ~~range~~ suitable range of moisture contents and at a compaction of 90% of the maximum dry density. The available ~~data are summarized in~~ diffusion coefficient and emanation fraction data are summarized with other associated parameters in Table ____. The optimum moisture and maximum dry density information ~~may~~ is discussed in section ____. Radium and other radionuclide contents are discussed in section ____.

TABLE
DIFFUSION COEFFICIENT, EMANATING FRACTION AND OTHER PARAMETERS FOR SHIPROCK [2]

TEST PIT	SPECIFIC GRAVITY	FRACTIONAL POROSITY	EMANATING FRACTION	PERCENT MOISTURE (dry wt. basis)	BULK DENSITY (g/cm^3 dry wt. basis)	PERCENT SATURATION	DIFFUSION COEF. (cm^2/sec)
TP-1 SLIMES	2.466	0.44	0.16	11.5	1.38	36	2.3×10^{-2}
				11.7	1.38	37	2.1×10^{-2}
				16.0	1.37	49	2.5×10^{-2}
				16.8	1.39	54	2.2×10^{-2}
				26.7	1.40	86	6.0×10^{-4}
				29.5	1.39	94	5.1×10^{-4}
TP-2 SANDS	2.55	0.41	0.14	6.0	1.50	22	4.0×10^{-2}
				6.8	1.50	25	3.8×10^{-2}
				9.3	1.51	34	3.8×10^{-2}
				9.4	1.51	35	1.9×10^{-2}
				13.3	1.51	49	1.0×10^{-2}
				13.5	1.51	50	9.8×10^{-3}
TP-2 SAND/SLIMES	2.51	0.35	0.28	6.8	1.61	31	4.8×10^{-2}
				7.2	1.59	31	9.3×10^{-2}
				9.7	1.61	44	3.0×10^{-2}
				9.7	1.61	44	2.1×10^{-2}
				11.5	1.59	50	2.7×10^{-2}
				13.8	1.61	62	8.3×10^{-3}
TP-3 SAND/SLIMES	2.53	0.35	0.28	6.5	1.68	33	4.0×10^{-2}
				7.2	1.67	35	4.1×10^{-2}
				9.7	1.70	50	2.9×10^{-2}
				9.9	1.70	51	1.8×10^{-2}
				12.9	1.71	68	7.1×10^{-3}
				13.4	1.71	71	5.9×10^{-3}

[2] SOURCE: Nielson 1983b, 1983c; SHP DSCD Dec 1983.

V. REFERENCES

FBDU (Ford, Bacon and Davis, Utah, Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings, Shiprock Site, Shiprock, New Mexico, DOE/UMT-0104, prepared for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

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Rogers, V.C., G.M. Sandquist, K.K. Nielson, 1981. Radon Attenuation Effectiveness and Cost Optimization of Composite Covers for Uranium Mill Tailings, UMTRA-DOE/ALO-165, prepared by Roger and Associates Engineering Corporation, Salt Lake City, Utah, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

Rogers, V.C. and K.K. Nielson, 1981. A Handbook for the Determination of Radon Attenuation Through Cover Materials, NUREG/CR-2340 RAE 18-1, prepared by Rogers and Associates Engineering Corporation, Salt Lake City, Utah for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

Rogers, V.C., K.K. Nielson and D.C. Rich, 1981b. Ambient Soil Moistures in Western Uranium Milling Regions, RAE-UMTRA Project report No. RAE-9-4, prepared by Rogers and Associates Engineering Corporation, Salt Lake City, Utah for Battelle Pacific Northwest Laboratory, Richland, Washington.

→ J Smith

ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

To: DLewis

From: ~~MJackson~~ MJ

Date: October 20, 1983

Subject: SHP Cover Moisture

Unless I am otherwise directed by you, I will use five percent moisture as the moisture content of the Shiprock cover. This is based on the in-situ moistures measured by SHB (see attached table). This will be the basis for the cover calculation.

MJ:sd
Attachment

cc: KBaker
WEricson
TSchruben
LStepp

TABULATION OF TEST RESULTS

Job No. L 1067

Project UMTRAP

Shiprock, New Mexico

Material

Source

HOLE NO.	LOCATION	DEPTH	UNIFIED CLASS.	LL	PI	SIEVE ANALYSIS – ACCUM % PASSING												LAB. NO.
						200	100	40	10	4	3/8	1/2	3/4	1	1-1/2	2	Moist.	
1		0-2.5'	SM	NV	NP	24	56	98	99	100							5.6	67-1
1		7.0'-12.0'	SP	NV	NP	5	12	32	59	85	100							67-2
2		2.0'-7.5'	ML	21	2	73	85	98	100								5.5	67-3
2		9.5'-11.0'	SM	NV	NP	29	62	96	99	100							2.3	67-4
3		7.0'-11.0'	SM	NV	NP	40	54	73	83	89	92	--	93	--	95	100	3.0	67-5
3		11.0'-15.0'	ML	24	2	75	85	90	93	96	98	--	100				5.3	67-6
4		1.0'-10.0'	ML	22	2	86	95	99	100								5.4	67-7
5		5.0'-13.0'	SM	NV	NP	15	21	50	75	88	100							67-8
8		0-4.0'	GC	30	11	23	24	25	26	49	56	--	80	--	82	100	4.1	67-9
	Devils Wash	8.0'-10.0'	ML	NV	NP	75	88	95	96	97	97	--	100				0.2	67-10

SERGENT, HAUSKINS & B

2.0 RADON BARRIER THICKNESS

I. PROBLEM STATEMENT

The tailings at the Shiprock, New Mexico site encompass about 72 acres. The two piles will be reshaped and contoured into a uniform configuration and will ultimately occupying approximately 75 acres. Windblown contamination from the surrounding area will be placed on top of the pile to help reduce the required amount of cover material for radon emission control. In order to meet the EPA flux standard of 20 pCi/m^2 sec, an earthen cover of locally available borrow material will be placed on top of the tailings.

II. METHODS, DATA, AND ASSUMPTIONS

The RAECO model (Rogers, V., et al., 1981) is utilized to calculate the thickness of cover material required on the site. The model and input parameters are described in the following sections.

A. RAECO Model

The development of the model begins with the following diffusion equation:

$$D \frac{d^2 C(x)}{dx^2} - \lambda C(x) + \frac{Q(x)}{P} = 0 \qquad (2\text{-}1)$$

where

$C(x)$ = radon concentration in the material pore space at position x

λ = radon decay constant

$Q(x)$ = radon source at position x

D = diffusion coefficient

P = porosity

This equation describes a system in which radon transport occurs through a one-dimensional radon concentration gradient. Upon solving this differential equation, the result for any layer i is:

$$C_i(x) = A_i \exp(a_i x) + B_i \exp(-a_i x) + S_i \qquad (2\text{-}2)$$

where

A_i, B_i = constants defined by boundary conditions

$a_i = (\lambda/D_i)^{\frac{1}{2}}$

$S_i = Q_i/(\lambda P_i)$

From Fick's Law, the radon flux, $J_i(x)$ is:

$$J_i(x) = -D_i P_i \frac{dC_i(x)}{dx} \qquad (2\text{-}3)$$

D_i = diffusion coefficient of layer i
P_i = porosity of layer i

Substituting C_i from equation (2-2) into equation (2-3), yields for the flux exiting layer i:

$$J_i(x) = -D_i P_i a_i ((A_i \exp(a_i x) - B_i \exp(-a_i x))) \qquad (2\text{-}4)$$

This equation applies to all layers in a multi-layer system and the RAECO model will analyze a system with up to 100 layers. The flux and concentration boundary conditions yield a complete set of equations for the constants A and B. These formulate a matrix which, when solved, gives the flux that will result from an assumed cover thickness. RAECO can vary the cover materials to obtain the optimum cover thickness that will meet the radon flux standard and/or any minimum cover thickness requirements.

The reader is referred to the Rogers reference (1981) for a complete analysis of the RAECO model.

B. Input Parameters

There are a number of input variables that are required to calculate the final radon flux through the cover and the cover thickness. These parameters are:

- Diffusion coefficients of tailings and cover, D_t, D_c
- Porosities of tailings and cover, P_t, P_c
- Pile thickness, X_o

- Background radon concentration, C_b
- Radon source term of tailings and cover, Q_t, Q_c

The radon source term, Q, is comprised of the following parameters:

- Radium content, R
- Bulk density, ρ
- Emanating power, E
- Radon decay constant, $\lambda = 2.1 \times 10^{-6}$/sec

Each of these parameters will be addressed in the following calculation section. The source of each value will be identified along with the value itself.

III. CALCULATION

A. Diffusion Coefficients

The cover thickness required to attenuate the radon emissions from the pile is greatly dependent on the diffusion coefficient of the material used for cover. Also, the amount of radon which is released from the tailings is dependent on the diffusion coefficient of the tailings. Therefore this parameter is the most critical for the RAECO model analysis.

The cover material is silty, sandy soil excavated from an area adjacent to the site. Rogers & Associates Engineering Corp., RAE, measured diffusion coefficients of this material from 6 test pits, the results are shown in Table 2.1 (Nielson, K.K., 1983a). It has been determined that the top foot of cover under the rock cover will maintain a moisture content of 5 percent, any material below that depth will have a moisture content of 7.5 percent. The data in Table 2.1 indicates the diffusion coefficient of the top foot of cover is 0.025 cm^2/sec, the remainder of the cover has a diffusion coefficient of 0.017 cm^2/sec.

Test pits were also dug in the tailings and samples were taken. RAE measured the diffusion coefficient at varying moisture contents for each of the samples and these data are in Table 2.2. The tailings pile has been divided into 10 separate layers, the top 5 layers consist of sands, the next 2 layers are slimes, and the bottom 3 layers are mixed sands and slimes. The sands diffusion coefficient is 0.039 cm^2/sec, the slimes, 0.00055 cm^2/sec and the sands/slimes mixture diffusion coefficient is 0.024 cm^2/sec. The windblown material, the top layer on the pile, is assumed to have the same diffusion coefficient as the tailings sands.

Table 2.1 Radon diffusion coefficients of cover material

Test Pit	% Moisture (dry)	Density (g/cm^3) dry	% Sat	D (cm^2/sec)
#1 0-2½'	1.6	1.74	9	4.5×10^{-2}
	3.5	1.74	20	3.7×10^{-2}
	6.6	1.74	38	3.6×10^{-2}
	6.7	1.73	38	4.3×10^{-2}
	12.5	1.75	73	2.9×10^{-3}
	12.8	1.75	75	4.3×10^{-3}
#2 2-7½'	2.3	1.75	12	3.0×10^{-2}
	3.0	1.74	15	1.9×10^{-2}
	7.6	1.71	37	2.9×10^{-2}
	7.6	1.71	37	3.0×10^{-2}
	13.0	1.74	66	9.9×10^{-3}
	13.6	1.73	68	4.2×10^{-3}
#3 7-11'	2.6	1.82	14	2.2×10^{-2}
	3.8	1.82	20	2.0×10^{-2}
	5.1	1.82	27	2.1×10^{-2}
	5.6	1.82	29	2.2×10^{-2}
	12.6	1.82	66	4.6×10^{-3}
	12.7	1.82	66	8.9×10^{-4}
#3 11'-15'	2.6	1.79	17	4.1×10^{-2}
	3.4	1.79	22	3.5×10^{-2}
	7.1	1.79	46	3.4×10^{-2}
	7.6	1.78	48	2.8×10^{-2}
	10.9	1.79	70	1.2×10^{-2}
	11.1	1.79	72	1.6×10^{-2}
#4 1-10'	3.0	1.71	15	4.2×10^{-2}
	3.2	1.77	18	2.1×10^{-2}
	3.5	1.66	16	2.7×10^{-2}
	5.5	1.77	30	2.4×10^{-2}
	6.5	1.77	36	1.8×10^{-2}
	12.8	1.77	70	6.1×10^{-3}
	13.2	1.77	72	4.0×10^{-3}
#8 (Shale)	3.4	1.85	18	2.0×10^{-2}
	3.5	1.84	19	1.8×10^{-2}
	5.4	1.85	29	2.2×10^{-2}
	6.1	1.84	32	1.6×10^{-2}
	12.2	1.85	66	8.0×10^{-4}
	13.0	1.85	70	9.8×10^{-4}

Table 2.1 Radon diffusion coefficients of cover material (Cont'd)

Test Pit	% Moisture (dry)	Density (g/cm^3) dry	% Sat	D (cm^2/sec)
#2 - 9½-11'	2.4	1.75	12	3.9×10^{-2}
+ Devils Wash	3.8	1.74	19	2.9×10^{-2}
	5.8	1.76	30	1.7×10^{-2}
	6.6	1.74	33	3.0×10^{-2}
	12.5	1.76	65	1.5×10^{-3}
	13.6	1.74	68	1.0×10^{-3}

Table 2.2 Radon diffusion coefficients of Shiprock tailings*

Sample	% Moisture (dry)	Density (g/cm^3) dry	Saturation %	D (cm^2/sec)
TP-1 Slimes	11.5	1.38	36	2.3×10^{-2}
TP-1 Slimes	11.7	1.38	37	2.1×10^{-2}
TP-1 Slimes	16.0	1.37	49	2.5×10^{-2}
TP-1 Slimes	16.8	1.39	54	2.2×10^{-2}
TP-1 Slimes	26.7	1.40	86	6.0×10^{-4}
TP-1 Slimes	29.5	1.39	94	5.1×10^{-4}
TP-2 Sands	6.0	1.50	22	4.0×10^{-2}
TP-2 Sands	6.8	1.50	26	3.8×10^{-2}
TP-2 Sands	9.3	1.51	34	3.6×10^{-2}
TP-2 Sands	9.4	1.51	35	1.9×10^{-2}
TP-2 Sands	13.3	1.51	49	1.0×10^{-3}
TP-2 Sands	13.5	1.51	50	9.8×10^{-3}
TP-2 Sand/Slime	6.8	1.61	31	4.8×10^{-2}
TP-2 Sand/Slime	7.2	1.59	31	4.3×10^{-2}
TP-2 Sand/Slime	9.7	1.61	44	3.0×10^{-2}
TP-2 Sand/Slime	9.7	1.61	44	2.1×10^{-2}
TP-2 Sand/Slime	11.5	1.59	50	2.7×10^{-3}
TP-2 Sand/Slime	13.8	1.61	62	8.3×10^{-3}
TP-3 Sand/Slime	6.5	1.68	33	4.0×10^{-2}
TP-3 Sand/Slime	7.2	1.67	35	4.1×10^{-2}
TP-3 Sand/Slime	9.7	1.70	50	2.9×10^{-2}
TP-3 Sand/Slime	9.9	1.70	51	1.8×10^{-3}
TP-3 Sand/Slime	12.9	1.71	68	7.1×10^{-3}
TP-3 Sand/Slime	13.4	1.71	71	5.9×10^{-3}

*(K.K. Nielson, 1983b).

The RAECO model requires diffusion coefficient data input in the form of the effective diffusion coefficient, which is the diffusion coefficient multiplied by the porosity of the material. The porosity P is calculated from:

$$P = 1 - \frac{\rho}{\rho_{SG}}$$

where

ρ = Dry bulk density (g/cm^3)
ρ_{SG} = Specific gravity of the soil

Table 2.3 presents the diffusion coefficient, porosity, and effective diffusion coefficient for each layer of the tailings and radon control cover.

Table 2.3 RAECO model diffusion coefficient input

Material	Diffusion coefficient (cm^2/sec)	Porosity	Effective diffusion coefficient Dxp (cm^{2}sec)
Tailings sand	0.039	0.41	0.016
Tailings slimes	0.00055	0.44	0.00024
Tailings sand/ slime	0.024	0.35	0.0084
Windblown	0.039	0.41	0.016
Silty sandy cover (top foot)	0.025	0.33	0.0082
Silty sand cover (below 1 foot)	0.017	0.33	0.0056

B. Tailings Thickness

The tailings piles will be contoured and reshaped in such a way that the tailings pile can be treated as 9 layers of tailings each 2-1/2 feet thick. The windblown contamination will be an additional layer of 7 inches. These thickness are direct input to the RAECO model.

C. Background Radon Concentration

In the vicinity of the Shiprock pile three background radon monitors were set-up and 24-hour samples taken. The readings ranged from 0.66 pCi/l to 0.98 pCi/l with an average radon concentration of 0.8 pCi/l (FBDU, 1981). This value was used as input to the RAECO model.

D. Radon Source Term

The radon source term, Q, is given by the following expression (Rogers, V.C.and K.K. Nielson, 1981):

$$Q = R\rho E\lambda$$

where

R = Average radium-226 concentration (pCi/g)
ρ = Dry bulk density (g/cm^3)
E = Emanating power
λ = Radon decay constant (2.1×10^{-6}/sec)

The average Radium-226 concentration of each tailings layer was calculated using over 350 sample analysis from more than 70 drill holes (Bendix, 1983). Evaluation of these data in the Earthwork Volume Calculations (SHP-01) indicates that the sand fraction of the tailings to be cut (excavated) average 400 pCi/g and the slime fraction averages 1040 pCi/g. Using these values the areas to be filled were provided with sands and slimes from the cut to bring the elevation up to the necessary grade. Figure 2.1 shows the outline of the areas to be cut and filled. This created a new radium profile for each hole on the pile. The radium concentration for each 2-1/2 foot layer of the new profiles were averaged to obtain a layer average radium concentration. These averages are presented in Table 2.4. The average radium concentration of the windblown layer was calculated from soil analysis of several 100 samples.

The average dry bulk density for each layer was obtained from the test results in Table 2.2 and are also given in Table 2.4

The emanating power of the tailings sample were measured and the average of the results are shown in Table 2.4.

Using these values the source term for each tailings layer was calculated and is in the last column of Table 2.4.

IV. RESULT

Using the inputs outlined in the previous section the RAECO model indicates that 211 cm of silty sandy soil are required to reduce the radon flux below 20 pCi/m^{2}sec. This is a minimum of 7 feet of radon attenuation cover, in addition, material will be added for erosion control. The material necessary for erosion control is not accounted for in the radon attenuation calculation.

Table 2.4 Tailings source terms for RAECO

Tailings layer (ft)	Material type	Average Ra-226 (pCi/g)	Density g/cm^3	Emanating Power *	Source term Q, (pCi/m^2-sec)
0-2.5	Sand	398.3	1.51	0.14	0.00018
2.5-5.0	Sand	396.4	1.51	0.14	0.00018
5.0-7.5	Sand	371.4	1.51	0.14	0.00016
7.5-10.0	Sand	360.2	1.51	0.14	0.00016
10.0-12.5	Slime	790.7	1.38	0.16	0.00037
12.5-15.0	Slime	495.5	1.38	0.16	0.00023
15.0-17.5	Sand/slime	462.2	1.65	0.28	0.00045
17.5-20.0	Sand/slime	308.3	1.65	0.28	0.00030
20.0-22.5	Sand/slime	485.7	1.65	0.28	0.00047
Windblown	Sand	47	1.51	0.14	0.000021

*(Nielson, K.K., 1983c).

V. REFERENCES

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2.0 RADON BARRIER THICKNESS

I. PROBLEM STATEMENT

The tailings at the Shiprock, New Mexico site encompass about 72 acres. The two piles will be reshaped and contoured into a uniform configuration and will ultimately occupying approximately 75 acres. Windblown contamination from the surrounding area will be placed on top of the pile to help reduce the required amount of cover material for radon emission control. In order to meet the EPA flux standard of 20 pCi/m^2 sec, an earthen cover of locally available borrow material will be placed on top of the tailings.

II. METHODS, DATA, AND ASSUMPTIONS

The RAECO model (Rogers, V., et al., 1981) is utilized to calculate the thickness of cover material required on the site. The model and input parameters are described in the following sections.

A. RAECO Model

The development of the model begins with the following diffusion equation:

$$D \frac{d^2 C(x)}{dx^2} - \lambda C(x) + \frac{Q(x)}{p} = 0 \qquad (2\text{-}1)$$

where

$C(x)$ = radon concentration in the material pore space at position x

λ = radon decay constant

$Q(x)$ = radon source at position x

D = diffusion coefficient

p = porosity

This equation describes a system in which radon transport occurs through a one-dimensional radon concentration gradient. Upon solving this differential equation, the result for any layer i is:

$$C_i(x) = A_i \exp(a_i x) + B_i \exp(-a_i x) + S_i \qquad (2\text{-}2)$$

where

A_i, B_i = constants defined by boundary conditions

$a_i = (\lambda/D_i)^{\frac{1}{2}}$

$S_i = Q_i/(\lambda P_i)$

From Fick's Law, the radon flux, $J_i(x)$ is:

$$J_i(x) = -D_i P_i \frac{dC_i(x)}{dx} \qquad (2\text{-}3)$$

D_i = diffusion coefficient of layer i
P_i = porosity of layer i

Substituting C_i from equation (2-2) into equation (2-3), yields for the flux exiting layer i:

$$J_i(x) = -D_i P_i a_i ((A_i \exp(a_i x) - B_i \exp(-a_i x))) \qquad (2\text{-}4)$$

This equation applies to all layers in a multi-layer system and the RAECO model will analyze a system with up to 100 layers. The flux and concentration boundary conditions yield a complete set of equations for the constants A and B. These formulate a matrix which, when solved, gives the flux that will result from an assumed cover thickness. RAECO can vary the cover materials to obtain the optimum cover thickness that will meet the radon flux standard and/or any minimum cover thickness requirements.

The reader is referred to the Rogers reference (1981) for a complete analysis of the RAECO model.

B. Input Parameters

There are a number of input variables that are required to calculate the final radon flux through the cover and the cover thickness. These parameters are:

- Diffusion coefficients of tailings and cover, D_t, D_c
- Porosities of tailings and cover, P_t, P_c
- Pile thickness, X_o

- Background radon concentration, C_b
- Radon source term of tailings and cover, Q_t, Q_c

The radon source term, Q, is comprised of the following parameters:

- Radium content, R
- Bulk density, ρ
- Emanating power, E
- Radon decay constant, $\lambda = 2.1 \times 10^{-6}$/sec

Each of these parameters will be addressed in the following calculation section. The source of each value will be identified along with the value itself.

III. CALCULATION

A. Diffusion Coefficients

The cover thickness required to attenuate the radon emissions from the pile is greatly dependent on the diffusion coefficient of the material used for cover. Also, the amount of radon which is released from the tailings is dependent on the diffusion coefficient of the tailings. Therefore this parameter is the most critical for the RAECO model analysis.

The cover material is silty, sandy soil excavated from an area adjacent to the site. Rogers & Associates Engineering Corp., RAE, measured diffusion coefficients of this material from 6 test pits, the results are shown in Table 2.1 (Nielson, K.K., 1983a). It has been determined that the top foot of cover under the rock cover will maintain a moisture content of 5 percent, any material below that depth will have a moisture content of 7.5 percent. The data in Table 2.1 indicates the diffusion coefficient of the top foot of cover is 0.023 cm^2/sec, the remainder of the cover has a diffusion coefficient of 0.017 cm^2/sec.

Test pits were also dug in the tailings and samples were taken. RAE measured the diffusion coefficient at varying moisture contents for each of the samples and these data are in Table 2.2. The tailings pile has been divided into 10 separate layers, the top 5 layers consist of sands, the next 2 layers are slimes, and the bottom 3 layers are mixed sands and slimes. The sands diffusion coefficient is 0.039 cm^2/sec, the slimes, 0.00055 cm^2/sec and the sands/slimes mixture diffusion coefficient is 0.024 cm^2/sec. The windblown material, the top layer on the pile, is assumed to have the same diffusion coefficient as the tailings sands.

Table 2.1 Radon diffusion coefficients of cover material

Test Pit	% Moisture (dry)		Density (g/cm^3) dry		% Sat		D (cm^2/sec)	
#1 0-2½'	1.6		1.74		9		4.5×10^{-2}	
	3.5		1.74		20		3.7×10^{-2}	
4.6	6.6	6.7	1.74		38	4.0	3.6×10^{-2}	1.0
	6.7		1.73		38		4.3×10^{-2}	
	12.5		1.75		73		2.9×10^{-3}	
	12.8	9.7	1.75		75	2.2	4.3×10^{-3}	
#2 2-7½'	2.3		1.75		12		3.0×10^{-2}	
	3.0		1.74		15		1.9×10^{-2}	2.7
5.1	7.6	7.6	1.71		37		2.9×10^{-2}	
	7.6		1.71		37	3.0	3.0×10^{-2}	
	13.0		1.74		66		9.9×10^{-3}	
	13.6		1.73		68		4.2×10^{-3}	
#3 7-11'	2.6		1.82		14		2.2×10^{-2}	
	3.8		1.82		20		2.0×10^{-2}	
	5.1		1.82		27		2.1×10^{-2}	2.2
5.4	5.6	9.0	1.82		29		2.2×10^{-2}	
	12.6		1.82		66	1.2	4.6×10^{-3}	
	12.7		1.82		66		8.9×10^{-4}	
#3 11'-15'	2.6		1.79		17		4.1×10^{-2}	
	3.4		1.79		22		3.5×10^{-2}	3.5
	7.1	7.4	1.79		46		3.4×10^{-2}	
5.2	7.6		1.78		48	3.1	2.8×10^{-2}	
	10.9		1.79		70		1.2×10^{-2}	
	11.1		1.79		72		1.6×10^{-2}	
#4 1-10'	3.0		1.71		15		4.2×10^{-2}	
	3.2		1.77		18		2.1×10^{-2}	
	3.5		1.66		16		2.7×10^{-2}	2.6
	5.5		1.77		30		2.4×10^{-2}	
4.3	6.5	6.0	1.77		36	4.1	1.8×10^{-2}	
	12.8	9.5	1.77		70		6.1×10^{-3}	
	13.2		1.77		72		4.0×10^{-3}	
#8 (Shale)	3.4		1.85		18	1.3	2.0×10^{-2}	
	3.5		1.84		19		1.8×10^{-2}	
	5.4	5.8	1.85		29		2.2×10^{-2}	2.0
4.4	6.1		1.84		32	1.9	1.6×10^{-2}	
	12.2	9.2	1.85		66		8.0×10^{-4}	
	13.0		1.85		70		9.8×10^{-4}	

1.0

5% 2.8×10⁻² at 4.8%
7.5% 7.5%
7.5%: 6.6%, 2.8×10⁻²
7.5%: 1.9×10⁻² at 8.4%
7.5%; avg. 2.4 at 7.5%

Table 2.1 Radon diffusion coefficients of cover material (Cont'd)

Test Pit	% Moisture (dry)	Density (g/cm^3) dry	% Sat	D (cm^2/sec)
#2 - 9½-11' + Devils Wash	2.4	1.75	12	3.9×10^{-2}
	3.8	1.74	19	2.9×10^{-2}
	5.8	1.76	30	1.7×10^{-2}
	6.6	1.74	33	3.0×10^{-2}
4.7	12.5	1.76	65	1.5×10^{-3}
	13.6	1.74	68	1.0×10^{-3}

6.2

9.4

2.47

2.9

1.2

Table 2.2 Radon diffusion coefficients of Shiprock tailings*

Sample	% Moisture (dry)	Density (g/cm^3) dry	Saturation %	D (cm^2/sec)
TP-1 Slimes	11.5	1.38	36	2.3×10^{-2}
TP-1 Slimes	11.7	1.38	37	2.1×10^{-2}
TP-1 Slimes	16.0	1.37	49	2.5×10^{-2}
TP-1 Slimes	16.8	1.39	54	2.2×10^{-2}
TP-1 Slimes	26.7	1.40	86	6.0×10^{-4}
TP-1 Slimes	29.5	1.39	94	5.1×10^{-4}
TP-2 Sands	6.0	1.50	22	4.0×10^{-2}
TP-2 Sands	6.8	1.50	25	3.8×10^{-2}
TP-2 Sands	9.3	1.51	34	3.8×10^{-2}
TP-2 Sands	9.4	1.51	35	1.9×10^{-2}
TP-2 Sands	13.3	1.51	49	1.0×10^{-3}
TP-2 Sands	13.5	1.51	50	9.8×10^{-3}
TP-2 Sand/Slime	6.8	1.61	31	4.8×10^{-2}
TP-2 Sand/Slime	7.2	1.59	31	4.3×10^{-2}
TP-2 Sand/Slime	9.7	1.61	44	3.0×10^{-2}
TP-2 Sand/Slime	9.7	1.61	44	2.1×10^{-2}
TP-2 Sand/Slime	11.5	1.59	50	2.7×10^{-2}
TP-2 Sand/Slime	13.8	1.61	62	8.3×10^{-3}
TP-3 Sand/Slime	6.5	1.68	33	4.0×10^{-2}
TP-3 Sand/Slime	7.2	1.67	35	4.1×10^{-2}
TP-3 Sand/Slime	9.7	1.70	50	2.9×10^{-2}
TP-3 Sand/Slime	9.9	1.70	51	1.8×10^{-2}
TP-3 Sand/Slime	12.9	1.71	68	7.1×10^{-3}
TP-3 Sand/Slime	13.4	1.71	71	5.9×10^{-3}

*(K.K. Nielson, 1983b).

The RAECO model requires diffusion coefficient data input in the form of the effective diffusion coefficient, which is the diffusion coefficient multiplied by the porosity of the material. The porosity P is calculated from:

$$P = 1 - \frac{\rho}{SG}$$

where

ρ = Dry bulk density (g/cm^3)
SG = Specific gravity of the soil

Table 2.3 presents the diffusion coefficient, porosity, and effective diffusion coefficient for each layer of the tailings and radon control cover.

Table 2.3 RAECO model diffusion coefficient input

Material	Diffusion coefficient (cm^2/sec)	Porosity	Effective diffusion coefficient Dxp (cm^2sec)
Tailings sand	0.039	0.41	0.016
Tailings slimes	0.00055	0.44	0.00024
Tailings sand/ slime	0.024	0.35	0.0084
Windblown	0.039	0.41	0.016
Silty sandy cover (top foot)	0.025	0.33	0.0082
Silty sand cover (below 1 foot)	0.017	0.33	0.0056

B. Tailings Thickness

The tailings piles will be contoured and reshaped in such a way that the tailings pile can be treated as 9 layers of tailings each 2-1/2 feet thick. The windblown contamination will be an additional layer of 7 inches. These thickness are direct input to the RAECO model.

C. Background Radon Concentration

In the vicinity of the Shiprock pile three background radon monitors were set-up and 24-hour samples taken. The readings ranged from 0.66 pCi/l to 0.98 pCi/l with an average radon concentration of 0.8 pCi/l (FBDU, 1981). This value was used as input to the RAECO model.

D. Radon Source Term

The radon source term, Q, is given by the following expression (Rogers, V.C.and K.K. Nielson, 1981):

$$Q = R\rho E\lambda$$

where

R = Average radium-226 concentration (pCi/g)
ρ = Dry bulk density (g/cm^3)
E = Emanating power
λ = Radon decay constant (2.1×10^{-6}/sec)

The average Radium-226 concentration of each tailings layer was calculated using over 350 sample analysis from more than 70 drill holes (Bendix, 1983). Evaluation of these data in the Earthwork Volume Calculations (SHP-01) indicates that the sand fraction of the tailings to be cut (excavated) average 400 pCi/g and the slime fraction averages 1040 pCi/g. Using these values the areas to be filled were provided with sands and slimes from the cut to bring the elevation up to the necessary grade. Figure 2.1 shows the outline of the areas to be cut and filled. This created a new radium profile for each hole on the pile. The radium concentration for each 2-1/2 foot layer of the new profiles were averaged to obtain a layer average radium concentration. These averages are presented in Table 2.4. The average radium concentration of the windblown layer was calculated from soil analysis of several 100 samples.

The average dry bulk density for each layer was obtained from the test results in Table 2.2 and are also given in Table 2.4

The emanating power of the tailings sample were measured and the average of the results are shown in Table 2.4.

Using these values the source term for each tailings layer was calculated and is in the last column of Table 2.4.

IV. RESULT

Using the inputs outlined in the previous section the RAECO model indicates that 211 cm of silty sandy soil are required to reduce the radon flux below 20 pCi/m^{2}sec. This is a minimum of 7 feet of radon attenuation cover, in addition, material will be added for erosion control. The material necessary for erosion control is not accounted for in the radon attenuation calculation.

Table 2.4 Tailings source terms for RAECO

Tailings layer (ft)	Material type	Average Ra-226 (pCi/g)	Density g/cm^3	Emanating Power *	Source term Q, (pCi/m^2-sec)
0-2.5	Sand	398.3	1.51	0.14	0.00018
2.5-5.0	Sand	396.4	1.51	0.14	0.00018
5.0-7.5	Sand	371.4	1.51	0.14	0.00016
7.5-10.0	Sand	360.2	1.51	0.14	0.00016
10.0-12.5	Slime	790.7	1.38	0.16	0.00037
12.5-15.0	Slime	495.5	1.38	0.16	0.00023
15.0-17.5	Sand/slime	462.2	1.65	0.28	0.00045
17.5-20.0	Sand/slime	308.3	1.65	0.28	0.00030
20.0-22.5	Sand/slime	485.7	1.65	0.28	0.00047
Windblown	Sand	47	1.51	0.14	0.000021

*(Nielson, K.K., 1983c).

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December 5, 1983

Dr. Vern C. Rogers, President
Rogers & Associates Engineering Corp.
P. O. Box 330
Salt Lake City, UT 84110

Dear Vern:

Enclosed is a copy of the summary radon barrier calculation for the Shiprock conceptual design. This is an appendix to the design document which you will be reviewing December 13 and 14, 1983.

This review is covered under Task 4a of your contract (ASD-34-6702-S-83-0029). Upon completion of your review you need to submit a TIM within one week to meet the deliverable for the contract.

If you have any questions, please call. See you December 12.

Very truly yours,
JACOBS ENGINEERING GROUP INC.

Mark A. Jackson
Project Engineer

MJ:sd
Enclosure

cc: KBaker
LStepp

DRAFT

SHP-02-001

2.0 RADON BARRIER THICKNESS

I. PROBLEM STATEMENT

The tailings at the Shiprock, New Mexico site encompass about 72 acres. The two piles will be reshaped and contoured into a uniform configuration and will ultimately occupying approximately 75 acres. Windblown contamination from the surrounding area will be placed on top of the pile to help reduce the required amount of cover material for radon emission control. In order to meet the EPA flux standard of 20 pCi/m^2 sec, an earthen cover of locally available borrow material will be placed on top of the tailings.

II. METHODS, DATA, AND ASSUMPTIONS

The RAECO model (Rogers, V., et al., 1981) is utilized to calculate the thickness of cover material required on the site. The model and input parameters are described in the following sections.

A. RAECO Model

The development of the model begins with the following diffusion equation:

$$D \frac{d^2 C(x)}{dx^2} - \lambda C(x) + \frac{Q(x)}{p} = 0 \qquad (2\text{-}1)$$

where

$C(x)$ = radon concentration in the material pore space at position x

λ = radon decay constant

$Q(x)$ = radon source at position x

D = diffusion coefficient

p = porosity

This equation describes a system in which radon transport occurs through a one-dimensional radon concentration gradient. Upon solving this differential equation, the result for any layer i is:

$$C_i(x) = A_i \exp(\varepsilon_i x) + B_i \exp(-\varepsilon_i x) + S_i \qquad (2\text{-}2)$$

where

A_i, B_i = constants defined by boundary conditions

$\varepsilon_i = (\lambda/D_i)^{\frac{1}{2}}$

$S_i = G_i/(\lambda P_i)$

From Fick's Law, the radon flux, $J_i(x)$ is:

$$J_i(x) = -D_i P_i \frac{dC_i(x)}{dx} \qquad (2\text{-}3)$$

D_i = diffusion coefficient of layer i
P_i = porosity of layer i

Substituting C_i from equation (2-2) into equation (2-3), yields for the flux exiting layer i:

$$J_i(x) = -D_i P_i \varepsilon_i ((A_i \exp(\varepsilon_i x) - B_i \exp(-\varepsilon_i x))) \qquad (2\text{-}4)$$

This equation applies to all layers in a multi-layer system and the RAECO model will analyze a system with up to 100 layers. The flux and concentration boundary conditions yield a complete set of equations for the constants A and B. These formulate a matrix which, when solved, gives the flux that will result from an assumed cover thickness. RAECO can vary the cover materials to obtain the optimum cover thickness that will meet the radon flux standard and/or any minimum cover thickness requirements.

The reader is referred to the Rogers reference (1981) for a complete analysis of the RAECO model.

B. Input Parameters

There are a number of input variables that are required to calculate the final radon flux through the cover and the cover thickness. These parameters are:

- Diffusion coefficients of tailings and cover, D_t, D_c
- Porosities of tailings and cover, P_t, P_c
- Pile thickness, X_p

- Background radon concentration, C_b
- Radon source term of tailings and cover, C_t; C_c

The radon source term, Q, is comprised of the following parameters:

- Radium content, R
- Bulk density, ρ
- Emanating power, E
- Radon decay constant, $\lambda = 2.1 \times 10^{-6}$/sec

Each of these parameters will be addressed in the following calculation section. The source of each value will be identified along with the value itself.

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III. CALCULATION

A. Diffusion Coefficients

The cover thickness required to attenuate the radon emissions from the pile is greatly dependent on the diffusion coefficient of the material used for cover. Also, the amount of radon which is released from the tailings is dependent on the diffusion coefficient of the tailings. Therefore this parameter is the most critical for the RAECO model analysis.

The cover material is silty, sandy soil excavated from an area adjacent to the site. Rogers & Associates Engineering Corp., RAE, measured diffusion coefficients of this material from 6 test pits, the results are shown in Table 2.1 (Nielson, K.K., 1983a). It has been determined that the top foot of cover under the rock cover will maintain a moisture content of 5 percent, any material below that depth will have a moisture content of 7.5 percent. The data in Table 2.1 indicates the diffusion coefficient of the top foot of cover is 0.025 cm^2/sec, the remainder of the cover has a diffusion coefficient of 0.017 cm^2/sec.

Test pits were also dug in the tailings and samples were taken. RAE measured the diffusion coefficient at varying moisture contents for each of the samples and these data are in Table 2.2. The tailings pile has been divided into 10 separate layers, the top 5 layers consist of sands, the next 2 layers are slimes, and the bottom 3 layers are mixed sands and slimes. The sands diffusion coefficient is 0.039 cm^2/sec, the slimes, 0.00055 cm^2/sec and the sands/slimes mixture diffusion coefficient is 0.024 cm^2/sec. The windblown material, the top layer on the pile, is assumed to have the same diffusion coefficient as the tailings sands.

Table 2.1 Radon diffusion coefficients of cover material

Test Pit	% Moisture (dry)	Density (g/cm^3) dry	% Sat	D (cm^2/sec)
#1 0-2½'	1.6	1.74	9	4.5×10^{-2}
	3.5	1.74	20	3.7×10^{-2}
	6.6	1.74	38	3.6×10^{-2}
	6.7	1.73	38	4.3×10^{-2}
	12.5	1.75	73	2.9×10^{-3}
	12.8	1.75	75	4.3×10^{-3}
#2 2-7½'	2.3	1.75	12	3.0×10^{-2}
	3.0	1.74	15	1.9×10^{-2}
	7.6	1.71	37	2.9×10^{-2}
	7.6	1.71	37	3.0×10^{-3}
	13.0	1.74	66	9.9×10^{-3}
	13.6	1.73	68	4.2×10^{-3}
#3 7-11'	2.6	1.82	14	2.2×10^{-2}
	3.8	1.82	20	2.0×10^{-2}
	5.1	1.82	27	2.1×10^{-2}
	5.6	1.82	29	2.2×10^{-2}
	12.6	1.82	66	4.6×10^{-3}
	12.7	1.82	66	8.9×10^{-4}
#3 11'-15'	2.6	1.79	17	4.1×10^{-2}
	3.4	1.79	22	3.5×10^{-2}
	7.1	1.79	46	3.4×10^{-2}
	7.6	1.78	48	2.8×10^{-2}
	10.9	1.79	70	1.2×10^{-2}
	11.1	1.79	72	1.6×10^{-2}
#4 1-10'	3.0	1.71	15	4.2×10^{-2}
	3.2	1.77	18	2.1×10^{-2}
	3.5	1.66	16	2.7×10^{-2}
	5.5	1.77	30	2.4×10^{-2}
	6.5	1.77	34	1.8×10^{-3}
	12.8	1.77	70	6.1×10^{-3}
	13.2	1.77	72	4.0×10^{-3}
#8 (Shale)	3.4	1.85	18	2.0×10^{-2}
	3.5	1.84	19	1.8×10^{-2}
	5.4	1.85	29	2.2×10^{-2}
	6.1	1.84	32	1.6×10^{-4}
	12.2	1.85	66	8.0×10^{-4}
	13.0	1.85	70	9.8×10^{-4}

Table 2.1 Radon diffusion coefficients of cover material (Cont'd)

Test Pit	% Moisture (dry)	Density (g/cm^3) dry	% Sat	D (cm^2/sec)
#2 - 9½-11' + Devils Wash	2.4	1.75	12	3.9×10^{-2}
	3.8	1.74	19	2.9×10^{-2}
	5.8	1.76	30	1.7×10^{-2}
	6.6	1.74	33	3.0×10^{-3}
	12.5	1.76	65	1.5×10^{-3}
	13.6	1.74	68	1.0×10^{-3}

Table 2.2 Radon diffusion coefficients of Shiprock tailings*

Sample	% Moisture (dry)	Density (g/cm^3) dry	Saturation %	D (cm^2/sec)
TP-1 Slimes	11.5	1.38	36	2.3×10^{-2}
TP-1 Slimes	11.7	1.38	37	2.1×10^{-2}
TP-1 Slimes	16.0	1.37	49	2.5×10^{-2}
TP-1 Slimes	16.8	1.39	54	2.2×10^{-4}
TP-1 Slimes	26.7	1.40	86	6.0×10^{-4}
TP-1 Slimes	29.5	1.39	94	5.1×10^{-4}
TP-2 Sands	6.0	1.50	22	4.0×10^{-2}
TP-2 Sands	6.8	1.50	25	3.8×10^{-2}
TP-2 Sands	9.3	1.51	34	3.8×10^{-2}
TP-2 Sands	9.4	1.51	35	1.9×10^{-2}
TP-2 Sands	13.3	1.51	49	1.0×10^{-3}
TP-2 Sands	13.5	1.51	50	9.8×10^{-4}
TP-2 Sand/Slime	6.8	1.61	31	4.8×10^{-2}
TP-2 Sand/Slime	7.2	1.59	31	4.3×10^{-2}
TP-2 Sand/Slime	9.7	1.61	44	3.0×10^{-2}
TP-2 Sand/Slime	9.7	1.61	44	2.1×10^{-2}
TP-2 Sand/Slime	11.5	1.59	50	2.7×10^{-3}
TP-2 Sand/Slime	13.8	1.61	62	8.3×10^{-4}
TP-3 Sand/Slime	6.5	1.69	33	4.0×10^{-2}
TP-3 Sand/Slime	7.2	1.67	35	4.1×10^{-2}
TP-3 Sand/Slime	9.7	1.70	50	2.9×10^{-2}
TP-3 Sand/Slime	9.9	1.70	51	1.8×10^{-2}
TP-3 Sand/Slime	12.9	1.71	68	7.1×10^{-3}
TP-3 Sand/Slime	13.4	1.71	71	5.9×10^{-4}

*(K.K. Nielson, 1983b).

The RAECO model requires diffusion coefficient data input in the form of the effective diffusion coefficient, which is the diffusion coefficient multiplied by the porosity of the material. The porosity P is calculated from:

$$P = 1 - \frac{\rho}{SG}$$

where

ρ = Dry bulk density (g/cm^3)
SG = Specific gravity of the soil

Table 2.3 presents the diffusion coefficient, porosity, and effective diffusion coefficient for each layer of the tailings and radon control cover.

Table 2.3 RAECO model diffusion coefficient input

Material	Diffusion coefficient (cm^2/sec)	Porosity	Effective diffusion coefficient Dxp ($cm^2 sec$)
Tailings sand	0.039	0.41	0.016
Tailings slimes	0.00055	0.44	0.00024
Tailings sand/ slime	0.024	0.35	0.0084
Windblown	0.039	0.41	0.016
Silty sandy cover (top foot)	0.025	0.33	0.0082
Silty sand cover (below 1 foot)	0.017	0.33	0.0056

B. Tailings Thickness

The tailings piles will be contoured and reshaped in such a way that the tailings pile can be treated as 9 layers of tailings each 2-1/2 feet thick. The windblown contamination will be an additional layer of 7 inches. These thickness are direct input to the RAECO model.

C. Background Radon Concentration

In the vicinity of the Shiprock pile three background radon monitors were set-up and 24-hour samples taken. The readings ranged from 0.66 pCi/l to 0.98 pCi/l with an average radon concentration of 0.8 pCi/l (FBDU, 1981). This value was used as input to the RAECO model.

D. Radon Source Term

The radon source term, Q, is given by the following expression (Rogers, V.C.and K.K. Nielson, 1981):

$$Q = R\rho E\lambda$$

where

R = Average radium-226 concentration (pCi/g)
ρ = Dry bulk density (g/cm^3)
E = Emanating power
λ = Radon decay constant (2.1×10^{-6}/sec)

The average Radium-226 concentration of each tailings layer was calculated using over 350 sample analysis from more than 70 drill holes (Bendix, 1983). Evaluation of these data in the Earthwork Volume Calculations (S-F-01) indicates that the sand fraction of the tailings to be cut (excavated) average 400 pCi/g and the slime fraction averages 1040 pCi/g. Using these values the areas to be filled were provided with sands and slimes from the cut to bring the elevation up to the necessary grade. Figure 2.1 shows the outline of the areas to be cut and filled. This created a new radium profile for each hole on the pile. The radium concentration for each 2-1/2 foot layer of the new profiles were averaged to obtain a layer average radium concentration. These averages are presented in Table 2.4. The average radium concentration of the windblown layer was calculated from soil analysis of several 100 samples.

The average dry bulk density for each layer was obtained from the test results in Table 2.2 and are also given in Table 2.4

The emanating power of the tailings sample were measured and the average of the results are shown in Table 2.4.

Using these values the source term for each tailings layer was calculated and is in the last column of Table 2.4.

IV. RESULT

Using the inputs outlined in the previous section the RAECO model indicates that 211 cm of silty sandy soil are required to reduce the radon flux below 20 pCi/m^{2}sec. This is a minimum of 7 feet of radon attenuation cover, in addition, material will be added for erosion control. The material necessary for erosion control is not accounted for in the radon attenuation calculation.

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Table 2.4 Tailings source terms for RAECO

Tailings layer (ft)	Material type	Average Ra-226 (pCi/g)	Density g/cm^3	Emanating Power *	Source term Q, (pCi/m^2-sec)
0-2.5	Sand	398.3	1.51	0.14	0.00018
2.5-5.0	Sand	396.4	1.51	0.14	0.00018
5.0-7.5	Sand	371.4	1.51	0.14	0.00016
7.5-10.0	Sand	360.2	1.51	0.14	0.00016
10.0-12.5	Slime	790.7	1.38	0.16	0.00037
12.5-15.0	Slime	495.5	1.38	0.16	0.00023
15.0-17.5	Sand/slime	462.2	1.65	0.28	0.00045
17.5-20.0	Sand/slime	308.3	1.65	0.28	0.00030
20.0-22.5	Sand/slime	485.7	1.65	0.28	0.00047
Windblown	Sand	47	1.51	0.14	0.000021

*(Nielson, K.K., 1983c).

V. REFERENCES

Bendix (Bendix Field Engineering Corporation), 1983. Radium-226 Analysis for Shiprock Site Tailings Samples, Chemistry Laboratory Geochemical Support Department Bendix Field Engineering Corporation, Grand Junction, Colorado, August 9, 1983 for the U.S. Department of Energy Uranium Mill Tailings Remedial Action Project Office, Albuquerque, Operations Office, Albuquerque, New Mexico.

FBDU (Ford, Bacon and Davis, Utah, Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings, Shiprock Site, Shiprock, New Mexico, DOE/UMT-0104, prepared for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

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Rogers, V.C., G.M. Sandquist, K.K. Nielson, 1981. Radon Attenuation Effectiveness and Cost Optimization of Composite Covers for Uranium Mill Tailings, UMTRA-DOE/ALO-165, prepared by Roger and Associates Engineering Corporation, Salt Lake City, Utah, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

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JE JACOBS ENGINEERING

Smith

DATE 10-17-83 SUBJECT Sliprock Cover Calculation SHEET NO. 1

BY MAG CHKD. JOB NO. VMTRA

1. Radium Concentration

1. The tailings pile radium-226 must be determined first. This was accomplished as follows. All the available radium-226 data analysis, from archived samples that were taken during the MSRD assay program for their economic evaluation reports, were input to the Radio Shack Model-12 micro computer data management system. The data was sorted and tabulated by hole number and depth. The computer print out (Table 2.1) gives all of the available data.

Since the pile is going to have a substantial amount of regrading and excavation done each drillhole was individual evaluated. Each sample represent the radium content for a 2½ foot interval in the drillhole. The drillholes in Table 2.1 that are highlighted in yellow (A-020, A-026, A-029, A-034, B-008, B-010, B-023 & B-0025) are to be totally excavated. Other holes only have partial excavation, this is indicated by at 'New TOH' designation at the depth that will be the new pile surface. Figure 2.1 shows the areas on the pile that are cut and fill, Figure 2.2 shows location of each drillhole. The depth of sands and slimes was determined from each drillhole and recorded (Table 2.2) along with the Radium concentrations. The ~~radon~~ average sands and slimes Rconcentration were calculated weighted on depth. Weighting based on area was not done because the drillholes are spaced evenly, and no dramatic areal effects would be encountered. The result

FORM 91-005-1 (4/81)

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Table 2.1

SHIPROCK SOURCE TERM ANALYSIS USING ARCHIVED MSRD SAMPLES- OCTOBER 13, 1983 PAGE 1

HOLE #	DEPTH	PCI/G	
~~A-016~~ ? B	0.0	392	342 SANDS
	7.5	430	
	10.0	302	
	~~12.5~~	~~243~~	
NEW TOH	15.0	370	
	17.5	483	
	~~20.0~~	~~362~~	
	22.5	502	
	25.0	453	
	~~27.5~~	~~219~~	
	30.0	331	
	32.5	375	
	~~37.5~~	~~319~~	
	40.0	478	
A-020	0.0	423	587
	7.5	817	
	10.0	522	
	15.0	377	
	~~17.5~~	~~893~~	760 avg.
	20.0	770	
	22.5	959	
	~~27.5~~	~~1222~~	
	30.0	1301	
	32.5	899	
	~~35.0~~	~~173~~	
A-022	22.5	225	322 SANDS
	25.0	237	
	27.5	414	
	30.0	412	
	35.0	1223	- 1223 - 4' SLIMES
A-024	0.0	196	381 SANDS
	5.0	445	
	10.0	459	
	12.5	252	
	15.0	552	
	17.5	383	
A-026	0.0	390	836
	5.0	854	
	7.5	1413	
	10.0	685	
	12.5	1528	842 avg.
	15.0	838	
	17.5	1040	
	20.0	442	
	25.0	398	
	27.5	841	
	30.0	388	
	32.5	490	
	35.0	1642	
A-028	5.0	849	445 SANDS
	7.5	568	
	10.0	342	
	12.5	331	
	15.0	316	
	17.5	262	

SHIPROCK SOURCE TERM ANALYSIS USING ARCHIVED MSRD SAMPLES- OCTOBER 13, 1983 PAGE 2

HOLE #	DEPTH	PCI/G	
A-029	10.0	403	418
	12.5	358	
	15.0	494	
	17.5	986	580 avg.
	22.5	968	
	25.0	369	
	30.0	830	
	32.5	40	
	35.0	776	
A-030	0.0	294	409 SAND
	2.5	313	
	5.0	356	
	7.5	496	
	10.0	413	
	12.5	629	
	15.0	528	
	17.5	239	
A-031	7.5	382	400 SANDS
	10.0	333	
	12.5	466	
	15.0	224	
	17.5	566	
	22.5	602	
	25.0	231	
	27.5	395	
	30.0	1409	4' @ 1409 SLIMES
	35.0	348	
A-032	5.0	2420	
	7.5	2084	
	10.0	1696	
A-033	0.0	361	344 SANDS
	2.5	353	
	5.0	318	
NEW TOH	7.5	435	
	10.0	366	
	12.5	249	
	15.0	297	
	17.5	327	
A-034	0.0	243	347
	2.5	580	
	5.0	443	
	7.5	215	
	10.0	252	
	12.5	680	535
	15.0	813	
	17.5	636	
	20.0	439	535 avg
	22.5	318	
	25.0	305	
	27.5	349	
	30.0	484	
	32.5	321	
	35.0	326	
	37.5	2161	avg
A-035	0.0	264	

TMG 10-17-83 Table 2.1 (cont)

SHIPROCK SOURCE TERM ANALYSIS USING ARCHIVED MSRD SAMPLES- OCTOBER 13, 1983 PAGE 3

266 SAND

	HOLE #	DEPTH	PCI/G	
	A-035	2.5	258	
		5.0	276	
NEW TOH		7.5	398	
		10.0	388	
		12.5	471	
		15.0	324	
		17.5	512	
9'-400 4'-1180	B-001	0.0	7+13' fill	
		7.5	469	
9'-400	B-002	7.5	355+20' fill	
11'-1180	B-003	2.5	523	4' @ 523 SLIMES — at
		5.0	32	
		7.5	81	
9'-400 9'-1200	B-004	0.0	498+18' fill	
	B-008	7.5	1463	
9'-400	B-009	12.5	1218+9' fill	
	B-010	2.5	404	429
		10.0	453	
		12.5	978	930 avg
		15.0	1354	
		20.0	1451	1180
		25.0	940	
9'-400 5'-1200	B-011	2.5	623+14' fill	
		5.0	281	
	B-012	7.5	910 0 fill	TOH 2.5
		12.5	409	
		22.5	72	
		25.0	102	
9'-400 5'-1200	B-013	0.0	315+14' fill	
		2.5	58	
		5.0	284	7.5
		7.5	341	
		10.0	433	
	B-014	0.0	230	265 SAND
		5.0	299	22
NEW TOH		10.0	296	25
		12.5	725	
		15.0	380	
		17.5	359	
		20.0	338	
		22.5	401	
9'-400 8'-1200	B-015	5.0	136+17' fill	
		7.5	24	
		10.0	17	
		12.5	16	
		15.0	13	
9'-400 1'-1200	B-017	0.0	679+10' fill	
		2.5	308	
		5.0	291	
		7.5	425	
		10.0	421	
	B-018	2.5	435	
		5.0	377	368 SANDS
		7.5	291	
NEW TOH		10.0	411	

MAJ 10/17/83 Table 2.1 (cont) 5

SHIPROCK SOURCE TERM ANALYSIS USING ARCHIVED MSRD SAMPLES- OCTOBER 13, 1983 PAGE 4

HOLE #	DEPTH	PCI/G	
B-018	12.5	340	
9'-400 — B-019	0.0	313	+11' fill
2'-1200	2.5	444	
	5.0	281	
	7.5	504	
	10.0	511	
	12.5	541	
B-021	0.0	363	
	2.5	401	
	7.5	402	380 SANDS
	10.0	259	
	12.5	489	
TOP	20.0	367	
	22.5	487	
	25.0	378	
	27.5	490	
B-023	7.5	432	
	10.0	1000	
	12.5	754	790 avg. SLIMES
	15.0	1247	
	17.5	1160	
	22.5	888	
	25.0	49	
B-025	0.0	131	
	2.5	279	442 SANDS
	5.0	499	
	12.5	638	
	15.0	453	
	17.5	649	741 avg
	20.0	1444	
	22.5	1586	1190 SLIMES
	25.0	985	
	30.0	748	
B-027	0.0	470	
	5.0	364	
	7.5	337	
	10.0	286	
	12.5	356	
	15.0	373	
	17.5	314	401 SAND
	20.0	427	
	22.5	680	
TOP OF TAILS	25.0	419	
	27.5	374	
	30.0	882	
	32.5	426	
	37.5	201	
1'-400 B-036	5.0	223	+1' fill
	7.5	410	
	10.0	220	
	12.5	372	
	15.0	251	
	17.5	205	
9'-400 C-072	0.0	104	+9' fill
	2.5	68	

B-032 Cut 4'

C-070 + 12' fill — 9'-400 3'-1200

SHIPROCK SOURCE TERM ANALYSIS USING ARCHIVED MSRD SAMPLES- OCTOBER 13, 1983 PAGE 5

	HOLE #	DEPTH	PCI/G	
	C-072	5.0	268	
		7.5	390	
8'-400	C-074	0.0	145	+ 8' fill
		2.5	357	
		5.0	495	
		7.5	407	
9'-400 3'-1200	- C-075	0.0	33	+ 12' fill
		2.5	249	
		5.0	150	
		7.5	353	
4'-400	- C-076	5.0	81	+ 4' fill
		7.5	337	
2'-400	C-077	5.0	47	+ 2' fill
	C-078	5.0	405	> 546
		7.5	687	
	C-080	0.0	419	> 385 SANDS
		2.5	228	
		5.0	507	
		7.5	1001	- 14.5' @ 1001 SLIMES
8'-400	C-081	5.0	70	+ 8' fill
		7.5	114	
	C-082	0.0	103	> 75 SAND
		5.0	60	
		7.5	61	
400	C-083	0.0	154	+ 7' fill
		2.5	41	
		5.0	93	
	C-084	0.0	248	14' @
		2.5	58	> 112 SANDS
		5.0	30	
	C-085	0.0	69	10'
		5.0	35	> 52 - SANDS
6'-400	- C-086	0.0	30	+ 6' fill
		7.5	102	
9'-400 3'-1200	- C-087	0.0	92	+ 12' fill
		2.5	30	
		5.0	365	
		7.5	420	
6'-400	- C-088	5.0	412	+ 6' fill
		7.5	651	
		10.0	619	
9'-400 4'-1200	- C-089	0.0	30	+ 13' fill
		2.5	53	
		5.0	9	
		7.5	124	
	C-090	0.0	8	> + 3' @ 20 - SANDS
		7.5	32	
	C-091	0.0	17	
		2.5	834	9' @
		5.0	245	> 276 SANDS
		7.5	7	
	C-092	0.0	4	> + 3' @ 371 SANDS
		5.0	640	
		7.5	468	
3'-400	- C-093	0.0	18	3' of fill

Table 2.1 (cont)

Mtg 10/17/83

SHIPROCK SOURCE TERM ANALYSIS USING ARCHIVED MSRD SAMPLES- OCTOBER 13, 1983 PAGE 6

HOLE #	DEPTH	PCI/G	
C-093	2.5	35	
	5.0	4	8'@ 242 SANDS
C-094	5.0	208	
	7.5	276	
C-095	0.0	72	
	5.0	83	
	7.5	331	19'@ 331 SANDS
C-096	0.0	44	
	2.5	30	8'@ 21 SANDS
	5.0	6	
	7.5	2	
C-097	0.0	587	
	2.5	582	560 SLIMES
	5.0	510	
C-098	0.0	407	
	2.5	431	
	5.0	366	17'@ 366 SANDS
	7.5	261	
8'-400 - C-099	0.0	21 + 8' fill	
	5.0	45	
	7.5	1254	
5'-400 - C-100	0.0	34 + 5' fill	
	5.0	169	
	7.5	14	
9'-400 1'-1200 C-101	0.0	10 + 10' fill	
	2.5	17	
	5.0	13	
	7.5	494	
8'-400 - D-042	2.5	272 + 8' fill	
7'-400 - D-044	0.0	295 + 7' fill	
	2.5	6	
	5.0	109	
9'-400 6'-1200 D-046	0.0	993 + 15' fill	
	2.5	606	
9'-400 3'-1200 D-055	2.5	66 + 12' fill	
	5.0	500	
	7.5	1674	
9'-400 1'-1200 - D-057	5.0	12 + 10' fill	
	7.5	440	
9'-400 1'-1200 - D-059	2.5	23 + 10' fill	
	5.0	13	
	7.5	742	
9'-400 2'-1200 - D-061	0.0	44 + 11' fill	
	2.5	48	
	5.0	237	
	7.5	183	
9'-400 2'-1200 - D-063	0.0	320 + 11' fill	
9'-400 3'-1200 - D-064	0.0	103 + 12' fill	
	2.5	167	
	5.0	82	
	7.5	23	
D-065	0.0	38	9'@ 53
	2.5	67	

D-040 + 8' fill - 400

D-051 + 3' fill - 400
D-048 + 13' fill - 9'-400 4'-1200
D-050 + 13' fill - 9'-400 4'-1200
D-053 + 12' fill - 9'-400 3'-1200

D-052 + 11' fill - 9'-400 0'-1200

D-056 + 10' fill - 9'-400 1'-1200
D-058 + 3' fill - 400

D-060 + 8' fill - 400

D-062 + 14' fill - 9'-400 5'-1200

SHIPROCK SOURCE TERM ANALYSIS USING ARCHIVED MSRD SAMPLES- OCTOBER 13, 1983 PAGE 6

	HOLE #	DEPTH	PCI/G	
	C-093	2.5	35	
		5.0	4	8'@ SANDS
	C-094	5.0	208	242
		7.5	276	
	C-095	0.0	72	
		5.0	83	
		7.5	331	19'@ 331 SANDS
	C-096	0.0	44	
		2.5	30	8'@ 21 SANDS
		5.0	6	
		7.5	2	
	C-097	0.0	587	
		2.5	582	560 SLIMES
		5.0	510	
	C-098	0.0	407	
		2.5	431	
		5.0	366	17'@ 366 SANDS
		7.5	261	
8'-400	C-099	0.0	21	+8' fill
		5.0	45	
		7.5	1254	
5'-400	C-100	0.0	34	+5' fill
		5.0	169	
		7.5	14	
1'-400 1200	C-101	0.0	10	+10' fill
		2.5	17	
		5.0	13	
		7.5	494	D-040 +8' fill -400
8'-400	D-042	2.5	272	+8' fill
7'-400	D-044	0.0	295	+7' fill
		2.5	6	
		5.0	109	
9'-400 6'-1200	D-046	0.0	993	+15' fill
		2.5	606	
9'-400 3'-1200	D-055	2.5	66	+12' fill
		5.0	500	
		7.5	1674	
9'-400 1'-1200	D-057	5.0	12	+10' fill
		7.5	440	
9'-400 1'-1200	D-059	2.5	23	+10' fill
		5.0	13	
		7.5	742	
9'-400 2'-1200	D-061	0.0	44	+11' fill
		2.5	48	
		5.0	237	
		7.5	183	
9'-400 2'-1200	D-063	0.0	320	+11' fill
9'-400 3'-1200	D-064	0.0	103	+12' fill
		2.5	167	
		5.0	82	
		7.5	23	
	D-065	0.0	38	9'@ 53
		2.5	67	
7'-400	D-066	5.0	187	7'-fill
	D-068	0.0	73	

D-051 + 3' fill - 400
D-048 + 13' fill - 9'-400 4'-1200
D-050 + 13' fill - 9'-400 4'-1200
D-053 + 12' fill 9'-400 3'-1200

D-052 +11' fill - 9'-400 2'-1200

D-056 + 10' fill - 9'-400 1'-1200
D-058 + 3' fill - 400

D-060 +8' fill -400

D-062 + 14' fill 9'-400 5'-1200

JACOBS ENGINEERING

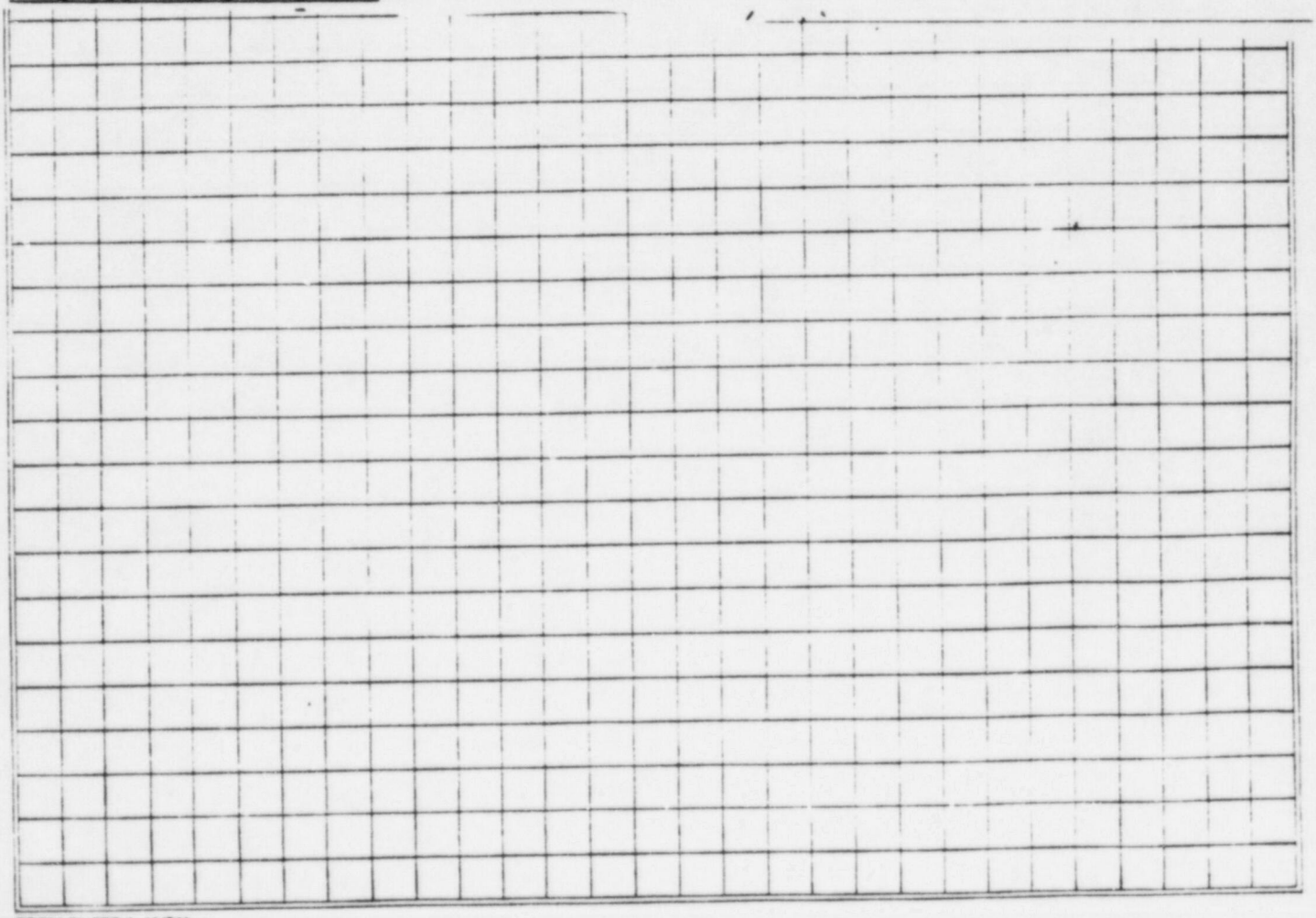
DATE 10/17/83 SUBJECT SHP cover SHEET NO. 8

BY MAG CHKD. JOB NO. UMTRA

Table 2.1 (cont)

SHIPROCK SOURCE TERM ANALYSIS USING ARCHIVED MSRD SAMPLES- OCTOBER 13, 1983 PAGE 7

HOLE #	DEPTH	PCI/G	
9'-400 2'-1200 - D-068	5.0	54+11'fill	
	7.5	303	4'
D-069	0.0	14	11 SANDS
	2.5	8	
D-070	0.0	118	— D-079 +20'fill 9'-400 11'-1200
	7.5	283	
D-102	0.0	276	+5'
	2.5	439	340 -SANDS
	5.0	249	
	7.5	397	
5'-400 D-103	0.0	27 +5'fill	
	2.5	39	
	5.0	23	D-104 +2'fill -400
D-105	0.0	742	723 -SLIMES
	2.5	704	
NEW TOH	5.0	1838	
	7.5	1884	
460 D-106	5.0	17 +4'fill	



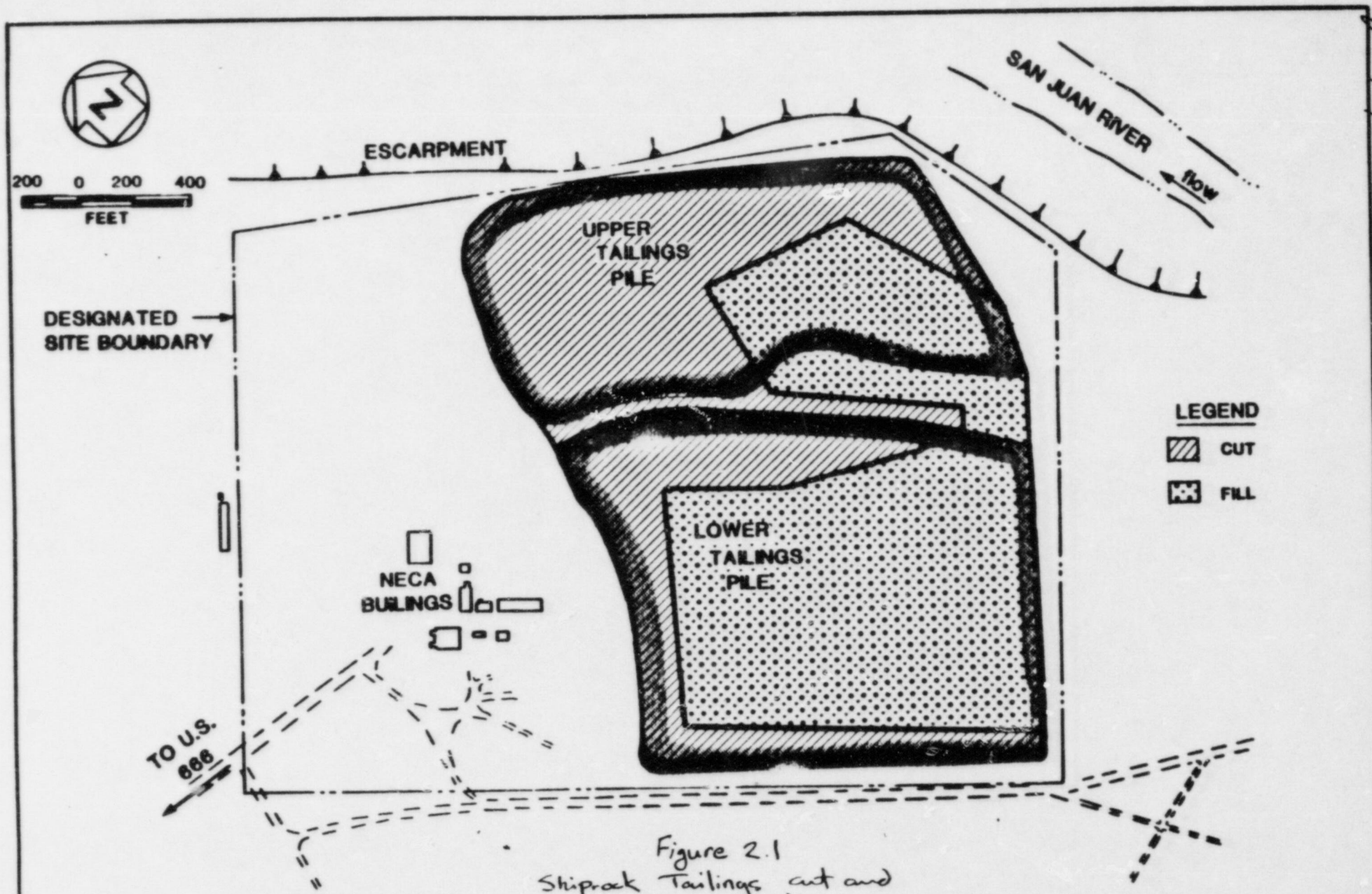


Figure 2.1
Shiprock Tailings cut and fill for regrading

Mag 11/9/83

Uncontrolled 12/6/83 (9A)

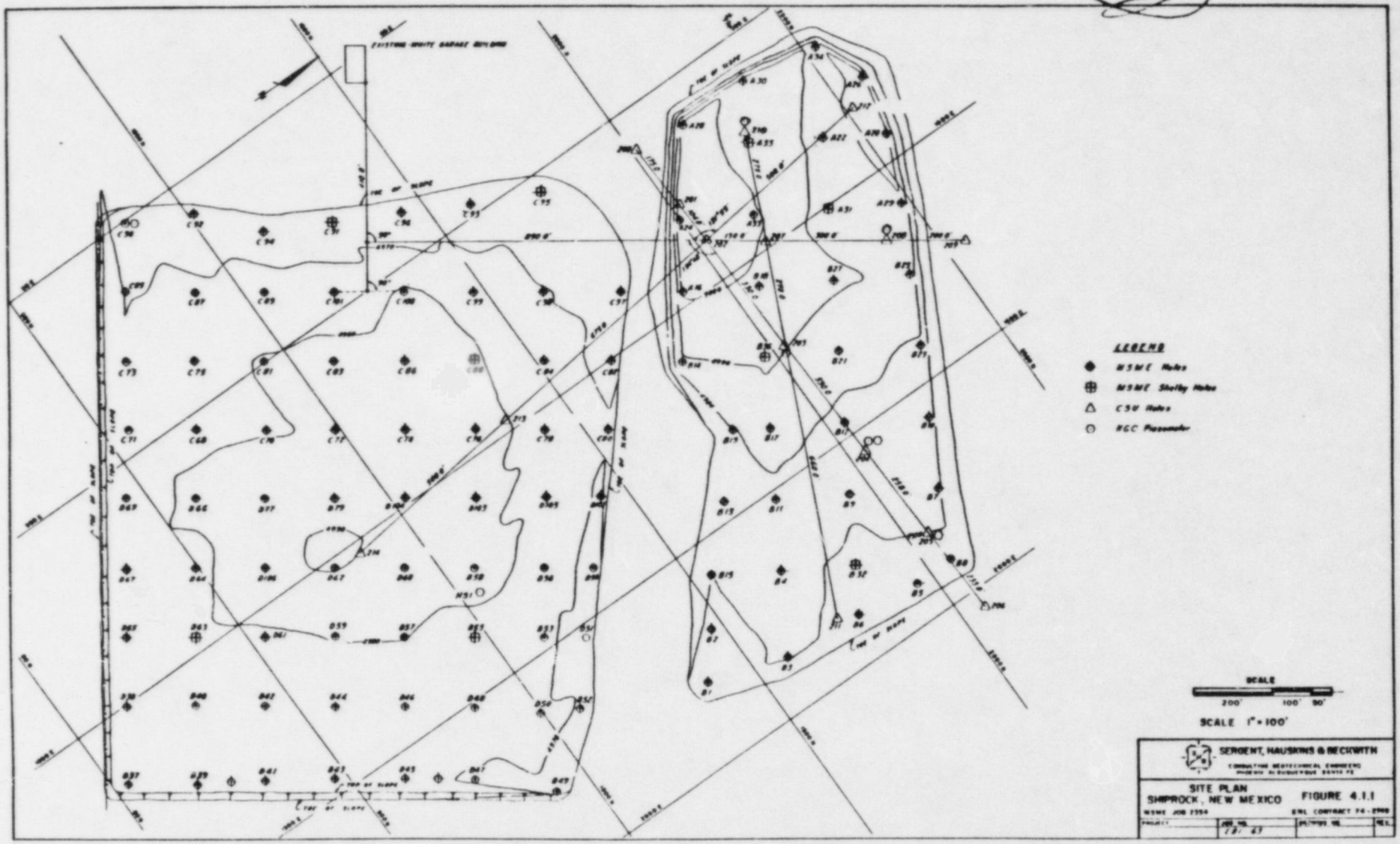


Figure 2.2-

NSWE Holes

JACOBS ENGINEERING

DATE 10/17/83 SUBJECT Cut 10-40 SHEET NO. SHP-10

BY ZMG CHKD. JOB NO. UMTRA

Table 2.2

Hole #	SAND Ft	SAND Rate	SAND Ft Rate	SLIMES Ft	SLIMES Rate	SLIMES Ft Rate
A-34	40	535	21400			
A-26	38	842	32000			
A-20	34	760	25840			
A-29	31	580	18000			
B-25	20	442	8840	10	1190	11900
B-23				25	790	19750
B-10	12½	429	5360	12½	1180	14750
B-7				17	1180	20060
B-8				10	1463	14630
B-5				14	1180	16520
B-6				13	1180	15340
A-22	33	322	10630	4	1223	4892
A-31	30	400	13800	4	1409	5636
B-27	25	401	10030			
A-30	28	409	11450			
A-35	8	266	2130			
A-33	6	344	2060			
B-18	8	368	2940			
A-28	29	445	12910			
A-24	19	381	7240			
B-16	15	342	5130			
B-14	7	265	1860			7840
C-97	~~46~~			14'-560	5/5	cut
C-82	18	75	1350			
C-80	7.5	385	2890	14.5	1001	14520
B-21	18	380	6840			
C-95	19	331	6290			
C-98	17	366	6220			
C-84	14	112	1568			
C-79	8	546	4368			
D-102	20	340	6809	4	723	56 2890
D-54	10	340	~~1~~ 3400	assumed same as D-102		
C-90	13	20	260			
C-85	10	52	520			
C-73	7	52	~~90~~ 360	ASSUMED		
D-69	4	11	44			

FORM 91-006-1 (4/81)

JACOBS ENGINEERING

DATE 10/17/83 SUBJECT Cut SHEET NO. SHP-11

BY [illegible] CHKD. Table 2.2 (cont) JOB NO. UMTRA

D-67	8	53	424	955			
D-65	9	53	477	~~955~~			
C-71	5	52	260	955			
D-38	6	53	318	955			
C-92	13	371	4823				
C-94	8	242	1936				
C-91	9	276	2484				
C-96	8	21	168				
B-32		~~180~~			4	1200	7200
B-3					4	523	2090
TOTAL	615		243410		152		158020

AVG ~~Sands~~ TAILS RA = 396 Sands

$\overline{RA}$ = 1040 = slimes Ra pCi/g

D-37	8	400	3200	
D-39	7	400	2800	
D-41	14	400	5600	
D-43	13	400	5200	
D-45	12	400	4800	
D-47	14	400	5600	
D-49	22	400	1800	
	90		36000	

705

279410 = 396 sands pCi/g Ra

705

705+152

82% SANDS

MAG 11/15/83

shows that the sands average 400 pCi/g and the slimes approximately 1940 pCi/g Ra-226. These values were used as average values were fill was required.

The cut/fill calculations shown on the next pages indicates there is 9' of sand available to fill where required. In Table 2.1 this was used to add fill where needed. In the left area in pencil the footage of fill required is indicated that is the amount of sands and slimes used to bring the area up to grade. It is assumed the top most material is sands for radon attenuation benefit and pile stability.

Using these number new profiles for the drill holes were developed. These profiles provide a bases for the source term calculations. Table 2.3 shows the new profiles sorted by depth, the depths indicate each 2½ foot layer in the pile. Layer 1 indicates from the surface to 2½ feet down, etc. In Table 2.3 also shows the average radium-226 concentration of each layer. These are used as input to the source term equation.

This analysis results in the radium concentration in each tailings layer. The radium concentration of the windblown material is 47 pCi/g, this is the average of several 100 measured values from the Bendix site characterization survey.

JACOBS ENGINEERING

DATE 10/17/83 SUBJECT DISTRIBUTION OF SANDS SHEET NO. SHP-13

BY DJS CHKD. JOB NO. UMTRA

Calculation 2.1

CUT - 812,102 CY

10% SHRINKAGE 81,210

TOTAL FILL 730,892 CY = 19,734,079 ft^3

FROM ANALYSIS OF 'DRILL HOLES' SAY 82% OF CUT IS 'SAND' @ 400 pCi/gm

SAND FILL = 19,734,079 (0.82) = 16,181,944 ft^3

AREA OF FILL = 1,776,000 ft^2

AVG THICKNESS OF 'SAND' FILL =

$\frac{16,181,944}{1,776,000}$ = 9' OF 'SAND' @ 400 pCi/gm where required for fill

Hole #	Depth	Ref.	REDISTRIBUTED TAILINGS DRILLHOLE PROFILES
B-014	1.0	296	Depths are in increments of 2.5'
B-021	1.0	367	
B-016	1.0	370	Table 2.3 10-22-83
A-035	1.0	398	
B-001	1.0	400	
B-002	1.0	400	
B-004	1.0	400	
B-009	1.0	400	
B-011	1.0	400	
B-013	1.0	400	
B-015	1.0	400	
B-017	1.0	400	
B-019	1.0	400	
B-036	1.0	400	
C-070	1.0	400	
C-072	1.0	400	
C-074	1.0	400	
C-075	1.0	400	
C-076	1.0	400	
C-077	1.0	400	
C-081	1.0	400	
C-083	1.0	400	
C-086	1.0	400	
C-087	1.0	400	
C-088	1.0	400	
C-089	1.0	400	
C-093	1.0	400	
C-099	1.0	400	
C-100	1.0	400	
C-101	1.0	400	
D-040	1.0	400	
D-042	1.0	400	
D-044	1.0	400	
D-046	1.0	400	
D-048	1.0	400	
D-050	1.0	400	
D-051	1.0	400	
D-052	1.0	400	
D-053	1.0	400	
D-055	1.0	400	
D-056	1.0	400	
D-057	1.0	400	
D-058	1.0	400	
D-059	1.0	400	
D-060	1.0	400	
D-061	1.0	400	
D-062	1.0	400	
D-063	1.0	400	
D-064	1.0	400	
D-066	1.0	400	
D-068	1.0	400	
D-079	1.0	400	
D-103	1.0	400	
D-104	1.0	400	
D-106	1.0	400	
B-018	1.0	411	
B-027	1.0	419	
A-033	1.0	439	398.3 I/6
C-093	2.0	16	
B-036	2.0	223	

10/17/83

14

Table 2.3 (cont)

AMD 10/17/83

B-018	2.0	340
A-033	2.0	366
B-027	2.0	374
A-035	2.0	388
B-001	2.0	400
B-002	2.0	400
B-004	2.0	400
B-009	2.0	400
B-011	2.0	400
B-013	2.0	400
B-015	2.0	400
B-017	2.0	400
B-019	2.0	400
C-070	2.0	400
C-072	2.0	400
C-074	2.0	400
C-075	2.0	400
C-076	2.0	400
C-081	2.0	400
C-083	2.0	400
C-086	2.0	400
C-087	2.0	400
C-088	2.0	400
C-089	2.0	400
C-099	2.0	400
C-100	2.0	400
C-101	2.0	400
D-040	2.0	400
D-042	2.0	400
D-044	2.0	400
D-046	2.0	400
D-048	2.0	400
D-050	2.0	400
D-052	2.0	400
D-053	2.0	400
D-055	2.0	400
D-056	2.0	400
D-057	2.0	400
D-059	2.0	400
D-060	2.0	400
D-061	2.0	400
D-062	2.0	400
D-063	2.0	400
D-064	2.0	400
D-066	2.0	400
D-068	2.0	400
D-079	2.0	400
D-103	2.0	400
D-106	2.0	400
B-016	2.0	483
B-021	2.0	487
B-014	2.0	725
D-103	3.0	27
C-086	3.0	30
C-100	3.0	34
C-093	3.0	35
C-076	3.0	81
A-033	3.0	249
B-016	3.0	362
B-021	3.0	378

396.4 ± 75

MAJ 10-17/83

Table 2.3 (cont.)

B-014	3.0	360
B-001	3.0	400
B-002	3.0	400
B-004	3.0	400
B-009	3.0	400
B-011	3.0	400
B-013	3.0	400
B-015	3.0	400
B-017	3.0	400
B-019	3.0	400
C-070	3.0	400
C-072	3.0	400
C-074	3.0	400
C-076	3.0	400
C-081	3.0	400
C-083	3.0	400
C-087	3.0	400
C-089	3.0	400
C-099	3.0	400
C-101	3.0	400
D-040	3.0	400
D-042	3.0	400
D-044	3.0	400
D-046	3.0	400
D-048	3.0	400
D-050	3.0	400
D-052	3.0	400
D-053	3.0	400
D-055	3.0	400
D-056	3.0	400
D-057	3.0	400
D-059	3.0	400
D-060	3.0	400
D-061	3.0	400
D-062	3.0	400
D-063	3.0	400
D-064	3.0	400
D-066	3.0	400
D-068	3.0	400
D-079	3.0	400
B-036	3.0	410
A-035	3.0	471
B-027	3.0	882
C-093	4.0	4
C-099	4.0	21
D-103	4.0	39
C-077	4.0	47
C-074	4.0	145
C-083	4.0	154
B-036	4.0	220
D-044	4.0	296
A-033	4.0	297
A-035	4.0	324
C-076	4.0	337
B-014	4.0	359
B-001	4.0	400
B-002	4.0	400
B-004	4.0	400
B-009	4.0	400
B-011	4.0	400

371.35 ± 132 d

Table 2.3 (cont)

B-013	4.0	400	
B-015	4.0	400	
B-017	4.0	400	
B-019	4.0	400	
C-072	4.0	400	
C-072	4.0	400	
C-075	4.0	400	
C-087	4.0	400	
C-089	4.0	400	
C-101	4.0	400	
D-046	4.0	400	
D-048	4.0	400	
D-050	4.0	400	
D-052	4.0	400	
D-053	4.0	400	
D-055	4.0	400	
D-056	4.0	400	
D-057	4.0	400	
D-059	4.0	400	
D-061	4.0	400	
D-062	4.0	400	
D-063	4.0	400	
D-064	4.0	400	
D-066	4.0	400	
D-079	4.0	400	
B-027	4.0	425	
B-021	4.0	490	
B-016	4.0	502	
B-012	4.0	910	360.2 = 145
D-044	5.0	6	
D-106	5.0	17	
D-103	5.0	23	
C-083	5.0	41	
C-072	5.0	104	
C-100	5.0	169	
D-042	5.0	272	
A-033	5.0	327	
B-014	5.0	338	
C-074	5.0	357	
B-036	5.0	372	
C-088	5.0	421	
B-016	5.0	453	
A-035	5.0	512	
B-001	5.0	~~1200~~	1040
B-002	5.0	~~1200~~	1040
B-004	5.0	~~1200~~	1040
B-011	5.0	~~1200~~	
B-013	5.0	~~1200~~	
B-015	5.0	~~1200~~	
B-017	5.0	~~1200~~	
B-019	5.0	~~1200~~	
C-068	5.0	~~1200~~	
C-072	5.0	~~1200~~	
C-075	5.0	~~1200~~	
C-087	5.0	~~1200~~	
C-089	5.0	~~1200~~	
C-101	5.0	~~1200~~	
D-046	5.0	~~1200~~	
D-048	5.0	~~1200~~	
D-050	5.0	~~1200~~	1040

MA9
10/17/83

	D-052	5.0	~~1208~~ 1040
In AQ 10/17/83	D-053	5.0	~~1208~~
	D-055	5.0	~~1208~~
	D-056	5.0	~~1208~~
	D-057	5.0	~~1208~~
	D-059	5.0	~~1208~~
	D-061	5.0	~~1208~~
	D-062	5.0	~~1208~~
	D-063	5.0	~~1208~~
	D-064	5.0	~~1208~~
	D-068	5.0	~~1208~~
	D-079	5.0	~~1208~~ 1040
	B-009	5.0	1218 ~~896.1 ± 461~~ AVG = 790.7 ± 387
	C-101	6.0	10
	C-100	6.0	14
	D-066	6.0	18
	C-075	6.0	33
	D-061	6.0	44
	C-099	6.0	45
	C-072	6.0	68
	C-081	6.0	70
	D-068	6.0	73
	C-087	6.0	92
	C-083	6.0	93
	C-086	6.0	102
	D-064	6.0	103
	D-044	6.0	109
	B-027	6.0	201
	B-016	6.0	217
	B-036	6.0	281
	B-019	6.0	313
	D-063	6.0	320
	B-014	6.0	401
	B-012	6.0	409
	C-074	6.0	475
	C-088	6.0	651
	B-017	6.0	679
	B-001	6.0	~~1208~~ 1040
	B-002	6.0	~~1208~~ 1040
	B-004	6.0	~~1208~~ 1040
	B-011	6.0	~~1208~~
	B-013	6.0	~~1208~~
	B-015	6.0	~~1208~~
	C-067	6.0	~~1208~~
	D-046	6.0	~~1208~~
	D-048	6.0	~~1208~~
	D-050	6.0	~~1208~~
	D-052	6.0	~~1208~~
	D-062	6.0	~~1208~~ 1040
	D-079	6.0	~~1208~~ 1040 ~~551.7 ± 508~~ AVG 495.5 ± 430
	C-101	7.0	17
	D-059	7.0	23
	C-087	7.0	30
	C-089	7.0	31
	D-061	7.0	48
	D-055	7.0	66
	C-081	7.0	114
	D-064	7.0	167
	B-036	7.0	215
	C-075	7.0	249

Table 2.3 (cont)

	C-072	7.0	268
	B-017	7.0	308
10/7/83	B-013	7.0	315
	B-016	7.0	331
	C-075	7.0	407
	B-019	7.0	444
	B-011	7.0	623
	D-046	7.0	993
	B-002	7.0	~~1200~~ 1040
	B-004	7.0	~~1255~~ 1040
	B-015	7.0	~~1200~~ 1040
	D-052	7.0	~~1285~~ 1040
	D-079	7.0	~~1200~~ 1040
	C-077	7.0	1254 ~~405 ± 473~~ ~~461.7 ± 288~~
	D-057	8.0	12
	C-101	8.0	13
	D-059	8.0	13
	C-089	8.0	53
	D-068	8.0	54
	B-013	8.0	58
	D-064	8.0	82
	B-015	8.0	136
	C-075	8.0	150
	D-061	8.0	237
	B-011	8.0	281
	B-019	8.0	281
	B-017	8.0	291
	C-067	8.0	365
	B-016	8.0	375
	C-072	8.0	390
	B-004	8.0	498
	D-055	8.0	500
	D-046	8.0	606
	B-002	8.0	~~1285~~ 1040
	D-079	8.0	~~1200~~ 1040 ~~257 ± 341~~ ~~308.3 ± 248~~
	C-089	9.0	9
	D-064	9.0	23
	B-015	9.0	24
	D-061	9.0	183
	B-013	9.0	284
	D-068	9.0	303
	B-016	9.0	319
	C-075	9.0	333
	C-087	9.0	420
	B-017	9.0	425
	D-057	9.0	440
	C-101	9.0	494
	B-019	9.0	504
	D-059	9.0	742
	B-002	9.0	~~1285~~ 1040
	D-079	9.0	1280 1040
	D-055	9.0	1674 ~~504.5 ± 459~~
	B-015	10.0	17
	C-089	10.0	124
	B-002	10.0	335
	B-013	10.0	341
	B-017	10.0	421
	B-016	10.0	478
	B-019	10.0	511
	B-015	11.0	16

AVG. 462.2 ± 414

AVG = 485.7 ± 431

Avegp = 477.5 pCi/g

2. Diffusion coefficients

Eight samples ~~were~~ of borrow material were sent to Rogers & Associates Engineering Corp. (RAE) to analyize for the radon diffusion coefficient. Table 2.4 gives the results of all the test. The results for the shale sample were not considered for this analysis because no shale is going to be used for cover. The values between 5 and 6 percent moisture were averaged to obtain the diffusion coefficient of the top foot of the radon cover. This average is 0.025 cm^2/sec. The diffusion coefficient of the material below the top ~~foot~~ of cover was determined from figure 2.3 (mi) All of the diffusion coefficient data was plotted versus saturation and a curve drawn through the data. 7½ percent moisture corresponds to approximately 41 percent saturation on average, this results in a diffusion coefficient of 0.017 cm^2/sec for the remainder of the cover.

Four tailing samples were sent to RAE to be analyized for radium diffusion coefficient the test results are in Table 2.5. The diffusion coefficient for the slimes is the averages of the tests made at 26.7 and 29.5 percent moisture, which is 5.5×10^{-4} cm^2/sec. These values were used because the in-situ moisture is 27.6 percent. The in situ moisture of the sands is 6 percent, therefore the diffusion coefficient from Table 2.5 is 0.039 cm^2/sec. The in-situ moisture of the sand/slime samples was approximately 9.4 percent therefore the average of the four samples at 9.7 and 9.9 percent moisture is used, that is 0.024 cm^2/sec

JACOBS ENGINEERING

DATE 11/4/83 SUBJECT SHP cover SHEET NO. 21

BY MJ CHKD. JOB NO. UMTRA

SHP-02-005

Table 24

Radon Diffusion Coefficients of Cover Material

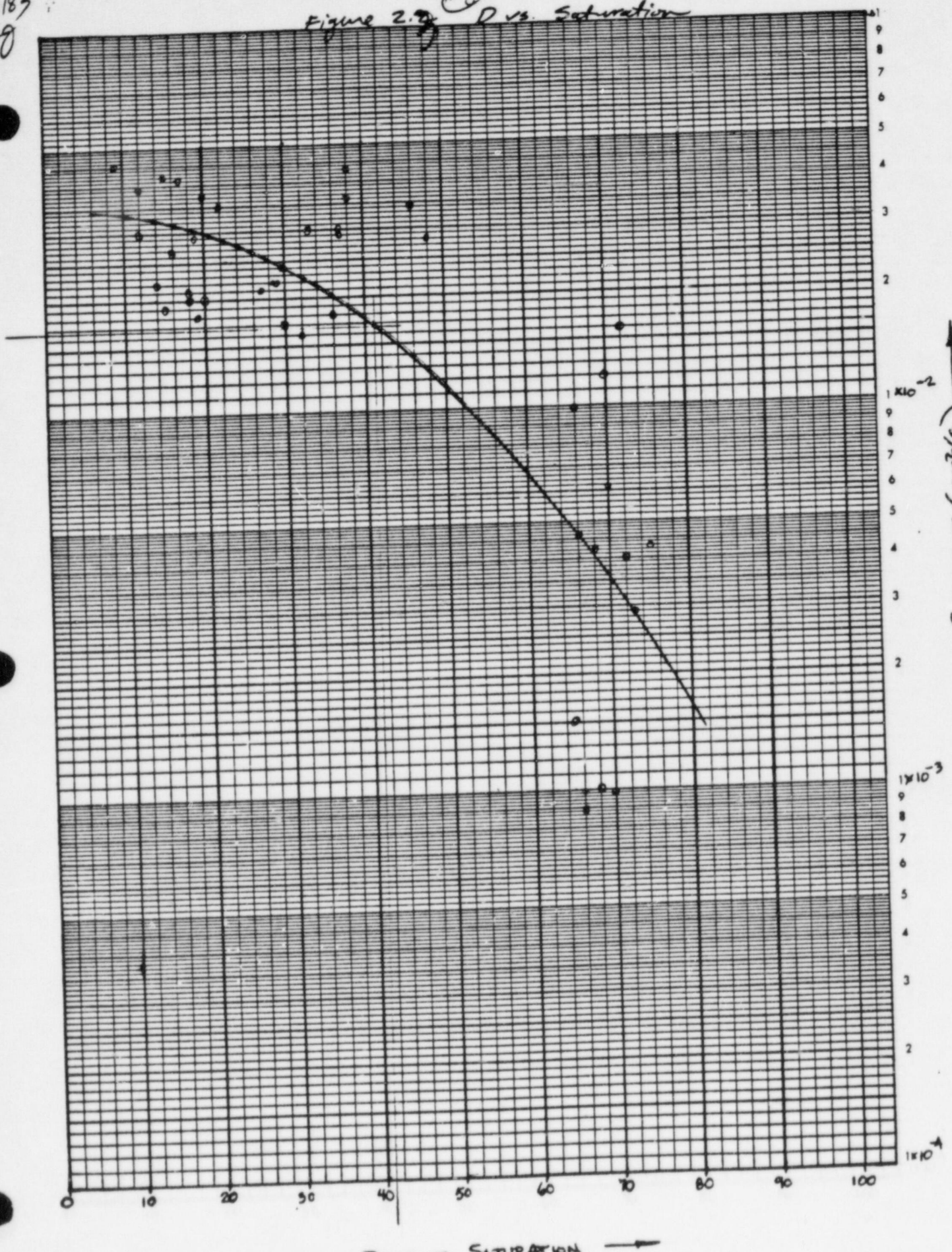
Test Pit	% Moisture (dry)	Density (g/cm^3) dry	% Sat.	D (m^2/sec)
#1 0-2½'	1.6	1.74	9	4.5×10^{-2}
	3.5	1.74	20	3.7×10^{-2}
	6.6	1.74	38	3.6×10^{-2}
	6.7	1.73	38	4.3×10^{-2}
	12.5	1.75	73	2.9×10^{-3}
	12.8	1.75	75	4.3×10^{-3}
#2 2.7½'	2.3	1.75	12	3.0×10^{-2}
	3.0	1.74	15	1.9×10^{-2}
	7.6	1.71	37	2.9×10^{-2}
	7.6	1.71	37	3.0×10^{-2}
	13.0	1.74	66	9.9×10^{-3}
	13.6	1.73	68	4.2×10^{-3}
#3 7-11'	2.6	1.82	14	2.2×10^{-2}
	3.8	1.82	20	2.0×10^{-2}
	* 5.1	1.82	27	2.1×10^{-2}
	* 5.6	1.82	29	2.2×10^{-2}
	12.6	1.82	66	4.6×10^{-3}
	12.7	1.82	66	8.9×10^{-4}
#3 11'-15'	2.6	1.79	17	4.1×10^{-2}
	3.4	1.79	22	3.5×10^{-2}
	7.1	1.79	46	3.4×10^{-2}
	7.6	1.78	48	2.8×10^{-2}
	10.9	1.79	70	1.2×10^{-2}
	11.1	1.79	72	1.6×10^{-2}
4 1-10'	3.0	1.71	15	4.2×10^{-2}
	3.2	1.77	18	2.1×10^{-2}
	3.5	1.66	16	2.7×10^{-2}
	* 5.5	1.77	30	2.4×10^{-2}
	6.5	1.77	36	1.8×10^{-2}
	12.8	1.77	70	6.1×10^{-3}
	13.2	1.77	72	4.0×10^{-3}

Table 2.4 (cont.)

Test Pit	% Moisture (dry)	Density (g/cm³) dry	% Sat	D (cm²/sec.)
8 (Shale)	3.4	1.85	18	2.0×10^{-2}
	3.5	1.84	19	1.8×10^{-2}
	5.4 –	1.85	29	2.2×10^{-2}
	6.1	1.84	32	1.6×10^{-2}
	12.2	1.85	64	8.0×10^{-4}
	13.0	1.85	70	9.8×10^{-4}
2- 9½-11' + Devils Wash	2.4	1.75	12	3.4×10^{-2}
	3.8	1.74	19	2.9×10^{-2}
	5.8 –	1.76	30	1.7×10^{-2}
	6.6	1.74	33	3.0×10^{-2}
	12.5	1.76	65	1.5×10^{-3}
	13.6	1.74	68	1.0×10^{-3}

11/4/83
mag

Figure 2.3 D vs. Saturation



JACOBS ENGINEERING

DATE 11/7/83 SUBJECT SHP cover SHEET NO. 24

BY MAJ CHKD. JOB NO. UMTRA

SHP-02-007

Table 25

Radon diffusion coefficients of Shiprock tailings.*

Sample	% Moisture (dry)	Density (g/cm³)	Saturation %	D (cm²/sec.)
TP-1 Slimes	11.5	1.38	36	2.3×10^{-2}
TP-1 Slimes	11.7	1.38	37	2.1×10^{-2}
TP-1 Slimes	16.0	1.37	40	2.5×10^{-2}
TP-1 Slimes	16.8	1.39	54	2.2×10^{-2}
TP-1 Slimes	26.7	1.40	86	6.0×10^{-4}
TP-1 Slimes	29.5	1.39	94	5.1×10^{-4}
TP-2 Sands	6.0	1.50	22	4.0×10^{-2}
TP-2 Sands	6.8	1.50	25	3.8×10^{-2}
TP-2 Sands	9.3	1.51	34	3.8×10^{-2}
TP-2 Sands	9.4	1.51	35	1.9×10^{-2}
TP-2 Sands	13.3	1.51	49	1.0×10^{-2}
TP-2 Sands	13.5	1.51	50	9.8×10^{-3}
TP-2 Sand/Slime	6.8	1.61	31	4.2×10^{-2}
TP-2 Sand/Slime	7.2	1.59	31	4.3×10^{-2}
TP-2 Sand/Slime	9.7	1.62	40	3.0×10^{-2}
TP-2 Sand/Slime	9.7	1.61	44	2.4×10^{-2}
TP-2 Sand/Slime	11.5	1.59	50	2.7×10^{-2}
TP-2 Sand/Slime	13.8	1.61	62	8.3×10^{-3}
TP-3 Sand/Slime	6.5	1.68	33	4.0×10^{-2}
TP-3 Sand/Slime	7.2	1.67	35	4.1×10^{-2}
TP-3 Sand/Slime	9.7	1.70	50	2.9×10^{-2}
TP-2 Sand/Slime	9.9	1.70	51	1.8×10^{-3}
TP-3 Sand/Slime	12.9	1.71	68	7.1×10^{-3}
TP-3 Sand/Slime	13.4	1.71	71	5.9×10^{-3}

* Reference Nielson, K.K., 1983b

These values are the diffusion coefficients used for the cover calculations.

3. Porositics

The porosity of each layer is calculated from

$$P = 1 - \frac{\rho}{SG}$$

where P = porosity
ρ = Dry bulk density g/cm³
SG = Specific gravity

The porosity of the tailings ~~sample~~ sands is 0.41, ρ = 1.51 and the S.G. is 2.56. Tailings slimes porosity is 0.44, ρ = 1.38 SG = 2.46. Tailings sands/slimes porosity is 0.35, ρ = 1.65 and SG = 2.54. The porosity of the cover is 0.33, ρ = 1.76 and SG = 2.62 (on average from Table 2.1).

4. Emanation Power

The tailings that were sent to Rogers and Associates Engineering Corp were also analyzed for their emanating power. Table 2.6 gives the results of all of these tests.
The tailings sands have an average emanation power of 0.14 regardless of the moisture content. The slimes average 0.16 emanation. For the sand/slime mixed tailings the high average of 0.28 emanation is used to give a conservative estimate for the sand/slime emanation.

JACOBS ENGINEERING

DATE 11/14/83 SUBJECT SHP Lower SHEET NO. 26

BY MMG CHKD. JOB NO. UMTRA

TABLE 2ll

Tailings Emanating Powers

Sample	%H2O	E	Ra (pCi/g)
TP-1 slime	12.2	.16 ± .01	1444 ± 5
	12.7	.16 ± .01	1515 ± 5
	17.9	.17 ± .01	1473 ± 5
	19.8	.17 ± .01	1527 ± 5
	46.4	.13 ± .01	1529 ± 5
	46.3	.15 ± .01	1644 ± 6
	49.8	.16 ± .01	1634 ± 6
	50.2	.15 ± .01	1670 ± 6
average .16			
TP-2 sand	5.2	.12 ± .01	204 ± 2
	5.4	.12 ± .01	211 ± 2
	5.6	.15 ± .01	219 ± 2
	5.6	.14 ± .01	211 ± 2
	9.2	.19 ± .01	214 ± 2
	9.2	.15 ± .01	216 ± 2
	12.8	.14 ± .01	220 ± 2
	13.5	.14 ± .01	227 ± 2
average .14			
TP-3 mix (sand/slime)	7.0	0.28 ± .01	405
	7.0	0.30 ± .01	422 ± 2
	8.2	0.28 ± .01	405 ± 2
	8.5	0.28 ± .01	410 ± 2
	14.7	0.29 ± .01	432 ± 3
	15.0	0.27 ± .01	388 ± 2
average .29			
TP-2 mix	10.6	.15 ± .01	312 ± 2
	10.8	.15 ± .01	319 ± 2
.15			

FORM 81-006-1 (4/81)

5. Source Term

From all the aforementioned data the source term, Q, is calculated.

$$Q = R\rho E\lambda$$

λ = radon decay constant, 2.1×10^{-6}/sec

Table 2.7 shows the source term for each layer

6. RAECO

The attached computer run shows the input and output of RAECO for Shiprock. The result is 21 cm of cover are needed to attenuate the radon below 20 pCi/m² sec

JACOBS ENGINEERING

DATE 11/14/83 SUBJECT SHP Comp

BY ZMAG CHKD.

SHEET NO. 28

JOB NO. VIMTRA

SHP-02-011

Table 2.7

Tailings source terms for RAECO

Tailings layer (m)	Material type	Average Ra^{226} (pCi/g)	Density g/cm³	Emanating power *	Source term, Q, (pCi/m²·sec)
0-2.5	sand	398.3	1.51	0.14	0.00018
2.5-5.0	sand	396.4	1.51	0.14	0.00018
5.0-7.5	sand	371.4	1.51	0.14	0.00016
7.5-10.0	sand	360.2	1.51	0.14	0.00016
10.0-12.5	slime	~~890.1~~ 790.7	1.38	0.16	0.00037 ~~0.00042~~
12.5-15.0	slime	~~551.7~~ 495.5	1.38	0.16	0.00023 ~~0.00026~~
15.0-17.5	sand/slime	~~495.5~~ 462.2	1.65	0.28	0.00045 ~~0.00048~~
17.5-20.0	sand/slime	~~323.6~~ 308.3	1.65	0.28	0.00030 ~~0.00031~~
20.0-22.5	sand/slime	~~504.5~~ 485.7	1.65	0.28	0.00047 ~~0.00049~~
windblown	sand	47	1.51	0.14	0.000021

*(Nielson, KK, 1983c.)

11-15-83 #247

***** MINIMUM COVER THICKNESS FOR SHIPROCK SCD DESIGN, NOVEMBER 14, 1983

DATE OF RUN 11/16/83 TIME 15:37:40

********** I N P U T P A R A M E T E R S **********

NUMBER OF LAYERS =12

INITIAL RADON FLUX = .000 PCI/SQM*SEC

SURFACE RADON CONCENTRATION = 8.000-001 PCI/LITER

COST FLAG = 0

FLUX CRITERIA FOR OPTIMIZATION = 2.000+001 PCI/SQM*SEC

ACC = .000

LAYER	THICKNESS (CM)	DIFF COEFF (SQCM/SEC)	POROSITY	SOURCE (PCI/CC*SEC)
1	.7620+002	.8400-002	.3500+000	.4700-003
2	.7620+002	.8400-002	.3500+000	.3000-003
3	.7620+002	.8400-002	.3500+000	.4500-003
4	.7620+002	.2400-003	.4400+000	.2300-003
5	.7620+002	.2400-003	.4400+000	.3700-003
6	.7620+002	.1600-001	.4100+000	.1600-003
7	.7620+002	.1600-001	.4100+000	.1600-003
8	.7620+002	.1600-001	.4100-001	.1800-003
9	.7620+002	.1600-001	.4100+000	.1800-003
10	.1600+002 17.8	.1600-001	.4100+000	.2100-004
11	.1810+003	.5600-002	.3300+000	.0000
12	.3048+002	~~.8200-002~~ .56	.3300+000	.0000

11-15-83
Hag

***** RESULT OF RADON DIFFUSION CALCULATION

LAYER	THICKNESS (CM)	EXIT FLUX (PCI/SQM*SEC)	EXIT CONC. (PCI/L)	EFF
1	76.	.5010+002	.5359+006	.0000
2	76.	-.1406+002	.5202+006	.0000
3	76.	.3856+002	.5095+006	.0000
4	76.	-.1072+002	.3258+006	.0000
5	76.	.2552+002	.2281+006	.0000
6	76.	.5826+000	.2220+006	.0000
7	76.	-.2417+002	.2275+006	.0000
8	76.	.9834+002	.2099+006	.0000
9	76.	.1137+003	.1607+006	.0000
10	16.	.9566+002	.1502+006	.0000
11	181.	.2063+002	.7475+004	.0000
12	30.	.1985+002	.8000+000	.0000

Stupp

Bendix Field Engineering Corporation
Grand Junction Operations
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Tel (303) 242-8621
A Subsidiary of
The Bendix Corporation

Date August 2, 1983

To James A. Morley, Project Manager, UMTRA/AL

Via Larry Ball, Project Management Division, GJAO

From R. B. Chessmore, BFEC

Subject Analysis of Shiprock Site Tailings Samples

The enclosed final report is submitted for your information.

A nine-track tape of the data is being sent to Mr. Ken Baker.

RBC:jp
Encl.
Xc: K. Baker
R. W. Osterstock
J. Allen

RADIUM-226 ANALYSIS
FOR
SHIPROCK SITE TAILINGS SAMPLES

CHEMISTRY LABORATORY
GEOCHEMICAL SUPPORT DEPARTMENT
BENDIX FIELD ENGINEERING CORPORATION
Grand Junction, Colorado

August 9, 1983

Prepared for U.S. Department of Energy
Uranium Mill Tailings Remedial
Action Project Office
Alburquerque Operations Office

1.0 Introduction

A laboratory radiometric analysis for radium-226 of Shiprock site tailings was requested by the Uranium Mill Tailings Project Office, Albuquerque. From the supplied lists a total of 360 samples were found in sufficient quantity for analysis. From the 360 samples, 29 sample splits were prepared as blind duplicates for quality control giving a total of 389 samples to be analyzed.

Of the 360 samples, 115 were of sufficient size to fill the standard 441 cc sample cans. Three duplicates were prepared from these 115 samples. The remainder of the samples and duplicates was analyzed in 22 cc sample containers.

2.0 Analytical Procedure

The determination of radium-226 content was performed using high resolution gamma-ray spectroscopy. The gamma detectors were calibrated with New Brunswick Laboratory (NBL) 100-A series certified gamma-ray standards. Amplifier gain and baseline were manually checked daily and two known controls analyzed daily.

2.1 Sample Preparation

After the samples, together with a request for analytical services, were received, they were logged in and an in-house number was assigned to each. The 115 samples were blended in a Patterson-Kelly cross-flow blender, packed, and sealed in the 441 cc sample cans. The remainder of the samples was packed and sealed in the 22 cc sample cans. The date and time of sealing were recorded on the can after which the samples were forwarded to the laboratory for Ra-226 determination. All samples were allowed to equilibrate for 21 days before analysis.

2.2 Data Handling

All raw data were transferred from a Canberra Series 80 MCA to a PDP 11/34 computer. The raw data were evaluated by GAMCAL V 1.0, a computer program which locates and quantifies the gamma-ray peaks.

2.3 Ra-226 Calculations

A linear least-squares fit of the count rates and the NBL certified values of the standards were used for the working curve. Intercepts for the working curve represent the expected environmental and constant system background as determined from analysis of an empty cave over a 3-day period. Gamma-ray attenuation corrections are applied to the samples of the 441 cc sample size.

The Ra-226 content for each sample was determined using the Bi-214 609 keV gamma ray for the 22 cc sample size and the Bi-214 1765 keV gamma ray for the 441 cc sample size. The 609 keV gamma ray was chosen over the 1765 keV gamma ray for the small sample sizes because the higher detector efficiency and greater intensity were needed to obtain the desired minimum detection limits.

Although use of the 609 ke[illegible] improved [illegible] detection limits considerably, samples with concentrations below 10 [illegible] pCi (eRa-226)/g have a greater variance than that estimated using normal error calculations. This occurs primarily because the calculated error is based on the assumption of a constant background. At concentrations below 10 pCi/gm and sample sizes less than 30 g, the fluctuations in environmental background, although small, can produce a statistically significant influence of up to 20 percent on the results. Because the actual variance cannot be calculated, these results are considered semi-quantitative.

2.4 Reported Error

The error reported with each Ra-226 determination is the total error of two sigma calculated as the square root of the sum of the squares of the relative errors. Errors include random (counting, sample weight, and sample positioning) and systematic (NBL-certified values, working curve and attenuation correction where applicable).

3.0 Results

The assay value of each sample, together with the uncertainty at two sigma, is reported in Table 1 in pCi (eRa-226)/g.

4.0 Duplicate

The assay value of the sample splits, together with the uncertainty, is reported in Table 2 in pCi (eRa-226)/g. Included is a repeat analysis of both duplicates for the duplicate sets whose values do not overlap at two sigma. Although the repeat analyses agree very well, the duplicates do not overlap at two sigma. These duplicates, therefore, are probably not homogeneous. All results, however, agree to better than the 30% required in the Statement of Work.

5.0 Data Tape

A supplementary data tape was created containing the analytical results. The data tape contains Table 1 in one file with the following characteristics:

- 800 bpi
- 9 track
- EBCDIC
- Unlabelled
- RECL = 40
- BLKL = 40

The record format is:

Customer ID - 12A1
Bendix ID - 9A1
Detection Code -A1
Radium Concentration - F10.0
Uncertainty - F6.0

TAI

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BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R 09-AUG-83 GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-001-01	MAX 001	? 7.	+/-	1.
B-002-04C	MAX 3	355.	+/-	30.
B-003-03	MAX 5	32.	+/-	3.
B-004-01	MAX 7	498.	+/-	42.
B-010-02	MAX 9	404.	+/-	34.
B-010-06	MAX 11	978.	+/-	45.
B-011-02C	MAX 13	623.	+/-	29.
B-012-04	MAX 15	910.	+/-	42.
B-013-01	MAX 17	315.	+/-	15.
B-013-03	MAX 19	284.	+/-	14.
B-013-05C	MAX 21	433.	+/-	20.
B-014-03	MAX 23	299.	+/-	14.
B-014-06	MAX 25	725.	+/-	34.
B-014-08	MAX 27	359.	+/-	30.
B-014-10	MAX 29	401.	+/-	34.
B-015-04	MAX 31	24.	+/-	3.
B-015-06	MAX 33	16.	+/-	2.
A-016-01	MAX 35	392.	+/-	33.
A-016-05	MAX 37	302.	+/-	15.
A-016-07	MAX 39	370.	+/-	18.
A-016-09	MAX 41	362.	+/-	31.
A-016-11	MAX 43	453.	+/-	38.
A-016-13	MAX 45	331.	+/-	28.
A-016-16	MAX 47	319.	+/-	15.
B-017-01	MAX 49	679.	+/-	31.
B-017-03	MAX 051	291.	+/-	14.
B-017-05	MAX 53	421.	+/-	20.
B-018-03	MAX 55	377.	+/-	18.
B-018-05	MAX 57	411.	+/-	34.
B-019-01	MAX 59	313.	+/-	26.
B-019-03	MAX 61	281.	+/-	24.
B-019-05	MAX 63	511.	+/-	43.
A-020-01	MAX 65	423.	+/-	35.
A-020-05	MAX 67	522.	+/-	25.
A-020-08	MAX 69	893.	+/-	42.
A-020-10	MAX 71	959.	+/-	80.
B-021-01	MAX 74	363.	+/-	31.
B-021-04	MAX 76	402.	+/-	34.
B-021-06	MAX 78	489.	+/-	41.
B-023-05	MAX 80	1000.	+/-	83.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-001-04	MAX 2	469.	+/-	39.
B-003-02C	MAX 4	523.	+/-	44.
B-003-04	MAX 6	81.	+/-	7.
B-008-04CP	MAX 8	1463.	+/-	121.
B-010-05	MAX 10	453.	+/-	38.
B-010-11C	MAX 12	940.	+/-	43.
B-011-03	MAX 14	281.	+/-	14.
B-012-06	MAX 16	409.	+/-	19.
B-013-02	MAX 18	58.	+/-	3.
B-013-04	MAX 20	341.	+/-	16.
B-014-01	MAX 22	230.	+/-	11.
B-014-05	MAX 24	296.	+/-	14.
B-014-07	MAX 26	380.	+/-	32.
B-014-09	MAX 28	338.	+/-	28.
B-015-03	MAX 30	136.	+/-	12.
B-015-05	MAX 32	17.	+/-	2.
B-015-07	MAX 34	13.	+/-	2.
A-016-04	MAX 36	430.	+/-	20.
A-016-06	MAX 38	242.	+/-	12.
A-016-08	MAX 40	483.	+/-	23.
A-016-10	MAX 42	502.	+/-	42.
A-016-12	MAX 44	219.	+/-	19.
A-016-14	MAX 46	375.	+/-	18.
A-016-17	MAX 48	478.	+/-	23.
B-017-02	MAX 50	308.	+/-	15.
B-017-04	MAX 52	425.	+/-	20.
B-018-02	MAX 54	435.	+/-	21.
B-018-04	MAX 56	291.	+/-	25.
B-018-06	MAX 58	340.	+/-	29.
B-019-02	MAX 60	444.	+/-	37.
B-019-04	MAX 62	504.	+/-	42.
B-019-06	MAX 64	541.	+/-	45.
A-020-04	MAX 66	817.	+/-	38.
A-020-07	MAX 68	377.	+/-	18.
A-020-09	MAX 70	770.	+/-	36.
A-020-12	MAX 72	1222.	+/-	101.
B-021-02	MAX 75	401.	+/-	34.
B-021-05	MAX 77	259.	+/-	22.
B-023-04	MAX 79	432.	+/-	36.
B-023-06	MAX 81	754.	+/-	35.

< : MINIMUM DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
! : USE OF A SECONDARY PEAK TO CALCULATE CONCENTRATION.
? : INSUFFICIENT COUNTRATE,ANALYSIS IS SEMIQUANTATIVE.
RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

SENIOR ANALYST Harold L Dunlap

C = composite
CP = composite pulp

Tab

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R 09-AUG-83 GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-023-07	MAX 82	1247.	+/-	58.
B-023-10	MAX 84	688.	+/-	41.
A-024-01	MAX 86	196.	+/-	10.
A-024-06	MAX 89	252.	+/-	12.
B-025-01	MAX 92	131.	+/-	7.
B-025-03	MAX 94	499.	+/-	23.
B-025-07	MAX 96	453.	+/-	21.
B-025-09	MAX 98	1444.	+/-	67.
B-025-11	MAX 100	985.	+/-	46.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
B-023-08	MAX 83	1160.	+/-	54.
B-023-S1	MAX 85	49.	+/-	3.
A-024-03	MAX 87	445.	+/-	21.
A-024-08	MAX 91	383.	+/-	18.
B-025-02	MAX 93	279.	+/-	14.
B-025-06	MAX 95	638.	+/-	30.
B-025-08	MAX 97	649.	+/-	31.
B-025-10	MAX 99	1586.	+/-	73.

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RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

SENIOR ANALYST Gerald L Dunbar

C = composite
CP = composite pulp

884-7900

Tab

(1760)

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R

09-AUG-83

GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-024-05	MAX 88	459.	+/-	31.
B-025-13	MAX 101	748.	+/-	62.
A-026-03	MAX 103	854.	+/-	52.
A-026-05	MAX 105	685.	+/-	43.
A-026-07	MAX 107	838.	+/-	60.
A-026-09	MAX 109	442.	+/-	29.
A-026-12	MAX 111	841.	+/-	39.
A-026-14	MAX 113	490.	+/-	41.
B-027-01	MAX 115	470.	+/-	39.
B-027-04	MAX 117	337.	+/-	28.
B-027-06	MAX 119	356.	+/-	17.
B-027-08	MAX 121	314.	+/-	27.
A-028-04	MAX 123	568.	+/-	47.
A-028-06	MAX 125	331.	+/-	28.
A-028-08	MAX 127	262.	+/-	22.
A-029-06	MAX 129	358.	+/-	30.
A-029-08	MAX 131	986.	+/-	46.
A-029-11	MAX 133	369.	+/-	18.
A-030-01	MAX 135	294.	+/-	24.
A-030-03	MAX 137	356.	+/-	28.
A-030-05	MAX 139	413.	+/-	29.
A-030-07	MAX 141	528.	+/-	35.
A-031-04	MAX 143	382.	+/-	18.
A-031-06	MAX 145	466.	+/-	37.
A-032-04	MAX 147	2084.	+/-	276.
A-033-01	MAX 149	361.	+/-	17.
A-033-03	MAX 151	318.	+/-	15.
A-033-05	MAX 153	366.	+/-	17.
A-033-07	MAX 155	297.	+/-	19.
A-034-01	MAX 157	243.	+/-	19.
A-034-03	MAX 159	443.	+/-	30.
A-034-05	MAX 161	252.	+/-	22.
A-034-07	MAX 163	813.	+/-	38.
A-034-09	MAX 165	439.	+/-	28.
A-034-11	MAX 167	305.	+/-	15.
A-034-13	MAX 169	484.	+/-	23.
A-034-15	MAX 171	326.	+/-	16.
A-035-01	MAX 173	264.	+/-	13.
A-035-03	MAX 175	276.	+/-	22.
A-035-04B	MAX 177	388.	+/-	30.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-024-07	MAX 90	552.	+/-	39.
A-026-01	MAX 102	390.	+/-	33.
A-026-04	MAX 104	1413.	+/-	117.
A-026-06	MAX 106	1528.	+/-	126.
A-026-08	MAX 108	1040.	+/-	86.
A-026-11	MAX 110	398.	+/-	25.
A-026-13	MAX 112	388.	+/-	28.
A-026-15	MAX 114	1642.	+/-	146.
B-027-03	MAX 116	364.	+/-	31.
B-027-05	MAX 118	286.	+/-	14.
B-027-07	MAX 120	373.	+/-	31.
A-028-03	MAX 122	849.	+/-	70.
A-028-05	MAX 124	342.	+/-	29.
A-028-07	MAX 126	316.	+/-	27.
A-029-05	MAX 128	403.	+/-	34.
A-029-07	MAX 130	494.	+/-	23.
A-029-10	MAX 132	968.	+/-	45.
A-029-13	MAX 134	830.	+/-	38.
A-030-02	MAX 136	313.	+/-	15.
A-030-04	MAX 138	496.	+/-	25.
A-030-06	MAX 140	629.	+/-	30.
A-030-08	MAX 142	239.	+/-	12.
A-031-05	MAX 144	333.	+/-	30.
A-032-03	MAX 146	2420.	+/-	316.
A-032-05	MAX 148	1696.	+/-	198.
A-033-02	MAX 150	353.	+/-	24.
A-033-04	MAX 152	439.	+/-	29.
A-033-06	MAX 154	249.	+/-	12.
A-033-08	MAX 156	327.	+/-	16.
A-034-02	MAX 158	580.	+/-	27.
A-034-04	MAX 160	215.	+/-	11.
A-034-06	MAX 162	680.	+/-	32.
A-034-08	MAX 164	636.	+/-	30.
A-034-10	MAX 166	318.	+/-	15.
A-034-12	MAX 168	349.	+/-	17.
A-034-14	MAX 170	321.	+/-	15.
A-034-16	MAX 172	2161.	+/-	99.
A-035-02	MAX 174	258.	+/-	13.
A-035-04A	MAX 176	398.	+/-	30.
A-035-05	MAX 178	409.	+/-	29.

no — not entered

< : MINIMUM DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
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RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

C = composite
CP = composite pulp

SENIOR ANALYST Donald L Dulat

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R

09-AUG-83

GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-035-06	MAX 179	471.	+/-	36.
A-035-08	MAX 181	512.	+/-	35.
B-036-04	MAX 183	410.	+/-	30.
B-036-06	MAX 185	372.	+/-	29.
B-036-08	MAX 187	205.	+/-	19.
D-044-01	MAX 189	295.	+/-	15.
D-044-03	MAX 191	109.	+/-	10.
D-046-02	MAX 193	606.	+/-	50.
D-055-03	MAX 195	500.	+/-	42.
D-057-03	MAX 197	12.	+/-	1.
D-059-02	MAX 199	23.	+/-	2.
D-059-04	MAX 201	742.	+/-	62.
D-061-02	MAX 203	48.	+/-	5.
D-061-04	MAX 205	183.	+/-	16.
D-064-01	MAX 207	103.	+/-	9.
D-064-03	MAX 209	82.	+/-	7.
D-065-01	MAX 211	38.	+/-	5.
D-066-03 ✓	MAX 213	18.	+/-	3.
D-068-03	MAX 215	54.	+/-	6.
D-069-01	MAX 217	14.	+/-	2.
D-070-01 ✓	MAX 219	118.	+/-	14.
C-072-02	MAX 221	68.	+/-	6.
C-072-04	MAX 223	390.	+/-	33.
C-074-02	MAX 225	357.	+/-	53.
C-074-04	MAX 227	407.	+/-	60.
C-075-02	MAX 229	249.	+/-	32.
C-075-04	MAX 231	353.	+/-	67.
C-078-03	MAX 235	405.	+/-	34.
C-080-01	MAX 237	419.	+/-	37.
C-080-03	MAX 239	507.	+/-	57.
C-081-03	MAX 241	70.	+/-	7.
C-082-01	MAX 243	103.	+/-	11.
C-084-02	MAX 250	58.	+/-	6.
C-085-03	MAX 253	35.	+/-	4.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-035-07	MAX 180	324.	+/-	25.
B-036-03	MAX 182	223.	+/-	11.
B-036-05	MAX 184	220.	+/-	19.
B-036-07	MAX 186	251.	+/-	20.
D-042-02 ✓	MAX 188	272.	+/-	23.
D-044-02	MAX 190	6.	+/-	1.
D-046-01	MAX 192	993.	+/-	82.
D-055-02	MAX 194	66.	+/-	6.
D-055-04	MAX 196	1674.	+/-	125.
D-057-04	MAX 198	440.	+/-	21.
D-059-03	MAX 200	13.	+/-	1.
D-061-01	MAX 202	44.	+/-	4.
D-061-03	MAX 204	237.	+/-	20.
D-063-01 ✓	MAX 206	3201.	+/-	27.
D-064-02	MAX 208	167.	+/-	15.
D-064-04	MAX 210	23.	+/-	2.
D-065-02	MAX 212	67.	+/-	6.
D-068-01	MAX 214	73.	+/-	7.
D-068-04	MAX 216	303.	+/-	35.
D-069-02	MAX 218	8.	+/-	1.
C-072-01	MAX 220	104.	+/-	9.
C-072-03	MAX 222	268.	+/-	23.
C-074-01	MAX 224	145.	+/-	17.
C-074-03	MAX 226	495.	+/-	71.
C-075-01	MAX 228	33.	+/-	6.
C-075-03	MAX 230	150.	+/-	25.
C-077-03 ✓	MAX 234	47.	+/-	9.
C-078-04	MAX 236	687.	+/-	51.
C-080-02	MAX 238	228.	+/-	27.
C-080-04	MAX 240	1001.	+/-	52.
C-081-04	MAX 242	114.	+/-	9.
C-083-03 ✓	MAX 248	93.	+/-	12. not entered
C-084-03	MAX 251	30.	+/-	3.
C-086-01	MAX 254	30.	+/-	4.

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RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

C = composite
CP = composite pulp

SENIOR ANALYST Donald L. Dulat

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R 09-AUG-83 GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-020-13	MAX 073	1301.	+/-	59.
C-076-03	MAX 232	81.	+/-	5.
C-082-03	MAX 244	60.	+/-	7.
C-083-01	MAX 246	154.	+/-	22.
C-084-01	MAX 249	248.	+/-	36.
C-086-04	MAX 255	102.	+/-	14.
C-087-02	MAX 257	30.	+/-	3.
C-087-04	MAX 259	420.	+/-	67.
C-088-04	MAX 261	651.	+/-	54.
C-089-01	MAX 263	30.	+/-	4.
C-089-03	MAX 265	9.	+/-	2.
C-090-01	MAX 267	8.	+/-	1.
C-091-01	MAX 269	17.	+/-	2.
C-091-03	MAX 271	245.	+/-	23.
C-092-01	MAX 273	4.	+/-	1.
C-092-04	MAX 275	468.	+/-	75.
C-093-02	MAX 277	35.	+/-	2.
C-094-03	MAX 279	208.	+/-	22.
C-095-01	MAX 281	72.	+/-	15.
C-095-04	MAX 283	331.	+/-	16.
C-096-02	MAX 285	30.	+/-	5.
C-096-04	MAX 287	2.	+/-	1.
C-097-02	MAX 289	582.	+/-	37.
C-098-01	MAX 291	407.	+/-	53.
C-098-03	MAX 293	366.	+/-	27.
C-099-01	MAX 295	21.	+/-	2.
C-099-04	MAX 297	1254.	+/-	66.
C-100-03	MAX 299	169.	+/-	16.
C-101-01	MAX 301	10	+/-	2.
C-101-03	MAX 303	13.	+/-	2.
D-102-01	MAX 305	276.	+/-	23.
D-102-03	MAX 307	249.	+/-	18.
D-103-01	MAX 309	27.	+/-	3.
D-103-03	MAX 311	23.	+/-	3.
D-105-02	MAX 313	704.	+/-	59.
D-105-04	MAX 315	1884.	+/-	117.
A-020-S1	MAX 317	899.	+/-	74.
A-022-10	MAX 319	225.	+/-	19.
A-022-12	MAX 321	414.	+/-	35.
A-022-15	MAX 323	1223.	+/-	101.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-036-04	MAX 183	408.	+/-	39.
C-076-04	MAX 233	337.	+/-	28.
C-082-04	MAX 245	61.	+/-	6.
C-083-02	MAX 247	41.	+/-	4.
C-085-01	MAX 252	69.	+/-	7.
C-087-01	MAX 256	92.	+/-	8.
C-087-03	MAX 258	365.	+/-	56.
C-088-03	MAX 260	412.	+/-	20.
C-088-05	MAX 262	619.	+/-	50.
C-089-02	MAX 264	53.	+/-	5.
C-089-04	MAX 266	124.	+/-	16.
C-090-04	MAX 268	32.	+/-	7.
C-091-02	MAX 270	834.	+/-	70.
C-091-04	MAX 272	7.	+/-	1.
C-092-03	MAX 274	640.	+/-	75.
C-093-01	MAX 276	18.	+/-	4.
C-093-03	MAX 278	4.	+/-	1.
C-094-04	MAX 280	276.	+/-	28.
C-095-03	MAX 282	83.	+/-	5.
C-096-01	MAX 284	44.	+/-	10.
C-096-03	MAX 286	6.	+/-	1.
C-097-01	MAX 288	587.	+/-	56.
C-097-03	MAX 290	510.	+/-	46.
C-098-02	MAX 292	431.	+/-	20.
C-098-04	MAX 294	261.	+/-	13.
C-099-03	MAX 296	45.	+/-	7.
C-100-01	MAX 298	34.	+/-	2.
C-100-04	MAX 300	14.	+/-	1.
C-101-02	MAX 302	17.	+/-	2.
C-101-04	MAX 304	494.	+/-	45.
D-102-02	MAX 306	439.	+/-	31.
D-102-04	MAX 308	397.	+/-	30.
D-103-02	MAX 310	39.	+/-	4.
D-105-01	MAX 312	742.	+/-	64.
D-105-03	MAX 314	1838.	+/-	153.
D-106-03	MAX 316	17.	+/-	2.
A-020-S2	MAX 318	173.	+/-	15.
A-022-11	MAX 320	237.	+/-	20.
A-022-13	MAX 322	412.	+/-	35.
A-029-S1	MAX 324	40.	+/-	4.

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RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

C = composite
CP = composite pulp

SENIOR ANALYST Arnold L Durlat

BENDIX FIELD ENGINEERING CORPORATION
CHEMISTRY LABORATORY (MED-621)

PROJECT 7A0002-100-R

09-AUG-83

GAMMA ANALYSIS

SHIPROCK SITE TAILINGS

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-029-S2	MAX 325	776.	+/-	64.
A-031-08	MAX 327	566.	+/-	26.
A-031-11	MAX 329	231.	+/-	11.
A-031-13	MAX 331	1409.	+/-	65.
B-005-S1	MAX 333	1272.	+/-	58.
B-007-S1	MAX 335	125.	+/-	7.
B-009-S1	MAX 337	529.	+/-	44.
B-010-09	MAX 339	1451.	+/-	120.
B-012-S2	MAX 341	102.	+/-	5.
B-021-10	MAX 343	487.	+/-	23.
B-021-12	MAX 345	490.	+/-	23.
B-027-09	MAX 347	427.	+/-	20.
B-027-11	MAX 349	419.	+/-	20.
B-027-13	MAX 351	882.	+/-	41.
B-027-S1	MAX 353	201.	+/-	10.
QUAD A COM	MAX 355	440.	+/-	30.
QUAD B COM	MAX 357	554.	+/-	38.
QUAD D COM	MAX 359	551.	+/-	26.

SAMPLE ID	LAB #	RA-226(PCI/GM)		UNCERT.
A-031-07	MAX 326	224.	+/-	11.
A-031-10	MAX 328	602.	+/-	29.
A-031-12	MAX 330	395.	+/-	19.
A-031-S1	MAX 332	349.	+/-	17.
B-005-S2	MAX 334	37.	+/-	2.
B-009-06	MAX 336	1218.	+/-	101.
B-010-07	MAX 338	1354.	+/-	112.
B-012-S1	MAX 340	72.	+/-	7.
B-021-09	MAX 342	367.	+/-	17.
B-021-11	MAX 344	378.	+/-	18.
B-021-S1	MAX 346	201.	+/-	10.
B-027-10	MAX 348	680.	+/-	32.
B-027-12	MAX 350	374.	+/-	18.
B-027-14	MAX 352	425.	+/-	20.
D-070-04	MAX 354	283.	+/-	28.
QUAD A TC	MAX 356	514.	+/-	37.
QUAD C COM	MAX 358	394.	+/-	34.
QUAD D TC	MAX 360	451.	+/-	31.

< : MINIMUM DETECTION LIMIT BASED ON' COMPTON BACKGROUND.
! : USE OF A SECONDARY PEAK TO CALCULATE CONCENTRATION.
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RADIUM ANALYSIS BASED ON BI-214 GAMMA MEASUREMENT

SENIOR ANALYST Gerald L. Dalat

C = composite
CP = composite pulp

TABLE 2

DUPLICATE ANALYSIS

Sample I.D.	Ticket	Ra-226	Repeat	Ticket	Ra-226	Repeat
B-010-07	MAX-338	1354 ± 112		MAX-361	1444 ± 119	
B-014-05	MAX-024	296 ± 14		MAX-362	289 ± 24	
B-015-06	MAX-033	16 ± 2		MAX-363	16 ± 2	
A-016-11	MAX-043	453 ± 38		MAX-364	486 ± 41	
B-017-05	MAX-053	421 ± 20		MAX-365	424 ± 35	
A-020-12	MAX-072	1222 ± 101		MAX-366	1097 ± 50	
B-023-08	MAX-083	1160 ± 54	1191 ± 55	MAX-367	1343 ± 111	1334 ± 110
B-025-01	MAX-092	131 ± 7		MAX-368	121 ± 11	
A-026-04	MAX-104	1413 ± 117		MAX-369	1362 ± 113	
A-026-14	MAX-113	490 ± 41	485 ± 41	MAX-370	543 ± 45	554 ± 46
A-028-04	MAX-123	568 ± 47		MAX-371	551 ± 46	
A-029-11	MAX-133	369 ± 18		MAX-372	338 ± 28	
A-031-04	MAX-143	382 ± 18		MAX-373	339 ± 33	
A-034-07	MAX-163	813 ± 38		MAX-374	827 ± 69	
A-035-01	MAX-173	264 ± 13		MAX-375	274 ± 23	
B-036-04	MAX-183	410 ± 30	408 ± 30	MAX-376	351 ± 45	343 ± 44
D-046-02	MAX-193	606 ± 50		MAX-377	601 ± 28	
D-061-02	MAX-203	48 ± 5		MAX-378	53 ± 3	
D-066-03	MAX-213	18 ± 3		MAX-379	18 ± 4	
C-072-03	MAX-222	268 ± 23	264 ± 23	MAX-380	326 ± 16	327 ± 16
C-076-03	MAX-232	81 ± 5		MAX-381	81 ± 5	
C-100-04	MAX-300	14 ± 1		MAX-382	13 ± 1	
D-103-02	MAX-310	39 ± 4		MAX-383	34 ± 6	
A-022-11	MAX-320	237 ± 20		MAX-384	239 ± 12	
A-031-12	MAX-330	395 ± 19		MAX-385	402 ± 19	
B-021-09	MAX-342	367 ± 17	366 ± 17	MAX-386	467 ± 39	446 ± 37
B-027-14	MAX-352	425 ± 20	428 ± 20	MAX-387	475 ± 40	473 ± 40
B-019-05	MAX-063	511 ± 43		MAX-388	514 ± 24	
A-033-05	MAX-153	366 ± 17		MAX-389	365 ± 17	

Mark

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

5301 CENTRAL AVENUE N.E. — SUITE 1700, ALBUQUERQUE, NEW MEXICO 87108
TELEPHONE (505) 846-4030

June 2, 1983

Mr. James A. Morley
UMTRA Project Manager
U.S. Department of Energy
Uranium Mill Tailings Project Office
5301 Central Avenue, N.E., Suite 1700
Albuquerque, New Mexico 87108

Re: Analysis of Archived MSRD
Samples at Bendix for Task 2
Contract No. DE-AC04-82AL14086

Dear Jim:

Samples from 11 sites that MSRD collected for the assay program need to be analyzed for radium-226 to obtain the pile source term for these sites. During the remainder of FY83, provisions should be made to have the samples from SHP and GUN analyzed by Bendix at an approximate cost of $12,000. Enclosed please find a list of samples for SHP that should be analyzed first. A list of GUN samples will be provided at a later date.

We estimate that the FY84 costs will be approximately $50,000. BFEC will complete the inventory of all samples within 90 days and will be able to provide a better estimate of the FY84 costs at that time.

Please make arrangements for Bendix to proceed with the analysis of the SHP samples.

Very truly yours,
JACOBS ENGINEERING GROUP INC.

for R. Krishnan, Vice President
Advanced Systems Division

RK/KRB:jd

Enclosure

The following samples at the Shiprock, New Mexico, site should be analyzed for radium-226, if available, to obtain the pile average radium content.

B-001-01
B-001-02
~~B-001-03~~
B-001-04
~~B-002-01~~
~~B-002-02~~
~~B-002-03~~
B-002-04
~~B-003-01~~
B-003-02
B-003-03
B-003-04
B-004-01
~~B-004-02~~
B-004-03
~~B-004-04~~
~~B-005-01~~
B-005-02
B-005-03
B-005-04
B-005-05
~~B-005-06~~
~~B-006-01~~
B-006-02
B-006-03
~~B-006-04~~
~~B-007-01~~
B-007-02
~~B-007-03~~
B-007-04
B-007-05
~~B-007-06~~
B-007-07
~~B-008-01~~
~~B-008-02~~
~~B-008-03~~
B-008-04
~~B-008-05~~
B-009-01
~~B-009-02~~
~~B-009-03~~
B-009-04

~~B-010-01~~
B-010-02
~~B-010-03~~
~~B-010-04~~
B-010-05
B-010-06
B-010-07
~~B-010-08~~
B-010-09
~~B-010-10~~
B-010-11
~~B-011-01~~
B-011-02
B-011-03
~~B-011-04~~
~~B-011-05~~
B-011-06
~~B-012-01~~
~~B-012-02~~
~~B-012-03~~
B-012-04
~~B-012-05~~
B-012-06
B-013-01
B-013-02
~~B-013-03~~
~~B-013-04~~
~~B-013-05~~
~~B-014-01~~
~~B-014-02~~
B-014-03
~~B-014-04~~
B-014-05
B-014-06
B-014-07
B-014-08
B-014-09
B-014-10
~~B-015-01~~
~~B-015-02~~
B-015-03
B-015-04

B-015-05
B-015-06
B-015-07
A-016-01
~~A-016-02~~
~~A-016-03~~
A-016-04
A-016-05
A-016-06
A-016-07
A-016-08
A-016-09
A-016-10
A-016-11
A-016-12
A-016-13
A-016-14
~~A-016-15~~
A-016-16
A-016-17
B-017-01
B-017-02
B-017-03
B-017-04
B-017-05
~~B-018-01~~
B-018-02
B-018-03
B-018-04
B-018-05
B-018-06
B-019-01
B-019-02
B-019-03
B-019-04
B-019-05
B-019-06
A-020-01
~~A-020-02~~
~~A-020-03~~
A-020-04
A-020-05

~~A-020-06~~
A-020-07
A-020-08
A-020-09
A-020-10
A-020-11
A-020-12
A-020-13
B-021-01
B-021-02
~~B-021-03~~
B-021-04
B-021-05
B-021-06
~~A-022-01~~
~~A-022-02~~
~~A-022-03~~
A-022-04
~~A-022-05~~
~~A-022-06~~
~~A-022-07~~
~~A-022-08~~
~~B-023-01~~
~~B-023-02~~
~~B-023-03~~
B-023-04
B-023-05
B-023-06
B-023-07
B-023-08
~~B-023-09~~
B-023-10
B-023-S1
A-024-01
~~A-024-02~~
A-024-03
~~A-024-04~~
A-024-05
A-024-06
A-024-07
A-024-08
B-025-01

B-025-02
B-025-03
~~B-025-04~~
~~B-025-05~~
B-025-06
B-025-07
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B-025-09
B-025-10
B-025-11
~~B-025-12~~
B-025-13
A-026-01
~~A-026-02~~
A-026-03
A-026-04
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A-026-08
A-026-09
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A-026-11
A-026-12
A-026-13
A-026-14
A-026-15
~~A-026-16~~
B-027-01
~~B-027-02~~
B-027-03
B-027-04
B-027-05
B-027-06
B-027-07
B-027-08
~~A-028-01~~
~~A-028-02~~
A-028-03
A-028-04
A-028-05
A-028-06

17 72 46 26 33

A-028-07
A-028-08
~~A-029-01~~
~~A-029-02~~
~~A-029-03~~
~~A-029-04~~
A-029-05
A-029-06
A-029-07
A-029-08
~~A-029-09~~
A-029-10
A-029-11
A-029-12
A-029-13
A-030-01
A-030-02
A-030-03
A-030-04
A-030-05
A-030-06
A-030-07
A-030-08
~~A-031-01~~
~~A-031-02~~
~~A-031-03~~
A-031-04
A-031-05
A-031-06
~~A-032-01~~
~~A-032-02~~
A-032-03
A-032-04
A-032-05
Could be "A's"
A-033-01
A-033-02
A-033-03
A-033-04
A-033-05
A-033-06
A-033-07
A-033-08
A-034-01
A-034-02
A-034-03
A-034-04
A-034-05
A-034-06
A-034-07
A-034-08
A-034-09
A-034-10

42

A-034-11
A-034-12
A-034-13
A-034-14
A-034-15
A-034-16
A-035-01
A-035-02
A-035-03
A-035-04
A-035-05
A-035-06
A-035-07
A-035-08
~~B-036-01~~
~~B-036-02~~
B-036-03
B-036-04
B-036-05
~~B-036-06~~
B-036-07
B-036-08
~~B-037-01~~
D-037-02
D-037-03
D-037-04
~~D-038-01~~
D-038-02
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D-038-04
D-039-01
D-039-02
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~~D-040-01~~
D-040-02
D-040-03
~~D-040-04~~
~~D-041-01~~
D-041-02
D-041-03
~~D-041-04~~
D-042-01
D-042-02
~~D-042-03~~
~~D-042-04~~
~~D-043-01~~
D-043-02
D-043-03
~~D-043-04~~
D-044-01
D-044-02

23

D-044-03
~~D-044-04~~
~~D-045-01~~
D-045-02
D-045-03
~~D-045-04~~
D-046-01
D-046-02
~~D-046-03~~
~~D-046-04~~
~~D-047-01~~
D-047-02
D-047-03
~~D-047-04~~
~~D-048-01~~
D-048-02
D-048-03
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~~D-049-01~~
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D-052-04
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D-053-03
D-053-04
D-054-01
D-054-02
D-054-03
D-054-04
~~D-055-01~~
D-055-02
D-055-03
D-055-04
D-056-01
D-056-02
D-056-03
D-056-04
~~D-057-01~~
~~D-057-02~~

16

D-057-03
D-057-04
D-058-01
D-058-02
D-058-03
D-058-04
~~D-059-01~~
D-059-02
D-059-03
D-059-04
D-060-01
D-060-02
D-060-03
D-060-04
D-061-01
D-061-02
D-061-03
~~D-061-04~~
~~D-062-01~~
~~D-062-02~~
~~D-062-03~~
D-062-04
D-063-01
D-063-02
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D-064-01
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D-064-04
D-065-01
D-065-02
~~D-065-03~~
D-065-04
~~D-066-01~~
~~D-066-02~~
D-066-03
~~D-066-04~~
D-067-01
D-067-02
D-067-03
D-067-04
D-068-01
~~D-068-02~~
D-068-03
D-068-04
D-069-01
D-069-02
~~D-069-03~~
~~D-069-04~~
D-070-01
~~B-070-02~~

May be "C's"

21

~~D-070-03~~
D-070-04
~~D-071-01~~
~~D-071-02~~
~~D-071-03~~
~~D-071-04~~
C-072-01
C-072-02
C-072-03
C-072-04
C-073-01
C-073-02
C-073-03
~~C-073-04~~
C-074-01
C-074-02
C-074-03
C-074-04
C-075-01
~~C-075-02~~
C-075-03
C-075-04
~~C-076-01~~
~~C-076-02~~
C-076-03
C-076-04
D-077-01
~~B-077-02~~
D-077-03
D-077-04
~~C-078-01~~
~~C-078-02~~
C-078-03
C-078-04
~~D-079-01~~
D-079-02
~~D-079-03~~
~~D-079-04~~
C-080-01
C-080-02
C-080-03
C-080-04
~~C-081-01~~
~~C-081-02~~
C-081-03
C-081-04
C-082-01
~~C-082-02~~
C-082-03
C-082-04
C-083-01
C-083-02

May be "C's"

28

~~C-083-03~~
C-083-04
~~C-084-01~~
C-084-02
C-084-03
~~C-084-04~~
C-085-01
~~C-085-02~~
C-085-03
~~C-085-04~~
C-086-01
~~C-086-02~~
~~C-086-03~~
C-086-04
C-087-01
C-087-02
C-087-03
C-087-04
~~C-088-01~~

10

~~C-088-02~~
C-088-03
C-088-04
C-088-05
C-089-01
C-089-02
C-089-03
C-089-04
C-090-01
~~C-090-02~~
~~C-090-03~~
C-090-04
C-091-01
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C-091-03
C-091-04
C-092-01
~~C-092-02~~
C-092-03

15

C-092-04
C-093-01
C-093-02
C-093-03
~~C-093-04~~
~~C-094-01~~
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C-094-03
C-094-04
C-095-01
~~C-095-02~~
C-095-03
C-095-04
C-096-01
C-096-02
C-096-03
C-096-04
C-097-01
C-097-02

15

C-097-03
~~C-097-04~~
C-098-01
C-098-02
C-098-03
C-098-04
C-099-01
~~C-099-02~~
C-099-03
C-099-04
C-100-01
~~C-100-02~~
C-100-03
C-100-04
C-101-01
C-101-02
C-101-03
C-101-04
D-102-01

16

D-102-02
D-102-03
D-102-04
D-103-01
D-103-02
D-103-03
~~D-103-04~~
~~D-104-01~~
~~D-104-02~~
D-104-03
D-104-04
D-105-01
D-105-02
D-105-03
~~D-105-04~~
~~D-106-01~~
~~D-106-02~~
D-106-03
~~D-106-04~~

12

97

Composite Test
Composite Test Quad

565

319

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

5301 CENTRAL AVENUE N.E. — SUITE 1700. ALBUQUERQUE. NEW MEXICO 87108
TELEPHONE (505) 846-4030

July 1, 1983

Ronald B. Chessmore, Ph.D.
Chemistry Laboratory Manager
Bendix Field Engineering Corporation
P.O. Box 1569
Grand Junction, CO 81502

Dear Ron:

Enclosed is the list of Shiprock samples that should be analyzed for radium-226, in lieu of the missing samples per your letter of June 30, 1983. These 44 samples plus the 311 samples you found should bring the total sample count to 355.

If you have any problems or questions, please call.

Very truly yours,
JACOBS ENGINEERING GROUP INC.

Mark A. Jackson
Project Engineer

MAJ:jd

Enclosure

SHIPROCK SAMPLES

A-020-S1	
A-020-S2	
A-022-10	
A-022-11	
A-022-12	
A-022-13	
A-022-15	Quad A
A-029-S1	Composite Test Chg
A-029-S2	Composite for Quad A
A-031-7	
A-031-8	Quad B
A-031-10	Composite Quad B
A-031-11	
A-031-12	Quad C
A-031-13	Composite for Quad C
A-031-S1	Composite Test Chg
B-005-S1	Quad D
B-005-S2	Composite Test Chg
B-007-S1	Quad D Composite
B-009-6	Quad D Test Charge
B-009-S1	
B-012-07	
B-012-S1	
B-012-S2	
B-021-9	
B-021-10	
B-021-11	
B-021-12	
B-021-S1	
B-027-9	
B-027-10	
B-027-11	
B-027-12	
B-027-13	
B-027-14	
B-027-S1	

MH
10/7/83

REDISTRIBUTED TAILINGS Drillhole PROFILES

Depths are in increments of 2.5'

Table 2.3

10-22-83

14

TO J Smith

Hole #	Depth	Ra-226
[illegible]	[illegible]	[illegible]
B-001	1.0	367
B-002	1.0	370
A-003	1.0	378
B-004	1.0	400
B-005	1.0	400
B-006	1.0	400
B-007	1.0	400
B-011	1.0	400
B-013	1.0	400
B-015	1.0	400
B-017	1.0	400
B-019	1.0	400
B-036	1.0	400
C-072	1.0	400
C-073	1.0	400
C-074	1.0	400
C-075	1.0	400
C-076	1.0	400
C-077	1.0	400
C-081	1.0	400
C-082	1.0	400
C-086	1.0	400
C-087	1.0	400
C-088	1.0	400
C-089	1.0	400
C-093	1.0	400
C-099	1.0	400
C-100	1.0	400
C-101	1.0	400
C-102	1.0	400
D-042	1.0	400
D-044	1.0	400
D-046	1.0	400
D-048	1.0	400
D-050	1.0	400
D-051	1.0	400
D-052	1.0	400
D-053	1.0	400
D-054	1.0	400
D-055	1.0	400
D-057	1.0	400
D-058	1.0	400
D-059	1.0	400
D-060	1.0	400
D-061	1.0	400
D-062	1.0	400
D-063	1.0	400
D-064	1.0	400
D-066	1.0	400
D-068	1.0	400
D-079	1.0	400
D-103	1.0	400
D-104	1.0	400
D-105	1.0	400
B-026	1.0	411
B-027	1.0	419
A-033	1.0	439
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
B-034	1.0	223

398.3 I 16

Table 2.3 (cont)

MM
10/17/83

B-018	2.0	340
A-030	2.0	355
B-027	2.0	374
A-035	2.0	388
B-001	2.0	400
B-002	2.0	400
B-004	2.0	400
B-009	2.0	400
B-011	2.0	400
B-013	2.0	400
B-015	2.0	400
B-017	2.0	400
B-019	2.0	400
C-070	2.0	400
C-072	2.0	400
C-074	2.0	400
C-075	2.0	400
C-076	2.0	400
C-081	2.0	400
C-083	2.0	400
C-086	2.0	400
C-087	2.0	400
C-088	2.0	400
C-089	2.0	400
C-099	2.0	400
C-100	2.0	400
C-101	2.0	400
D-040	2.0	400
D-042	2.0	400
D-044	2.0	400
D-046	2.0	400
D-048	2.0	400
D-050	2.0	400
D-052	2.0	400
D-058	2.0	400
D-060	2.0	400
D-062	2.0	400
D-063	2.0	400
D-064	2.0	400
D-065	2.0	400
D-068	2.0	400
D-077	2.0	400
D-079	2.0	400
D-080	2.0	400
D-082	2.0	400
B-016	2.0	403
B-021	2.0	407
B-014	2.0	725
D-100	3.0	27
C-084	3.0	30
C-100	3.0	34
C-090	3.0	38
C-076	3.0	81
A-033	3.0	249
B-015	3.0	362
B-021	3.0	378

396.4 ± 75

MJ
10-17/83

Table 2.3 (cont.)

B-014	3.0	380
B-021	3.0	420
B-022	3.0	420
B-024	3.0	420
B-029	3.0	420
B-011	3.0	420
B-013	3.0	420
B-015	3.0	420
B-017	3.0	420
B-019	3.0	420
C-072	3.0	420
C-073	3.0	420
C-074	3.0	420
C-075	3.0	420
C-081	3.0	420
C-083	3.0	420
C-087	3.0	420
C-089	3.0	420
C-099	3.0	420
C-101	3.0	420
D-040	3.0	420
D-042	3.0	420
D-044	3.0	420
D-048	3.0	420
D-043	3.0	420
D-050	3.0	420
D-052	3.0	420
D-053	3.0	420
D-055	3.0	420
D-057	3.0	420
D-059	3.0	420
D-060	3.0	420
D-061	3.0	420
D-062	3.0	420
D-063	3.0	420
D-064	3.0	420
D-066	3.0	420
D-068	3.0	420
D-075	3.0	420
B-026	3.0	420
A-035	3.0	471
B-027	3.0	882

371.35 ± 132 d

C-098	4.0	4
C-099	4.0	21
D-103	4.0	39
C-107	4.0	47
C-074	4.0	145
C-083	4.0	194
B-036	4.0	220
D-044	4.0	295
A-033	4.0	297
A-035	4.0	324
C-076	4.0	337
B-014	4.0	359
B-021	4.0	420
B-022	4.0	420
B-024	4.0	420
B-029	4.0	420
B-011	4.0	420

Table 2.3 (cont)

B-013	4.0	400
B-015	4.0	400
B-017	4.0	400
B-019	4.0	400
C-070	4.0	400
C-072	4.0	400
C-078	4.0	400
C-057	4.0	400
C-059	4.0	400
C-061	4.0	400
D-045	4.0	400
D-048	4.0	400
D-051	4.0	400
D-053	4.0	400
D-033	4.0	400
D-035	4.0	400
D-036	4.0	400
D-037	4.0	400
D-039	4.0	400
D-041	4.0	400
D-060	4.0	400
D-063	4.0	400
D-064	4.0	400
D-068	4.0	400
D-079	4.0	400
B-007	4.0	400
B-021	4.0	490
B-016	4.0	500
B-018	4.0	510

$\bar{x}$ 0.2 ± 145

D-044	5.0	5
D-046	5.0	17
D-050	5.0	27
D-052	5.0	41
C-072	5.0	104
C-058	5.0	169
D-040	5.0	272
A-023	5.0	287
B-014	5.0	338
C-074	5.0	357
B-036	5.0	372
C-060	5.0	424
B-012	5.0	453
A-032	5.0	512
B-020	5.0	1000
B-022	5.0	1000
B-024	5.0	1000
B-026	5.0	1000
B-028	5.0	1000
B-030	5.0	1000
B-032	5.0	1000
B-034	5.0	1000
C-062	5.0	1000
C-076	5.0	1000
C-080	5.0	1000
C-082	5.0	1000
C-084	5.0	1000
C-086	5.0	1000
D-042	5.0	1000
D-043	5.0	1000
D-055	5.0	1000

in AQ
10/7/83

D-052	5.0	1055	
D-053	5.0	1065	
D-056	5.0	1069	
D-056	5.0	1085	
D-057	5.0	1095	
D-059	5.0	1099	
D-061	5.0	1105	
D-062	5.0	1109	
D-063	5.0	1115	
D-064	5.0	1119	
D-068	5.0	1125	
D-077	5.0	1131	
D-079	5.0	1135	E96.14 ± 46'
D-081	6.0	10	
D-100	6.0	14	
D-066	6.0	18	
D-073	6.0	33	
D-061	6.0	44	
D-059	6.0	48	
D-072	6.0	68	
D-081	6.0	78	
D-068	6.0	73	
D-057	6.0	92	
D-053	6.0	93	
D-056	6.0	103	
D-064	6.0	113	
D-044	6.0	137	
D-027	6.0	201	
D-026	6.0	217	
D-036	6.0	231	
D-037	6.0	243	
D-050	6.0	322	
D-044	6.0	401	
D-042	6.0	409	
D-041	6.0	478	
D-035	6.0	551	
D-017	6.0	619	
D-001	6.0	1005	
D-002	6.0	1015	
D-004	6.0	1035	
D-003	6.0	1045	
D-013	6.0	1055	
D-037	6.0	1065	
D-046	6.0	1075	
D-048	6.0	1085	
D-050	6.0	1095	
D-052	6.0	1105	
D-062	6.0	1115	
D-079	6.0	1125	551.7 ± 52'
D-001	7.0	17	
D-057	7.0	23	
D-037	7.0	30	
D-059	7.0	37	
D-061	7.0	45	
D-055	7.0	55	
D-081	7.0	114	
D-064	7.0	157	
D-036	7.0	213	
D-072	7.0	249	

Table 2.3 (cont)

C-072	7.0	265	
B-017	7.0	308	
B-013	7.0	318	
B-016	7.0	331	
C-074	7.0	407	
B-019	7.0	444	
B-011	7.0	623	
D-045	7.0	993	
B-002	7.0	1000	
B-004	7.0	1000	
B-003	7.0	1000	
D-050	7.0	1200	
D-079	7.0	1200	
C-077	7.0	1254	4955 ± 473
D-037	8.0	12	
C-101	8.0	13	
D-057	8.0	13	
C-057	8.0	50	
D-068	8.0	64	
B-003	8.0	88	
D-044	8.0	82	
B-018	8.0	136	
C-078	8.0	180	
D-061	8.0	237	
B-011	8.0	281	
B-019	8.0	281	
B-017	8.0	291	
C-057	8.0	365	
B-016	8.0	378	
C-072	8.0	387	
B-004	8.0	498	
D-055	8.0	500	
D-046	8.0	606	
B-002	8.0	1000	
D-078	8.0	1010	5235.7 ± 341
C-057	9.0	9	
D-064	9.0	23	
B-015	9.0	24	
D-061	9.0	183	
B-013	9.0	284	
D-068	9.0	303	
B-016	9.0	319	
C-078	9.0	333	
C-057	9.0	420	
B-017	9.0	403	
D-057	9.0	440	
C-101	9.0	494	
B-019	9.0	504	
D-057	9.0	742	
B-002	9.0	1000	
D-079	9.0	1200	5045 ± 459
D-055	9.0	1474	
B-018	10.0	17	
C-057	10.0	124	
B-002	10.0	335	
B-013	10.0	341	
B-017	10.0	421	
B-016	10.0	478	
B-019	10.0	511	
B-015	11.0	18	

Average = 477.5 pCi/g

INTERNATIONAL ENGINEERING COMPANY, INC.
A MORRISON-KNUDSEN COMPANY

ORIGINAL DENT 4-25-85

DOCUMENT TRANSMITTAL

TO :	Banad Jagannath	**DATE :** 25 April 1985
LOCATION :	NRC/Washington, D.C.	**SITE :** Shiprock, NM
NO. :	4005-SHP-N-01-00945-00	**COPY NO.(S) :**

Per your request by telephone on 25 April 1985, enclosed are the following:

1. Radon Barrier, Embankment Radium Content
   Document No. 4005-SHP-C-01-00793-00, Cal. No. 04-07-R0-14

2. Radon Barrier, Thickness Design
   Document No. 4005-SHP-C-01-00807-00, Cal. No. 04-07-R0-15

3. Geotechnical Field Investigation at Shiprock Site, New Mexico
   Document No. 4005-SHP-I-01-00875-00

4. Test Pit Logs and Map
   Document No. 4005-SHP-R-01-00645-00

T. R. Wathen

COMMENTS :

cc: John Thenilus, DOE, w/o enclosures
K. A. Carson, DOE, w/o enclosures
Leon Stepp, TAC, w/o enclosures
R. E. Hopkins, RAC, w/o enclosures

The above information, Items (1) and (2) were transmitted to REH, JGO/M-K under Transmittal No. 4005-SHP-N-01-00907-00 on 21 March 1985. Items (3) and (4) transmitted to Leon Stepp/ Jacobs Engineering on 5 February 1985 under Transmittal No. 4005-SHP-N-01-00808-00.