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United States Department of Energy

Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site At Gunnison, Colorado

Received by DSTI

JAN 19 1993

Attachment 5, Supplemental Radiological Data

Final

October 1992

**Appendix B of the
Cooperative Agreement
No. DE-FC04-81AL16257**

Uranium Mill Tailings Remedial Action Project

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DOE/UMTRA--050508-0000-Attach.5

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SEP 17 1991

Mr. Mark L. Matthews P.E.
Project Manager
Uranium Mill Tailings Remedial Action
Project Office
Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. Matthews:

Your letter of September 6, 1991, requested U.S. Nuclear Regulatory Commission (NRC) concurrence in the use of a procedure for determining and verifying radium-226 concentrations at locations with large quantities of cobbly material. Your letter states that at several Title I sites, DOE has encountered large quantities of radium-226 or thorium-230 contaminated material with a high content of cobbly material (greater than a No. 4 sieve size). Your tests show that the contained radioactivity is concentrated in the finer fraction with the coarse fraction containing negligible quantities (less than 5 percent). Procedures presently in use by your contractors for sampling and analyses are designed for relatively fine grained homogeneous soils with a minimum of larger material and are not adequate to characterize the radioactive concentrations in the heterogeneous size material being encountered. Your proposed approach would rely on measurement of the radium-226 or thorium-230 content in the finer fraction to obtain an average concentration for the entire sample.

We agree that determining an average radium-226 or thorium-230 content over an entire sample would be consistent with the Environmental Protection Agency (EPA) standards in 40 CFR 192 if the radium-226 content of the two size fractions and the percentage of each size fraction are properly factored. Part 192.12 states that the concentration of radium-226 in land can be averaged over an area of 100 square meters to meet the standards of not exceeding background level by more than 5 pCi/g averaged over the first 15 cm of soil below the surface and 15 pCi/g averaged over 15 cm thick layers of soil more than 15 cm below the surface.

You plan to address the details of the procedure in a section to be added to Procedure RAC-015 which will define when the procedure would be used, the number and distribution of samples to be taken, the determination of the radium-226 distribution and size fractions, and other appropriate details.

We agree that the proposed approach has the potential for maintaining compliance with EPA's standards while avoiding over excavation of contaminated

Mark Matthews

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material. However, for final concurrence, we will have to review the details of your revised Procedure RAC-015 and the effects of its implementation on a site-specific basis. Any questions can be addressed to Allan Mullins of my staff at FTS-492-0578.

Sincerely,

A handwritten signature in cursive script, reading "John J. Surmeier". The signature is written in dark ink and is positioned above the printed name and title.

John J. Surmeier, Chief
Uranium Recovery Branch
Division of Low-Level Waste Management
and Decommissioning, NMSS

cc: D. Metzler, DOE, Alb.

U.S. Department of Energy
DOE Agreement No. DE-FC04-83AL19454
Appendix B
MODIFICATION NO. 1
RIVERTON, WYOMING
FINAL REMEDIAL ACTION PLAN
CHANGE NO 1
Rev. 4, 3/3/89

A. Description:

The purpose of this change is to establish an excavation protocol for thorium-230 contamination in the absence of excess radium-226 at the Riverton, Wyoming, mill tailings site. As per 40 CFR 192.21(f), Th-230 will be excavated to levels that are as low as is reasonably achievable (ALARA). ALARA conditions at the Riverton site will be met by the following (refer to Enclosure 1):

- 1) Material located above the saturated zone will be excavated to 35 pCi/g Th-230; and
- 2) Th-230 contaminated materials within the saturated zone will be left in place.

The Department of Energy's commitment to comply with Environmental Protection Agency (EPA) standards for groundwater remains unchanged.

B. Resulting changes to the RAP:

Page B-2 of UMTRA-DOE/AL 050507.0000, October 1987, "Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site at Riverton, Wyoming." Add the following paragraphs before the last paragraph of Section B.1, "Introduction":

"If other residual radionuclides other than Ra-226 and its decay products are present in sufficient quantity and concentration to pose a significant radiation hazard, supplemental standards shall be applied (40 CFR 192.21(f)). Remedial actions, in addition to satisfying the control and cleanup standards, shall reduce other residual radioactivity to levels that are as low as reasonably achievable (40 CFR 192.22(b)).

Supplemental standards may be applied when thorium-230 (Th-230) contamination is present in the absence of excess Ra-226. The need for excavation of this material will be determined by comparing the Th-230 concentration to a guideline equivalent to the Ra-226 standard. This guideline is based upon the residual Ra-226, corrected for decay, and the Ra-226 ingrowth from Th-230. If the guideline is exceeded, the Th-230 will be excavated to levels that are as low as reasonably achievable (ALARA). ALARA conditions at the Riverton site will be met by excavating the material above the saturated zone to the Th-230 guideline and leaving in place, within the saturated zone, any Th-230 contamination above the guideline. Supplemental standards will be applied to the excess Th-230 contamination left in the saturated zone."

Page B-6, add the following paragraphs to the end of Section B.3.3,
"Final Radiological Verification Survey for Land":

"For areas in which a significant fraction of the material being sampled is rock or gravel, the nine-plug composite 30x30 foot grid may be collected by using a shovel to take bulk samples, separating the fines from the rock using a #4-mesh screen and determining the weight of the fines and rock fractions. The fines shall then be counted for Ra-226 following the standard RAC-015 specifications and quality controls. The resulting radium concentration will be corrected to a final, reportable concentration utilizing the mass ratios of the rock/fines fractions.

In areas where elevated Th-230 is present, excavation first should be to prescribed Ra-226 standards, then verified in accordance with standard procedures, as discussed above. At the time that the radium analysis sample is collected in each grid, a duplicate, 200-gram sample of the well-mixed material shall be analyzed for Th-230 concentration. Grid-by-grid results for thorium analyses (corrected for the rock/fines fractions, as above) shall be compared to a Th-230 guideline which is equivalent to the Ra-226 standard. This guideline is based on the residual Ra-226 corrected for decay, and the Ra-226 ingrowth from Th-230. Grids or groups of grids exceeding the 35 pCi/g guideline shall be excavated to the level of the saturated zone. The level of the saturated zone shall be determined utilizing available field data.

For those grids or grid groups which are excavated to the level of the saturated zone, standard verification gridding and sampling requirements shall be modified from the RAC-015 specifications by appending the following: A single sample aliquot shall be taken from the center of each of up to nine contiguous grids forming a 90x90 foot grid block. These aliquots shall be composited into a single, well-mixed sample, and separated into rock/fines fractions as discussed above. The fines fraction shall be sent to a vendor laboratory for Th-230 and chemical contaminants (V, Se, As, Mo, Pb, Cd), routine turnaround. For areas excavated to or below the level of the saturated zone, reporting of analysis results is not necessary prior to backfill.

Supplemental Standards will be applied to residual radioactive material in the saturated zone exceeding 35 pCi/g Th-230 based on the criteria in 40 CFR 192.21 paragraphs (b) and (f). Estimated area, volume, and average concentration will be documented in the site completion report."

C. Overall Impact to Design and Completed Remedial Action

This change simplifies construction and avoids expenditures which would be unreasonably high relative to the long-term benefits. The change results in low-level contaminated material remaining in portions of the saturated zone of the subsurface soil. This material will produce an estimated average radon flux of $0.4 \text{ pCi/m}^2\text{-sec}$ after 1,000 years. (See Enclosure 1). Since the material does not cover the entire area of the designated site, the actual average flux from the site will be less. Furthermore, material is in a location where construction of homes is not likely and any future excavation will mix the contamination with clean materials and dilute the concentration. Groundwater impact is expected to be negligible since the thorium appears to be in the insoluble hydroxide form, which is not mobile. Available water quality analyses indicate that the Th-230 and chemical-contaminant concentrations do not exceed proposed EPA groundwater standards (Enclosure 2). Once EPA groundwater standards are finalized, DOE will re-evaluate groundwater conditions at the Riverton site and take any action which may be required to ensure compliance with these standards.

D. Compliance of Revised Design with EPA Standards

The revised design complies with Supplemental Standards defined under 40 CFR 192.22(a) as "coming as close to meeting the otherwise applicable standard as is reasonable under the circumstances" and 40 CFR 192.22(b) as reducing other "residual radioactivity to levels that are as low as is reasonably achievable". Available data indicates that the residual Th-230 will not constitute a groundwater hazard. Additional excavation should not be required to meet the proposed EPA groundwater standards for chemical contaminants.

The residual Th-230 is a radionuclide "other than radium-226 and its decay products" that is "present in sufficient quantity and concentration" and may "constitute a significant radiation hazard...", per 40 CFR 192.21(f). The significant radiation hazard could occur from exposure to contaminated dust and radon daughter products. However, due to site-specific conditions (i.e. the saturation of the soil), the present and future hazards are insignificant (see Enclosure 1). The introduction to 40 CFR 192.21 states that Supplemental Standards in Section 192.22 "shall" be applied in the case of subsection 192.21(f). Paragraph 192.22(b) requires compliance with the Ra-226 cleanup standards and reduction of other residual radioactivity (i.e. Th-230) to levels as low as reasonably achievable (ALARA). Determination of ALARA levels requires consideration of cost-benefit aspects. As discussed in Enclosure 1, the benefits of excavation into the saturated zone are insignificant. The costs include the cost of excavating and transporting the saturated soil, the additional cost of special equipment to excavate in the saturated zone, the cost of special trucks to transport saturated material, and so on. The revised design complies with the intent of ALARA; therefore, supplemental standards per paragraph 192.22(b) are applicable.

The criterion for Supplemental Standards discussed in 40 CFR 192.21(b) requires that the remedial action would "directly produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near the site, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated." The saturated zone consists of cobbly material with approximately 26% fines (smaller than #4-mesh). Excavation into the saturated zone would be followed by backfilling with soil consisting entirely of fines from the borrow area, which would have different hydrological properties than the in-situ cobbly material. This would impact the location and the flow of water in the shallow aquifer. The changes in this aquifer may cause environmental harm; however, this harm cannot be quantified. As discussed in Enclosure 1, the health benefits from excavating the residual Th-230 in the saturated zone are insignificant. Any environmental harm would be grossly disproportionate to the health benefits. Therefore, the criterion in paragraph (b) is also applicable.

The criterion in 40 CFR 192.21(f) allows the application of supplemental standards (40 CFR 192.22(b)) which require residual radioactivity to be reduced to levels as low as reasonably achievable (ALARA). The revised design complies with the ALARA principle by removing contaminated materials to a level where the expected health impacts are negligible. Also, the revised design complies with the intent of the standards in 40 CFR 192.12(b) and should not affect future compliance with EPA groundwater standards.

E. Reason for Change

This change reduces the residual radioactivity to levels as low as reasonably achievable while avoiding potential environmental harm which would be unreasonably high relative to the benefits. The contaminants do not pose a significant present or future threat to the general public.

U.S. Department of Energy
DOE Agreement No. DE-FC04-83AL19454
Appendix B
Enclosure 1
Radiological Impact Analysis
Residual Thorium-230
Riverton UMTRA Site

Introduction

Excavation to a specific Th-230 guideline, such as 35 pCi/g, in all areas of the Riverton site would require extensive, deep removal of materials. Elevated Th-230 concentrations (greater than 35 pCi/g) have been encountered at depths in excess of 14 feet below the tailings interface. At previous UMTRA Project sites where Th-230 separated from Ra-226 has been encountered, a 35 pCi/g limit has been applied by the Project to guide cleanup of shallow-buried material. This concentration is derived from an ingrowth of Ra-226 from Th-230 over 1,000 years, added to a pre-existing concentration of 5 pCi/g Ra-226 remaining after remedial action, resulting in a Ra-226 concentration in 1,000 years of approximately 15 pCi/g. More deeply buried material has been subject to higher Th-230 allowable concentrations on UMTRAP, based on calculated radon release rate at 1,000 years. Such calculations show that, under certain conditions, subsurface material should not pose a significant radiation hazard and that further excavation is not required as per 40 CFR 192.22(b).

Because the principal reason for radium (and thorium) removal is reduction of radon daughter concentrations (RDC) in homes which may be built onsite at some future date, and because radon produced at great depths will be attenuated in clean fill cover before entering such homes, calculation of potential RDC's in such homes is appropriate. Potential impact was assessed through radon emanation estimation, using the RAECOM computer model (Reference 1). The radon flux value obtained from RAECOM can be used to calculate the RDC expected in a hypothetical structure located on the property, as in Reference 2. An analysis of the available data, with the results implemented in the RAECOM model, follows.

Elevated Th-230 concentrations were encountered during final radium excavation of the eastern edge of the tailings pile. The radium clean line was found at an approximate elevation of 4932 feet above MSL; Th-230 concentrations ranging up to 400 pCi/g were found at this level. Verification-type samples taken after an additional 3 feet of excavation depth (approximately 4929 feet) show Th-230 concentrations in excess of 200 pCi/g, after correction for the fraction of non-contaminated, large rock (see attached lab results). Elevated Th-230 levels are found to be associated with heterogeneous areas of material. The soil in this area is cobbly, with approximately 26% passing the #4 Mesh (Table 1). Radiological analysis of the various soil components shows the majority of the Th-230 activity to be associated with the fines (<#4 Mesh). Results of Th-230 analyses reported in this document have been weight corrected to compensate for this bias.

Groundwater is shallow in the area around the Riverton site. The unconfined surface aquifer is not extensively used and does not communicate with the confined aquifer below.

Impact Analysis:

Radon concentration in a hypothetical structure built over a Ra-226 deposit is given in Appendix J of Reference 2 by:

$$C = FAB/(VR * 1000)$$

Where: C = Rn-222 concentration (pCi/l)
F = Rn-222 flux (pCi/m²-sec)
A = Area over which flux enters (m²)
B = Flux reduction factor in entering structure
V = Volume of structure (m³)
R = Effective Rn-222 removal rate (s⁻¹)

Radon-222 flux was calculated by RAECOM. The flux reduction factor is a fairly conservative value given in Reference 2. The Rn-222 removal rate is from Reference 3.

The coefficients used in the analysis were:

A = 103m², B = 0.5, V = 250m³, and R = 1.98E-4 s⁻¹ (one air change per 1.4 hours). Using these assumptions, a radon flux of 3.9 pCi/m²-sec will produce an indoor air concentration of approximately 4.0 pCi/l, which, assuming 50 percent equilibrium, will result in an RDC of 0.02 WL.

The assumed value for the air change rate is conservative based on the information in ICRP 50, "Lung Cancer Risk from Indoor Exposure to Radon Daughters", page 7.

Assumptions:

Emanation fraction: The site-specific emanating fraction of Rn-222 produced from Th-230 decay is not available. Literature suggests that the emanating fraction would be similar to that from the Ra-226. An emanating fraction of 0.2 was assumed, based on information provided in Reference 5. The emanating fraction of radium produced from the decay of Th-230 is expected to be the same (or less) as that of radium deposited during mill operations.

RAECOM model parameters: A diffusion coefficient of 0.022 was selected as representative of the unsaturated fill material covering the thorium deposit. The moisture content was assumed to be 10%. The diffusion coefficient of the saturated layer is much smaller, about 10⁻⁵ cm²/s (Reference 2, page G-12). The assumed bulk density was 1.43 g/cm³, and the assumed porosity was 0.48 (Reference 5).

Structure: Slab-on-grade construction is assumed, based on the depth-to-groundwater information. Basements are not common in the area and would be unlikely due to the shallow groundwater conditions.

Radium-226 in-growth time period: A 1,000 year in-growth period was used. The 40 CFR 192 Standards reference a 1,000 year design life for "Designated processing or depository sites under Section 108 of the Uranium Mill Tailings Radiation Control Act of 1978". After 1,000 years, the Ra-226 concentration will be 35.2 percent of the Th-230 concentration plus 64.8 percent of the Ra-226 concentration remaining after remedial action.

Other: After excavation to radium clean conditions, standard verification-type soil samples will be taken. Areas showing elevated levels of thorium will be excavated to the level of the saturated zone. Radon escaping from the residual material must diffuse first through the saturated soil layer, and then through the 4 foot thick unsaturated backfill layer.

Results:

Analysis shows that when excavated to the level of the saturated zone, residual Th-230 concentrations of 71 pCi/g of Th-230 (the average of the 90 samples listed in Table 1) would produce a radon flux of 0.4 pCi/m²-sec and working levels of 0.001.

Analysis using the maximum observed concentration of 218 pCi/g of Th-230 would produce a radon flux of 1.2 pCi/m²-sec and working levels of 0.004.

Excavating to the radium interface would leave approximately one foot of thorium contaminated material above the saturated zone. RAECOM analysis of this scenario shows that 71 pCi/g Th-230 would produce 0.02 WL in a hypothetical structure, and that 218 pCi/g would produce 0.05 WL. Due to the low construction hazard and minimal expense of removing this one-foot thick unsaturated layer, ALARA considerations dictate that the material above the water table should be excavated to the Th-230 guideline.

Additional Concerns

As discussed in Reference 7, the predominant land use in the immediate vicinity of the site is agricultural, with the primary crop being hay. An active sulfuric acid plant is immediately adjacent to the site. The operators of the acid plant have agreed to purchase the site after remedial action is complete. The future land use should be either light industrial or agricultural. Therefore, residential development is not expected.

Another scenario for possible health impacts is one where future construction activities bring the contaminated material to the ground surface. The Th-230 contaminated material would then be available for dispersion by both natural and human forces. Possible pathways for human exposure would then be inhalation of airborne radioactive particulates, radon daughter inhalation, and direct gamma radiation. If the material were excavated after being backfilled, the contaminated material would be

diluted by the volume of clean fill covering the deposit. Mixing the contaminated material with clean fill would lower the Ra-226 concentration. The resulting concentrations should not be significantly greater than the EPA standard for Ra-226 in surface soil (5 pCi/g) and probably should be below the standard for subsurface soil (15 pCi/g). Therefore, the possible health impacts from excavation of the contaminated material would not be excessive.

Finally, a future inhabitant of the site could drill a shallow well to obtain drinking water. This scenario is unlikely because of the other sources of drinking water available. As discussed in Reference 7, shallow groundwater is not the primary source for domestic, municipal, or industrial water supplies in the Riverton area because of the insufficient quantity or poor chemical quality of the water. Use of the shallow groundwater has been primarily limited to areas upstream and upgradient from the site. This is due to the natural decrease of the quality of shallow groundwater in the downstream direction and the availability of better quality water in the nearby Wind and Little Wind Rivers and in the confined aquifer.

References:

1. Radon Attenuation Effectiveness and Cover Optimization (RAECOM, IBM PC Version).
2. Draft Generic Environmental Impact Statement on Uranium Milling; NUREG-0511; April 1979.
3. Lung Cancer Risk from Indoor Exposure to Radon Daughters; ICRP 50; 1979.
4. USNRC, 1987. Draft Regulatory Guide and Value/Impact Statement, Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers. Task WM 503-4.
5. USDOE, 1984. Draft Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Riverton, Wyoming; Appendix B of the Cooperative Agreement No. DE-FC04-83AL19454. DOE/EA-050507.0000
6. Code of Federal Regulations, Title 40 Part 192; Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings.
7. USDOE, 1987. Environmental Assessment of Remedial Action at the Riverton Uranium Mill Tailings Site, Riverton, Wyoming. DOE/EA-0254.

U.S. Department of Energy
DOE Agreement No. DE-FC04-83AL19454
Appendix B

TABLE 1
THORIUM-230 VERIFICATION SOIL SAMPLES

SAMPLE NO. *	UNCORRECTED	WT % fines (< #4)	CORRECTED
	TH-230 CONCENTRATION (pCi/g fines)		TH-230 CONCENTRATION (pCi/g)
RV-SV-J-29-13	720	30	218
RV-SV-J-37-8	240	29	70
RV-SV-J-45-18	610	19	116
RV-SV-J-37-18	280	35	97
RV-SV-J-45-8	280	15	43
RV-SV-J-21-13	165	20	32
RV-SV-J-21-18	140	21	29
RV-SV-J-21-8	98	20	20
RV-SV-J-37-13	170	20	34
RV-SV-J-21-23	64	14	9
RV-SV-J-45-13	480	23	110
RV-SV-J-29-18	380	27	101
RV-SV-J-45-3	90	25	22
RV-SV-J-13-13	460	44	203
RV-SV-J-37-23	123	20	24
RV-SV-J-37-3	170	38	64
RV-SV-J-29-8	480	14	65
RV-SV-J-29-3	190	17	32
RV-SV-J-21-3	190	20	39
RV-SV-J-13-18	270	31	83
RV-SV-J-12-14	41	28	11
RV-SV-J-21-2	350	28	98
RV-SV-J-13-11	190	32	61
RV-SV-J-21-1	590	35	207
RV-SV-J-37-6	80	17	14
RV-SV-J-29-21	250	23	58
RV-SV-J-45-7	460	17	78
RV-SV-J-29-11	220	40	88
RV-SV-J-29-16	75	24	18
RV-SV-J-37-1	98	31	30
RV-SV-J-37-2	170	17	29
RV-SV-J-29-12	530	35	186
RV-SV-J-12-24	56	26	15
RV-SV-J-13-12	370	24	89
RV-SV-J-21-21	410	22	90
RV-SV-J-21-6	190	29	55
RV-SV-J-20-9	370	19	70
RV-SV-J-13-21	290	25	73
RV-SV-J-37-7	230	28	64
RV-SV-J-29-22	180	28	50
RV-SV-J-13-16	220	41	90

TABLE 1 Cont'd.
THORIUM-230 VERIFICATION SOIL SAMPLES

SAMPLE NO. *	UNCORRECTED TH-230 CONCENTRATION (pCi/g fines)	WT % fines (< #4)	CORRECTED TH-230 CONCENTRATION (pCi/g)
RV-SV-J-12-25D	94	37	35
RV-SV-J-20-25	320	31	99
RV-SV-J-28-9	86	23	20
RV-SV-J-28-5	420	26	109
RV-SV-J-20-24	640	31	198
RV-SV-J-45-22	220	17	37
RV-SV-J-45-17	420	14	59
RV-SV-J-45-16	470	25	118
RV-SV-J-45-11	770	19	146
RV-SV-J-45-21	85	22	19
RV-SV-J-29-17	200	19	38
RV-SV-J-21-22	430	47	202
RV-SV-J-21-11	210	41	86
RV-SV-J-12-25	88	37	33
RV-SV-J-12-15	80	26	21
RV-SV-J-12-19	98	32	31
RV-SV-J-21-7	280	17	48
RV-SV-J-28-15	43	31	13
RV-SV-J-20-20	150	31	47
RV-SV-J-20-15	460	18	83
RV-SV-J-13-22	210	20	42
RV-SV-J-21-12	111	23	26
RV-SV-J-45-1	390	28	109
RV-SV-J-45-12	160	21	34
RV-SV-J-21-17	380	17	65
RV-SV-J-20-5	106	32	34
RV-SV-J-29-2	270	26	70
RV-SV-J-20-14	240	24	58
RV-SV-J-37-17	240	32	77
RV-SV-J-37-16	190	23	44
RV-SV-J-29-7	500	27	135
RV-SV-J-45-2	310	25	78
RV-SV-J-37-22	320	33	106
RV-SV-J-37-12	380	34	129
RV-SV-J-21-16	290	24	70
RV-SV-J-20-10	300	41	123
RV-SV-J-29-1	230	24	55
RV-SV-J-13-17	170	29	49

TABLE 1 Cont'd.
THORIUM-230 VERIFICATION SOIL SAMPLES

SAMPLE NO. *	UNCORRECTED	WT % fines (< #4)	CORRECTED
	TH-230 CONCENTRATION (pCi/g fines)		TH-230 CONCENTRATION (pCi/g)
RV-SV-J-12-20	56	20	11
RV-SV-J-20-4	150	22	33
RV-SV-J-29-6	270	38	103
RV-SV-J-37-11	280	23	64
RV-SV-J-37-21	150	38	57
RV-SV-J-45-6	150	29	44
RV-SV-J-20-25D	490	37	181
RV-SV-J-20-19	400	24	96
RV-SV-J-28-10	240	25	60
RV-SV-J-28-4	240	24	58
RV-SV-J-28-14	61	30	18

AVERAGE FINE %: 26

AVERAGE CORRECTED TH-230 CONCENTRATION: 71 pCi/g

*Refer to Drawing Nos. RVT-SV-0000 and RVT-SV-009 for locations.

ENGINEERS
AND
CONSTRUCTORS

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

HEADQUARTERS OFFICE
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CLEVELAND, OHIO U.S.A. 44114
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REPLY TO: MK-FERGUSON COMPANY
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May 14, 1991

91-3050-415

Mr. Mark L. Matthews
Project Manager
U.S. Department of Energy
Uranium Mill Tailings Remedial Action Project Office
First National Bank Building
5301 Central Avenue N.E.
Suite 1700
Albuquerque, New Mexico 87108

SUBJECT: Proposed Modification No. 4 to Durango Site RAP (Ponds Area Th-230), Rev. B.

REFERENCE: 1) Letter No. 91-3050-365 dated April 17, 1991 from J.G. Oldham to M.L. Matthews

2) Contract No. DE-AC04-83AL18796

Dear Mr. Matthews:

Pursuant to Steve Hamp's request, attached is Revision B of the proposed Remedial Action Plan Modification (RAP Mod) No. 4 for the Durango, Colorado Site.

Reference to the monetary costs associated with the RAP Mod was removed from the text during the change from Revision A to Revision B. A change was also made to section C to mention that the follow-on groundwater work will be considered under Uranium Mill Tailings Groundwater Restoration Project.

MK-FERGUSON COMPANY
A MOORESCO-KRUGER COMPANY

Mr. M.L. Matthews
Page 2 - 91-3050-415
May 14, 1991

If you have any questions, please contact Dr. Frank Petelka at (505) 766-3047.

Sincerely,

MK-Ferguson Company

J.G. Oldham
Project Director

JGO/MFP/drh

cc: S. Hamp - DOE/UMTRA (w/attach)
C. Esparza Baca - DOE/UMTRA (w/attach)
M. Miller - TAC/UMTRA (w/attach)

MODIFICATION NO. 4
DURANGO, COLORADO
PRELIMINARY REVISED FINAL REMEDIAL ACTION PLAN
CHANGE NO 1
REV. B, 5/14/91

A. Description:

The purpose of this change is to establish an excavation protocol for thorium-230 (Th-230) contamination in the absence of excess radium-226 (Ra-226) at the Durango, Colorado, mill tailings site. As required in 40 CFR 192.21(f), Th-230 will be excavated to levels that are as low as is reasonably achievable (ALARA). ALARA conditions at the Durango site will be met by imposing the following supplemental standard:

Excavate Th-230 to a 1,000 year ingrowth corrected Ra-226 concentration of 5 pCi/g above background (14 pCi/g Th-230 with no residual Ra-226 today) in the first 6 inch soil layer and 15 pCi/g above background (42 pCi/g Th-230 with no residual Ra-226 today) in any subsequent 6 inch layer.

The change also allows for the use of a mass correction factor to eliminate measurement bias.

The Department of Energy's commitment to comply with Environmental Protection Agency (EPA) standards for groundwater remains unchanged.

B. Resulting changes to the RAP:

Page C-2 of UMTRA-DOE/AL 050503.0000, June 1986, "Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site at Durango, Colorado." Add the following paragraphs before the last paragraph of Section C.1, "Introduction":

"If other residual radionuclides other than Ra-226 and its decay products are present in sufficient quantity and concentration to pose a significant radiation hazard, supplemental standards shall be applied (40 CFR 192.21(f)). Remedial actions, in addition to satisfying the control and cleanup standards, shall reduce other residual radioactivity to levels that are as low as reasonably achievable (40 CFR 192.22(b)).

Supplemental standards may be applied when Th-230 contamination is present in the absence of excess Ra-226. The need for excavation of this material will be determined by comparing the Th-230 concentration to a guideline equivalent to the Ra-226 standard. This guideline is based upon the residual Ra-226, corrected for decay, and the Ra-226 ingrowth from Th-230."

Page C-7, add the following paragraphs to the end of Section C.3.4, "Final Radiological Verification Survey for Land":

"For areas in which a significant fraction of the material being sampled is rock or gravel, the nine-plug composite 30x30 foot grid may be collected by using a shovel to take bulk samples, separating the fines from the rock using a #4-mesh screen and determining the weight of the fines and rock fractions. The fines shall then be counted for Ra-226 following the standard RAC-015 specifications and quality controls. The resulting Ra-226 and Th-230 concentrations will be corrected to a final, reportable bulk concentration by dividing the activity measured in the fine fraction by the mass of the entire sample (rocks plus fines). Larger areas with uniform composition will be corrected by the average of the measured fractions.

In areas where elevated Th-230 is present, excavation first should be to prescribed Ra-226 standards, then verified in accordance with standard procedures, as discussed above. At the time that the radium analysis sample is collected in each grid, a duplicate, 200-gram sample of the well-mixed material shall be analyzed for Th-230 concentration. Grid-by-grid results for thorium analyses shall be compared to a Th-230 guideline which is equivalent to the Ra-226 standard. This guideline is based on the residual Ra-226, corrected for decay, and the Ra-226 ingrowth from Th-230."

C. Overall Impact to Design and Completed Remedial Action

This change simplifies construction and avoids environmental harm which would be unreasonably high relative to the long-term benefits. The change results in low-level contaminated material remaining in the fines at depth in some areas of the former raffinate ponds area. The material is in a location where construction of structures is not likely and any future excavation will mix the contamination with clean materials and dilute the concentration. As part of the Uranium Mill Tailings Groundwater Restoration Project, DOE will re-evaluate groundwater conditions at the Durango site and take any action which may be required to ensure compliance with applicable standards.

D. Compliance of Revised Design with EPA Standards

The revised design complies with Supplemental Standards defined under 40 CFR 192.22(a) as "coming as close to meeting the otherwise applicable standard as is reasonable under the circumstances" and 40 CFR 192.22(b) as "reducing other residual radioactivity to levels that are as low as is reasonably achievable".

The mass averaging technique is required because soil, as defined by the EPA standards in 40 CFR 192.11 includes "all unconsolidated materials...including...gravels and small rocks". It has been demonstrated that the activity encountered on the UMTRA Project is associated with the fine particles and that the larger particles (small rocks and cobbles) are not contaminated. The typical soil analysis

performed on the UMTRA Project excludes these uncontaminated larger particles and the reported activity is therefore biased high. The mass fraction correction factor eliminates this bias.

The residual Th-230 is a radionuclide "other than radium-226 and its decay products" that is "present in sufficient quantity and concentration" and may "constitute a significant radiation hazard...", per 40 CFR 192.21(f). If not removed, a significant radiation hazard could occur from exposure to contaminated dust and radon daughter products. However, after excavation, the present and future hazards will be insignificant. The introduction to 40 CFR 192.21 states that Supplemental Standards in Section 192.22 "shall" be applied in the case of subsection 192.21(f). Section 192.22(b) requires compliance with the Ra-226 cleanup standards and reduction of other residual radioactivity (i.e. Th-230) to levels as low as reasonably achievable (ALARA). Excavation of Th-230 to levels below the 1,000 year ingrowth corrected values, equivalent to the EPA Ra-226 standards, does not further reduce health hazards significantly. The revised design complies with the intent of ALARA, therefore, the criterion in paragraph (f) is applicable. Additional excavation should not be required to meet the proposed EPA groundwater standards for chemical contaminants.

In summary, the revised design complies with Supplemental Standards, using the criterion in 40 CFR 192.21(f) in that residual radioactivity is reduced to levels as low as reasonably achievable. The revised design should not affect future compliance with EPA groundwater standards.

E. Reason for Change

This change reduces the residual radioactivity to levels as low as reasonably achievable. The contaminants left in place will not pose a significant present or future threat to the general public.

**MEASUREMENTS OF RADON GAS DIFFUSION
IN COBBLY SOILS**

Rogers & Associates Engineering Corporation
Salt Lake City, Utah 84110

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EXECUTIVE SUMMARY

Several UMTRA Project sites contain radiologically contaminated subsurface soils composed predominately of cobbles, gravels and sands. For these sites, up to 75 percent by weight of the bulk soil has been observed to consist of uncontaminated cobbles, pebbles and gravels larger than a #4 sieve, and elevated residual radioactivity was associated with the finer fraction that passes this mesh size (4.76 millimeter mesh dimension). An assessment of the diffusion of radon through cobbly soil has not been adequately characterized to date. However, a clearer understanding of the radon diffusion properties of cobbly subsoil is required to reasonably determine the health impacts of residual radium-226 and thorium-230 radioactivity in cobbly media, to develop appropriate cleanup protocols for these constituents, and to evaluate radon barrier covers for long-term stabilization of radiologically contaminated cobbly soils.

Apparatus and procedures are developed to measure radon diffusion through a large soil sample column, containing 80 to 100 pounds of cobbly soil. The apparatus consists of a 14 inch diameter by 13 inch high steel drum with attachments at the base to form a radon source plenum, and an alpha particle detection system on the steel lid to detect the alpha emissions from either radon that has diffused through the cobbly soil column packed into the drum, or radon daughters that are formed in the sensitive volume above the cobbly soil column. The cobbly soil is hand packed into the apparatus at approximately the optimum moisture, in a manner to uniformly distribute the cobbles, pebbles, and gravels throughout the finer soil fraction (<#4 mesh), and to provide a bedding of fine grain soil along wall surfaces for coarser material to prevent radon channeling. Bulk test moisture is attained by oven drying the compacted column.

The radon diffusion coefficient for the cobbly soil is determined by relating the measured transient alpha activity with the time dependent solution of the one-dimensional radon diffusion equation based on bulk material and radiological properties and the apparatus geometry. The transient diffusion code developed is a modification of a similar code used for some years to determine radon diffusion coefficients for small-volume samples

(approximately 220 ml) of tailings and fine soil. Intercalibration of the large and small sample systems using dry sand as a medium with known radon diffusion properties was used to construct and verify the transient diffusion analyses algorithm for cobbly soil.

Radon diffusion measurements on two samples of cobbly soil from the Gunnison, Colorado UMTRA site were made at bulk moisture contents of approximately 4.5 and 6.6 percent by weight, corresponding to bulk fractional moisture saturations of about 0.38 and 0.61, respectively. Bulk diffusion coefficients obtained were compatible with previous diffusion coefficient measurements for typical soil without a fraction greater than a #4 sieve, and having similar porosities and moisture saturations. In addition, diffusion coefficient measurements were also made and analyzed for the fine fraction (<#4 mesh) of the cobbly soils based on the moisture content and density that corresponded to the values occurring in the pores of the larger fraction in the bulk samples. A close correspondence between the diffusion coefficients for only the fine fraction and the bulk cobbly soil was observed.

Therefore, the following basic conclusions were drawn from this investigation:

- Apparatus and procedures are now available to adequately measure bulk radon diffusion coefficients for large samples of cobbly soil.
- Radon diffusion through cobbly soil can be reasonably modeled using one-dimensional equations based on estimates of bulk material and radon diffusion parameters for the media.
- It is suggested that the radon diffusion coefficients for cobbly soils can be estimated by corresponding measurements made on only the fine soil fraction passing a #4 sieve.

1. INTRODUCTION

Diffusion coefficients for radon (^{222}Rn) gas in earthen materials are required to design suitable radon-barrier covers for uranium tailings impoundments and other materials that emit radon gas. Many early measurements of radon diffusion coefficients relied on the differences in steady-state radon fluxes measured from a radon source before and after installation of a cover layer of the material being tested.⁽¹⁻²⁾ Tests with this method often required hundreds of kilograms of material, and took several months to attain steady-state conditions for the source and cover radon fluxes.

More recent measurements have utilized the small-sample transient (SST) technique⁽³⁾ for greater control on moistures and densities of the test soils, greater measurement precision, and reduced testing time and costs. The SST technique exposes one end of a 10-cm x 10-cm diameter test column at the desired test density and moisture to a gaseous radon source. The alpha activity from radon and daughters at the other end of the column is measured as a function of time from the start of exposure, and is fitted to the time-dependent radon diffusion equation to determine the radon diffusion coefficient. The procedures for sample preparation and data analysis by this method have been documented previously.⁽⁴⁻⁵⁾

Several of the project sites for the U. S. Department of Energy's Uranium Mill Tailings Remedial Action (UMTRA) Program contain radiologically contaminated subsurface material composed predominantly of cobbles, gravels and sands. Since remedial action designs require radon diffusion coefficients for the source materials as well as the cover materials, these cobbly and gravelly materials also must be tested. Their testing poses a problem for the SST method because many individual rocks in this material exceed the total test column diameter of 10-cm. A modification of the SST method therefore was developed by Rogers & Associates Engineering Corp. (RAE) to accommodate a larger test column of cobbly material while still maintaining the precision and accuracy advantages of the method.

This report contains the following information:

1. A description of the test materials used and the methods developed to conduct the SST radon diffusion measurements on cobbly soils.
2. The protocol for conducting radon diffusion tests on cobbly soils.
3. The results of measurements on the test samples.
4. Modifications to the FITS computer code for analyzing the time-dependent radon diffusion data.

2. MATERIALS AND METHODS

2.1 TEST SAMPLES

Two sets of test samples were used in this study. Sand was used as a reference and intercomparison material because of its relatively constant and well-known radon diffusion coefficient at dryness.⁽³⁾ Cobbly soils also were used to evaluate the method and to measure what effect the cobbles have on the diffusion coefficients. The sands were obtained from a supplier of concrete and masonry sands, and had a relatively uniform particle size of about 1 mm.

The cobbly soils used in this study were obtained from the Gunnison, CO UMTRAP site, as sampled by the UMTRAP Remedial Action Contractor (RAC). Three samples were submitted to RAE as candidates for the analyses. Upon receipt of the three samples, RAE analyzed radium concentrations in the fine fractions of the samples by the sealed-can gamma assay method.⁽⁴⁾ These analyses indicated radium concentrations as presented in Table 1. Based on these radium concentrations and previous measurements made by the RAC, samples TP-1 and TP-10 were selected for the bulk diffusion testing. After completion of the diffusion testing, aliquots of the fine fraction (<#4 mesh) of each sample were separated and used to complete a standard SST diffusion test and a standard measurement of the radium(²²⁶Ra) concentrations and radon emanation coefficients. Densities and water contents were computed for the fine-fraction diffusion tests from the values achieved with the bulk cobbly soil diffusion tests, assuming that all of the water occurred in the fine fraction, and that the density of the fine fraction should be defined by its mass divided by the pore volume between the cobbles (i.e., the pores of the fraction >#4 mesh).

Gradation tests provided by Jacobs Engineering Group (JEG) for subsurface soils at this site (>15 cm depth) indicate that 70 to 75 percent of the material by weight is uncontaminated cobbles and gravels retained on the #4 sieve, and that the residual radioactivity is associated with the finer fraction passing a #4 sieve. A similar radiological distribution has been observed at the Riverton, Wyoming and Durango, Colorado sites, and

Table 1. Initial RAE radium screening for the Gunnison cobbly soils.^a

Sample	²²⁶Ra Concentration in Fines (pCi g⁻¹)
TP-1,5.0-7.0	51±1
	121±1
TP-10,7.5-9.5	6.1±0.2
	4.7±0.2
TP-26,0-2	2.6±0.2
	2.8±0.2

^a Two 5-gal samples were received from each test pit (TP designation), and the ²²⁶Ra concentration of the fine fraction (<#4 sieve) was determined for each sample.

other UMTRAP sites at Grand Junction, Naturita, and Slick Rock in Colorado also have the potential for similar subsoil characteristics. The gradations for the two Gunnison samples are shown in Table 2. Because the radium was predominantly in the fine size fractions, the prior analyses of total radium was variable due to sampling uncertainties. The gradation fraction passing a #4 sieve for sample TP-1 was measured by RAE. A full gradation test for sample TP-10 was provided by the RAC for another cobbly subsoil sample taken from the same test pit (8.5' - 9.5').

2.2 APPARATUS

The apparatus generally used for the SST radon diffusion measurement method⁽³⁾ was modified to accommodate the cobbly soils in a larger sample chamber. The larger chamber is illustrated in Figure 1. It consisted of a 7-gal steel drum (14" diameter x 13") with attachments at the base to form a radon source plenum and with fittings mounted on its lid to perform the radon and radon daughter measurements determined from their alpha emissions. Because of the weight of the modified chamber when filled, it was not attached directly to the radon source chamber, but was fitted with recirculating air flow tubes between the radon source chamber and the radon source plenum of the modified sample chamber. Air circulation was driven by a small air pump attached to the radon source chamber.

The radon source plenum at the base of the chamber was defined by a 3/8" mesh steel wire-cloth screen placed beneath a #8 mesh steel wire-cloth screen. A paper filter was placed over the #8 mesh screen to prevent fine soil particles from entering the plenum region. Brass hose barbs were soldered on each side of the plenum region for connection of the recirculating radon source chamber. The lid of the drum was fitted as illustrated with a 10-cm diameter alpha scintillation detector (Model 43-1, Ludlum Instruments Inc., Sweetwater, TX) at a distance of 2.5-cm from a metal screen that served to define the detection region. As in the conventional SST apparatus,⁽⁴⁾ a +300-volt bias was maintained on the screen relative to the detector to attract radon daughters to the alpha detector. A circulating fan was installed in the upper plenum region to achieve uniform radon concentrations. The gasket for the drum

Table 2. Sample gradation for the Gunnison test samples.

Sample	Gradation^a	
TP-1,5.0-7.0	<#4	32.94% ^b
	<4"	100.00%
TP-10,7.5-9.5	<3"	77.61%
	<2"	70.59%
	<1.5"	52.48%
	<1"	47.19%
	<3/4"	39.87%
	<1/2"	34.65%
	<3/8"	30.81%
	<#4	25.00%
	<#10	21.02%
	<#20	16.34%
	<#40	9.95%
	<#100	4.86%
	<#200	3.91%

a Weight percentages passing U.S. standard sieve sizes.
b Determined by RAE in this study.

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Figure 1. Modified radon diffusion test chamber for cobbly soils.

lid was replaced by a closed-cell neoprene o-ring lubricated with silicone vacuum grease to achieve a consistent air-tight seal.

2.3 TESTING PROTOCOL

The sample material to be tested is first brought to the approximate desired moisture content for compaction by measuring the present moisture (gravimetrically) and adjusting the sample moisture accordingly by oven heating the bulk sample, as described previously for the SST protocol.⁽⁴⁾ If packing and test moistures and densities are not specified, as was the case for the present Gunnison tests, the sample is brought to an approximate optimum moisture content as estimated visually from the fine (<#4 mesh) fraction of the sample. The sample then is compacted in nominal 2-inch lifts into the test drum, with manual placement of any rocks exceeding 2" in diameter in a maximum-distance spacing from each other and from the drum walls. An edge criterion used for placement of large cobbles is to avoid placement of a rock with its edge closer than one-half its diameter to the drum wall. Once the sample is compacted to within about 2.5 cm of the plane of the lid, the drum is weighed to estimate the wet mass of the sample, and then is subjected to any moisture adjustments that are required. The approximate moisture content and dry density of the sample are estimated as

$$M_{\text{bulk}} = M_{\text{fine}} f_{<\#4} \quad (1)$$

where

$$\begin{aligned} M_{\text{bulk}} &= \text{Bulk sample moisture (\% dry wt.)} \\ M_{\text{fine}} &= \text{Fine-fraction moisture (\% dry wt., from <\#4 mesh aliquot)} \\ f_{<\#4} &= \text{Fraction of sample mass passing a \#4 mesh sieve (wt./wt.)} \end{aligned}$$

and

$$\text{Dens}_{\text{bulk}} = (W_s - W_{\text{tare}}) / [V (1 + 0.01 M_{\text{bulk}})] \quad (2)$$

where

$Dens_{bulk}$ = Sample bulk dry density ($g\ cm^{-3}$)
 W_s = Drum weight with wet sample (g)
 W_{tare} = Drum tare weight (g)
 V = Volume of sample in drum (cm^3)

Moisture adjustments performed on the bulk Gunnison test samples required addition of water to first achieve test moistures of approximately 60% of saturation in the bulk sample, and then drying to achieve a second test moisture of approximately 35% of saturation. To attain the higher water contents, the compacted sample was permeated with an excess of water in the test drum while evacuating the bottom plenum region until water penetrated the sample. Then additional water was added until about 6-8 liters of water had been pulled through the sample. Pumping then was continued several hours until no further water could be removed, and the drum then was placed inside a 110°C laboratory oven. Drying was continued until the approximate test weight was achieved, as calculated by

$$W_{test} = W_{tare} + V\ Dens_{bulk}\ (1 + 0.01M_{test}) \quad (3)$$

where

W_{test} = Desired weight of drum & sample for test (g)
 M_{test} = Desired bulk moisture content for diffusion test (dry wt. %).

Because of the large mass of the soil sample compacted into the drum (55-60 kg), approximately 18-24h were required to achieve complete heating of the sample, and a similar time period was required to cool the sample prior to testing. While hot, moisture loss from the sample drum was accelerated by pumping air through the sample from the bottom plenum. Several days were required to adjust moistures between tests. For the duplicate diffusion measurements at different moistures, the sample water content was adjusted by the above procedure without removing and recompacting the sample except for sample TP-1, where recompaction was performed between each pair of tests to examine the variations resulting from recompaction.

When the water content of the compacted sample was adjusted to the desired value, the lid and detector assembly (Fig. 1) were prepared by attaching the detector to a scaler (Model 2200, Ludlum Instruments, Sweetwater, TX) and a 300 v bias power supply (Eveready

No. 493). After several periods of background measurements, the lid assembly was sealed to the drum with a silicone-greased gasket, and secured with the bolt-ring. Plastic tubes immediately were attached to the bottom plenum chamber of the drum and to the radon source chamber, and the sampling ports on the detector assembly were closed. To initiate the diffusion test, the gate valve on the radon source chamber was opened and the circulation pump was started. Simultaneously the detector scaler was reset, and the starting time, sample information, and measurement interval were recorded. The experiment then was allowed to proceed until radon breakthrough was complete, as indicated by a plateau in the observed alpha count rate. An example radon breakthrough curve for Gunnison sample TP-1 is illustrated in Figure 2.

After completion of the radon diffusion test, the detector assembly was removed from the drum and the entire sample was dried to determine the actual total water content of the sample. For some of the tests, the sample was disassembled while wet to estimate water contents of different parts of the sample to assess homogeneity of the water distribution. If a replicate test was to be conducted at a lower water content, the drum with the sample was placed into the laboratory oven and dried down to the next desired test moisture content, as estimated from the weight of the drum.

2.4 DATA ANALYSIS

The transient alpha activity curves are basically similar to those obtained by the usual SST method,⁽⁴⁾ except that they contain two competing differences. They appear to correspond to lower diffusion coefficients because of the longer sample diffusion length, but they also have a competing earlier (higher diffusion) bias due to the larger volume in the detection region (between the top of the sample and the lid of the sample container), and the associated sample diameter being greater than the detector diameter. The option to specify a longer column length already was present in the FITS code for analyzing SST radon diffusion data,⁽⁵⁾ and thus did not require modification. The code was modified to account for the altered sample-detector geometry, however, by expressing the effective change as a simple function of the volume in the detector region. Because the detector and bias assembly was

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Figure 2. Alpha activity curve for radon diffusion through sample GUN-TP-1.

identical to that used in the standard SST method,⁽⁴⁾ individual radon and daughter efficiencies remained the same. The modified FITS code was designated CFITS, and required entry of the total volume in the detector region (sensitive detection region plus plenum region above the soil sample). The function employed in the CFITS code to use the detector volume was benchmarked with the empirical measurements of diffusion in sand that were made in this study.

3. RESULTS AND DISCUSSION

The results of the comparative diffusion measurements for radon in dry sand are presented in Table 3. The corresponding detector region volumes used in the cobble drum system also are presented. The detector region volumes were varied for the first case by reducing the drum diameter with a 2.5-cm closed-cell neoprene rubber annulus. The other analyses used the entire inside area of the drum. By definition, the volume for which the two systems should correspond was that of the SST apparatus, which was 0.24 L. This point also was used as a benchmark in defining the relation between the two systems. The hypothesized linear relationship between the detector geometry efficiency and the detection region volume was examined by plotting the D_{det} to D_{drum} ratios as a function of the detector volumes (Figure 3). The average slope of the lines through the reference point to each measured point gives values within the measured uncertainties of the diffusion coefficients, as shown by comparing the mean slope in Figure 3 with the error bars on the measured points.

The radium concentrations and radon emanation coefficients for use in analyzing the radon diffusion data were estimated from the aliquots of <#4 mesh material. The results of the radium and radon emanation measurements on these samples are summarized in Table 4. The radium concentrations were multiplied by the percent passing the #4 mesh sieve to estimate the bulk radium concentrations in the complete samples.

An additional estimate of the radon source term for sample TP-1 was made from the bulk sample while contained in the diffusion test drum. This estimate was made by thoroughly purging the air in the drum using a vacuum pump, sealing closed all sampling and radon source ports, and then measuring the radon ingrowth curve that resulted only from the radium in the sample over the next 48 hours. The resulting ingrowth curve had the form

$$y = A_0 [1 - \exp(-\alpha t)] \quad (4)$$

Table 3. Comparison of diffusion coefficients for radon in dry sand.^a

D_{det} ($\text{cm}^2 \text{ s}^{-1}$)	Cobble Drum		$D_{\text{det}}/D_{\text{drum}}$ (Ratio)
	D_{drum} ($\text{cm}^2 \text{ s}^{-1}$)	V_{det} (Liters)	
0.064±0.006	0.090±0.003	1.98	0.71
0.064±0.006	0.149±0.009	3.22	0.43
0.059±0.006	0.149±0.008	3.22	0.39
		0.24	1.00

^a Uncertainties are obtained from the FITS code.⁽⁵⁾

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Figure 3. Comparison of radon diffusion coefficient responses for the SST and cobble measurement systems as a function of detector region volume.

Table 4. Radium and radon emanation measurements on the fine fraction passing #4 Mesh of the Gunnison cobbly soils.

<u>Sample</u>	<u>Moisture (dry wt. %)</u>	<u>Radium Concentration (pCi g⁻¹)</u>	<u>Radon Emanation Coefficient</u>	<u>Radium x Fraction <#4^a (pCi g⁻¹)</u>
TP-1	18.4	126±1	0.23±0.01	41.5±0.3
TP-10	11.6	11.3±0.3	0.24±0.01	2.8±0.1

a Bulk radium concentration of cobbly sample = radium concentration of fraction passing a #4 sieve times the fraction by weight of bulk cobbly soil passing the #4 sieve.

where

y	=	Count rate at time t (c/10 min)
A_0	=	Equilibrium count rate (c/10 min)
α	=	Ingrowth time constant (min^{-1})
t	=	time (min)

It was transformed to the natural logarithm of its time derivative, and plotted as a function of time to estimate the numerical value of A_0 . The value of A_0 was estimated from a least-squares linear fit by dividing the exponential of the intercept by the negative of the slope. The resulting value, 63,600 counts/10m, corresponds to 23,000 pCi/L based on the detector calibration against Lucas cell grab samples. Based on an effective air volume in the drum of 7.2 L, the bulk average radon source term (radium x radon emanation) was estimated to be 2.8 pCi/g. This can be compared with the corresponding product of the radon emanation coefficient and the bulk radium concentration (last column of Table 4) for TP-1 of 9.5 pCi/g. The difference between these estimates is mainly due to the time for diffusion of radon to the detector region. Because of this bias, the standard measurements in Table 4 were used to represent the cobbly samples.

The results of the radon diffusion measurements on the Gunnison test samples are presented in Table 5. The detailed printouts of the diffusion data analyses by the CFITS Code are presented in the Appendix. The CFITS Code is similar to the FITS Code⁽⁵⁾ except that it incorporates the relationship from Figure 3. The diffusion coefficients for sample TP-10 average within 20% of typical values for soils, as represented by a predictive correlation⁽⁶⁾ of measured diffusion coefficients with soil porosities and water saturation fractions. Measured diffusion coefficients for sample TP-1 are higher than the soil predictions by an average factor of 3.6. This may be partially due to the difficulty of avoiding open pores between cobbles when compacting cobbly soils.

Relative estimates of the water distributions in the samples were obtained from unsieved grab samples of the fines from four regions in TP-1 and from three regions in TP-10. These data are summarized in Table 6, and suggest nominal uniformity of the water distributions, particularly if uncertainties from sampling variation are considered.

Table 5. Results of bulk radon diffusion measurements in the Gunnison cobbly soil samples.

<u>Sample</u>	<u>Density (g cm⁻³)</u>	<u>Porosity^a</u>	<u>Moisture (dry wt. %)</u>	<u>Moisture Saturation</u>	<u>Radon Diffusion^b Coefficient (cm² s⁻¹)</u>
TP-10	2.05	0.24	4.5	0.38	0.023±0.003
TP-10	2.05	0.24	0.0	0.00	0.024±0.003
TP-10	2.05	0.24	6.6	0.57	0.0034±0.0008
TP-1	2.07	0.23	4.4	0.39	0.026±0.005
TP-1	2.07	0.23	6.8	0.61	0.012±0.003
TP-1	2.10	0.22	3.6	0.34	0.032±0.003
TP-1	2.10	0.22	6.6	0.63	0.015±0.003

a Assuming a specific gravity of 2.7 g cm⁻³.

b Uncertainties are obtained from the CFITS code.⁽⁵⁾

Table 6. Water distributions measured in the Gunnison cobbly soils after radon diffusion testing.

Sample	Layer	Moisture (% dry wt.)
TP-1	1 (top)	6.6
TP-1	2	7.4
TP-1	3	7.4
TP-1	4	7.3
TP-10	1 (top)	10.1
TP-10	2	10.3
TP-10	3	12.2

Corresponding measurements of the radon diffusion coefficients on the separated fine fractions of TP-1 and TP-10 by the SST method were performed under conditions as close as achievable to the water contents and densities of the fine fractions as they occurred in the pore space of the above cobbly-sample tests. The water contents of the fine fractions were computed from the moistures in the cobbly-sample tests as

$$M_{fine} = M_{bulk} f_{<#4} \quad (5)$$

where

- M_{fine} = water content in the fine size fraction [$<#4$ mesh] (% dry wt.)
- M_{bulk} = water content in the bulk cobbly soil (% dry wt.)
- $f_{<#4}$ = weight fraction of the cobbly soil passing a #4 mesh sieve.

The densities of the fine fractions were computed from the densities as they occurred in the cobbly-sample tests as

$$\text{Dens}_{fine} = \text{Dens}_{bulk} f_{<#4} / [1 - \text{Dens}_{bulk} f_{>#4} / \text{SpGr}] \quad (6)$$

where

- Dens_{fine} = bulk dry density of the fine size fraction (g cm^{-3})
- Dens_{bulk} = bulk dry density of the cobbly soil (g cm^{-3})
- $f_{>#4}$ = weight fraction of the cobbly soil not passing a #4 mesh sieve
- SpGr = specific gravity of the cobbly fraction [$>#4$ mesh] (2.7 g cm^{-3}).

The water contents and densities computed for the fine fractions in the cobbly-sample tests (at 0.34-0.39 saturation) and those attained in the subsequent SST tests are presented in Table 7 with the results of the SST radon diffusion measurements on the fine fractions. The detailed printouts of the diffusion data analyses by the FITS code are presented in the Appendix.

The close correspondence between the radon diffusion coefficients measured on the fine size fractions ($<#4$ mesh) and those measured in the bulk cobbly soil can be observed by comparing the values in the last column of Table 7 with those for the 0.34 - 0.39 saturation measurements in the last column of Table 5. The measurements have overlapping uncertainty ranges, suggesting that the diffusion coefficients of the pores of the cobbly soil

Table 7. SST measurements of radon diffusion in the fine fractions (<#4 Mesh) of Samples TP-1 and TP-10.

<u>Sample</u>	<u>Properties of Fines from Cobble Test</u>		<u>Properties in SST Test</u>			<u>SST^a Radon Diffusion Coefficient (cm² s⁻¹)</u>
	<u>Density (g cm⁻³)</u>	<u>Moisture (dry wt. %)</u>	<u>Density (g cm⁻³)</u>	<u>Moisture (dry wt. %)</u>	<u>Moisture Saturation</u>	
TP-1	1.43	12.1	1.43	11.8	0.36	0.027±0.004
TP-10	1.20	17.9	1.21	17.6	0.38	0.027±0.005

^a Uncertainties are obtained from the FITS code.⁽⁵⁾

11.8

$$M_{bulk} = M_{fine} f,$$

are identical to those of the fine material contained in its pores. This suggests that the radon diffusion coefficients of cobbly soils are also dominated by their fraction of water saturation, and can be represented for testing purposes by a SST diffusion test on the fine fraction at a moisture content and density that correspond to the values expected to occur in the pores of the larger-sized fraction. Equations (5) and (6) can be used to compute these test conditions.

4. REFERENCES

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2. V. C. Rogers, R. F. Overmyer, K. M. Putzig, C. M. Jensen, K. K. Nielson, and B. W. Sermon, "Characterization of Uranium Tailings Cover Materials for Radon Flux Reduction," Washington DC: U. S. Nuclear Regulatory Commission report NUREG/CR-1081, 1980.
3. K. K. Nielson, D. C. Rich, and V. C. Rogers, "Comparison of Radon Diffusion Coefficients Measured by Transient Diffusion and Steady-State Laboratory Methods," Washington DC: U. S. Nuclear Regulatory Commission report NUREG/CR-2875, 1982.
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5. K. K. Nielson, V. C. Rogers, and G. B. Merrell, "Laboratory Measurements of Radon Diffusion Coefficients with the FITS Data Reduction Code," Salt Lake City: Rogers & Associates Engineering Corp. report RAE-8944-2 to U. S. Department of Energy Technical Assistance Contractor, 1990.
6. V. C. Rogers and K. K. Nielson, "Correlations for Predicting Air Permeabilities and ^{222}Rn Diffusion Coefficients of Soils," Health Physics 61, 225-230, 1991.

APPENDIX A

ANALYSES OF RADON DIFFUSION DATA BY THE CFITS AND FITS CODES

AA
 A CFTS 1.0-R 26-JUL-91 14:48:45 A
 A R I F F U S I O N R F A
 AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

INPUT DATA SUMMARY

TP-10 M=4.5%

DATA SET FOR THIS RUN IS CONVI.DAT
 DETECTOR REGION VOLUME IS 3103. CM3
 LOW SOURCE CONCENTRATION RANGE (25-523 PCI/CC)
 NUMBER OF TERMS FOR SUMMATIONS IS 30
 CONVERGENCE CRITERION FOR SUMS IS 0.00010
 COLUMN LENGTH IS 36.60 CM
 DWELL TIME IS 10.0 MINUTES
 DWELL DENSITY IS 2.053 GM/CC
 POROSITY IS 0.23
 RADIUM CONTENT IS 2.0 PCI/GM
 EXAMINATION COEFFICIENT IS 0.240
 NUMBER OF DATA POINTS IS 10

POINT NO.	UNITS OF DT	COUNT RATE 1	COUNT RATE 2
1	6	9.50E+03	1.52E+04
2	6	2.17E+04	3.13E+04
3	10	4.03E+04	5.07E+04
4	10	9.92E+04	1.10E+05
5	15	1.93E+05	1.63E+05
6	20	2.30E+05	2.43E+05
7	25	3.92E+05	3.05E+05
8	30	3.50E+05	3.50E+05
9	40	3.97E+05	4.08E+05
10	50	4.80E+05	5.16E+05
R	C = 3.7E+02	ST DEV = 1.28E+04	
R	C = 3.00E+02	ST DEV = 1.67E+04	
R	C = 3.00E+02	ST DEV = 1.29E+04	

COUNTS DETECTED IN DWELL TIME = 10. MINUTES

CHANNEL NUMBER	CHAN 1	CHAN 2	CHAN 3	CHAN 4	CHAN 5	CHAN 6	CHAN 7	CHAN 8	CHAN 9	CHAN 10
AAAAAAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA
9.30E+03	3.27E+03	6.95E+03	1.91E+04	4.45E+04	3.21E+04	4.45E+04	3.30E+04	6.44E+04	7.27E+04	8.62E+04
1.63E+03	6.35E+03	1.70E+04	4.45E+04	7.64E+04	1.07E+05	1.07E+05	1.34E+05	1.57E+05	1.53E+05	1.98E+05
6.00E+01	3.46E+02	2.19E+03	1.50E+04	2.96E+04	3.96E+04	3.21E+05	1.01E+05	1.51E+05	4.06E+05	4.96E+05
TOTAL CALC.	3.67E+03	1.04E+04	4.42E+04	7.86E+04	1.48E+05	2.31E+05	2.97E+05	3.50E+05	3.96E+05	4.91E+05
TOTAL EXP.	9.56E+01	1.26E+04	4.04E+04	9.92E+04	1.64E+05	2.31E+05	2.97E+05	3.50E+05	3.96E+05	4.91E+05
FILE. ENDF.	3.05E+02	2.87E+03	2.64E+03	2.49E+03	3.34E+02	3.37E+02	3.21E+02	3.17E+02	3.12E+02	3.11E+02
PM CONC PCI/CC	3.01E+00	7.08E+00	1.30E+01	4.14E+01	6.95E+01	9.36E+01	1.19E+02	1.39E+02	1.57E+02	1.87E+02

RADON SOURCE CONCENTRATION IS 300.0 PCI/CC
 THE DIFFUSION COEFFICIENT IS 2.344E-07 CM2/SEC +/- 3.49E-03
 STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE B IS 1.30E+04
 THERE WERE 10 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT

47KMS 9104 11:30

NUMBER OF DATA POINTS IS 10		COUNT	COUNT
DATA	TIME IN	DATE 1	DATE 2
COUNT NO	MINUTE OF DAY		
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10

[illegible]

POINTS DETECTED IN WELL TIME - 10. MINUTES

CHAN 1	CHAN 2	CHAN 3	CHAN 4	CHANNEL NUMBER	CHAN 5	CHAN 6	CHAN 7	CHAN 8	CHAN 9	CHAN 10
44444444	44444444	44444444	44444444	44444444	44444444	44444444	44444444	44444444	44444444	44444444
1.41E+04	2.39E+04	4.87E+04	6.95E+04	9.72E+04	1.07E+05	1.40E+05	1.75E+05	1.73E+05	1.37E+05	1.47E+05
1.05E+04	1.34E+04	1.19E+04	1.01E+05	1.35E+05	1.48E+05	1.78E+05	2.39E+05	2.38E+05	2.38E+05	3.33E+05
3.52E+01	1.47E+04	1.19E+04	1.01E+05	1.35E+05	1.48E+05	1.78E+05	2.39E+05	2.38E+05	2.38E+05	3.33E+05
4.77E+04	4.77E+04	7.10E+05	3.75E+05	4.55E+05	5.58E+05	6.35E+05	7.03E+05	8.04E+05	8.27E+05	8.70E+05
3.39E+04	9.15E+04	1.99E+05	3.17E+05	4.25E+05	5.58E+05	6.35E+05	7.03E+05	8.04E+05	8.27E+05	8.70E+05
3.46E+02	9.38E+02	2.77E+02	1.51E+02	1.89E+02	2.26E+02	2.35E+02	2.66E+02	3.61E+02	3.61E+02	3.61E+02
3.03E+01	3.14E+01	1.04E+02	1.51E+02	1.89E+02	2.26E+02	2.35E+02	2.66E+02	3.61E+02	3.61E+02	3.61E+02
44444444	44444444	44444444	44444444	44444444	44444444	44444444	44444444	44444444	44444444	44444444
1.41E+04	2.39E+04	4.87E+04	6.95E+04	9.72E+04	1.07E+05	1.40E+05	1.75E+05	1.73E+05	1.37E+05	1.47E+05
1.05E+04	1.34E+04	1.19E+04	1.01E+05	1.35E+05	1.48E+05	1.78E+05	2.39E+05	2.38E+05	2.38E+05	3.33E+05
3.52E+01	1.47E+04	1.19E+04	1.01E+05	1.35E+05	1.48E+05	1.78E+05	2.39E+05	2.38E+05	2.38E+05	3.33E+05
4.77E+04	4.77E+04	7.10E+05	3.75E+05	4.55E+05	5.58E+05	6.35E+05	7.03E+05	8.04E+05	8.27E+05	8.70E+05
3.39E+04	9.15E+04	1.99E+05	3.17E+05	4.25E+05	5.58E+05	6.35E+05	7.03E+05	8.04E+05	8.27E+05	8.70E+05
3.46E+02	9.38E+02	2.77E+02	1.51E+02	1.89E+02	2.26E+02	2.35E+02	2.66E+02	3.61E+02	3.61E+02	3.61E+02
3.03E+01	3.14E+01	1.04E+02	1.51E+02	1.89E+02	2.26E+02	2.35E+02	2.66E+02	3.61E+02	3.61E+02	3.61E+02

BARON SOURCE CONCENTRATION IS 375.0 PC/CC
THE DIFFUSION COEFFICIENT IS 2.377E-07 CM²/SEC ± 3.72E-03
STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE 0 IS 3.08E+04
STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT
WAS 10 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT
WAS 11.4 %

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
 A CPTS 1-0-R 26-JUL-91 14:50:22 A
 A B I F H C I N M C R N F A
 AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TP-10 M=6.6%

INPUT DATA SUMMARY:

DATA SET FOR THIS RUN IS COMJ.DAT
 DETECTOR REGION VOLUME IS 1963. cc3
 LOW SOURCE CONCENTRATION RANGE (75-525 PCI/CC)
 NUMBER OF TERMS FOR SUMMATIONS IS 30
 CONVERGENCE CRITERION FOR SUMS IS 0.00010
 COLUMN LENGTH IS 26.670 CM
 WELL TIME IS 10.0 MINUTES
 PRT DENSITY IS 1.055 GM/CC
 POPOSITY IS 0.234 P.P PCI/GM
 RADIUM CONFIRM IS 0.24
 EXAMINATION COEFFICIENT IS 0.24
 NUMBER OF DATA POINTS IS 10

POINT NO.	UNITS OF PT	COUNT RATE 1	COUNT RATE 2
1	30	7.73E+04	3.56E+04
2	40	4.56E+04	3.44E+04
3	60	8.16E+04	9.00E+04
4	80	1.13E+05	1.22E+05
5	100	1.46E+05	1.53E+05
6	150	2.09E+05	2.14E+05
7	200	2.54E+05	2.59E+05
8	300	3.10E+05	3.13E+05
9	400	4.27E+05	4.27E+05
10	500	4.43E+05	4.43E+05
R	1.70E+02	ST DEV	5.86E+04
R	1.00E+02	ST DEV	2.79E+04
R	1.00E+02	ST DEV	2.53E+04

COUNTS DETECTED IN WELL TIME = 10. MINUTES

CHAM 1	CHAM 2	CHAM 3	CHAM 4	CHAM 5	CHAM 6	CHAM 7	CHAM 8	CHAM 9	CHAM 10
30	40	60	70	100	150	200	300	400	500
AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA
1.23E+03	2.97E+03	9.61E+03	1.68E+04	2.34E+04	3.68E+04	4.64E+04	3.78E+04	6.83E+04	6.86E+04
2.92E+03	8.32E+03	2.34E+04	4.11E+04	5.74E+04	9.07E+04	1.14E+05	1.43E+05	1.69E+05	1.70E+05
1.23E+03	3.01E+03	1.84E+04	3.70E+04	5.45E+04	9.09E+04	1.17E+05	1.48E+05	1.72E+05	1.78E+05
3.41E+03	1.68E+04	5.14E+04	9.49E+04	1.38E+05	2.18E+05	2.70E+05	3.49E+05	4.15E+05	4.16E+05
3.74E+04	4.56E+04	9.17E+04	1.15E+05	1.46E+05	3.09E+05	3.55E+05	3.11E+05	4.28E+05	4.44E+05
5.54E+05	4.86E+03	4.11E+03	3.69E+03	3.43E+03	3.03E+03	2.83E+03	2.57E+03	2.67E+03	2.97E+03
3.71E+00	7.50E+00	2.08E+01	3.63E+01	5.06E+01	7.96E+01	1.00E+02	1.25E+02	1.48E+02	1.48E+02

RADON SOURCE CONCENTRATION IS 200.0 PCI/CC
 THE DIFFUSION COEFFICIENT IS 3.48E-03 CM²/SEC +- 7.94E-04 + 32.8 Z
 STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE R IS 2.53E+04
 THERE WERE 9 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
 A CPT9 1-D-R 26-JUL-91 14:51:46 A
 A N I F F H S I R M C O R F A
 AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TP-1 M=4.4%

INPUT DATA SUMMARY

DATA SET FOR THIS RUN IS C0004.DAT
 REFLECTOR REGION VOLUME IS 1952.403
 LOW SOURCE CONCENTRATION RANGE (75-533 PCU/CC)
 NUMBER OF TERMS FOR SUMMATIONS IS 50
 CONVERGENCE CRITERION FOR SUMS IS 0.00010
 COLUMN LENGTH IS 28.560 CM
 WELL TIME IS 10.6 MINUTES
 NET DENSITY IS 2.070 GM/CC
 POROSITY IS 0.234
 RADIUM CONTENT IS 41.5 PCU/GM
 EMANATION COEFFICIENT IS 0.230
 NUMBER OF DATA POINTS IS 10

DATA NO.	UNITS OF RT	COUNT RATE 1	COUNT RATE 2
1	10	2.394E+04	3.059E+04
2	15	6.177E+04	6.397E+04
3	20	1.134E+05	1.236E+05
4	30	2.184E+05	2.383E+05
5	40	3.191E+05	3.783E+05
6	50	4.044E+05	4.168E+05
7	70	5.263E+05	5.658E+05
8	100	7.206E+05	7.333E+05
9	150	8.843E+05	8.867E+05
10	200	9.638E+05	9.670E+05
C = 3.75E+02		ST DEV = 3.370E+04	
E = 1.00E-02		ST DEV = 3.237E+04	
M = 8.39E-03		ST DEV = 3.556E+04	
P = 3.03E-03		ST DEV = 3.561E+04	

COUNTS DETECTED IN BUELL TIME = 10. MINUTES

CHAN 1	CHAN 2	CHAN 3	CHAN 4	CHAN 5	CHAN 6	CHAN 7	CHAN 8	CHAN 9	CHAN 10
10	15	20	30	40	50	70	100	150	200
AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA
1.80E+03	0.17E+03	1.73E+04	3.88E+04	3.78E+04	7.43E+04	1.00E+05	1.25E+05	1.45E+05	1.57E+05
3.81E+03	1.85E+04	4.11E+04	9.27E+04	1.41E+05	1.82E+05	2.47E+05	3.09E+05	3.61E+05	3.83E+05
4.49E+03	4.74E+03	1.73E+04	6.13E+04	1.14E+05	1.62E+05	2.38E+05	3.12E+05	3.78E+05	3.93E+05
6.11E+03	3.14E+04	7.58E+04	1.92E+05	3.12E+05	4.19E+05	5.85E+05	7.46E+05	8.81E+05	9.37E+05
2.39E+04	6.40E+04	1.13E+05	2.18E+05	3.19E+05	4.03E+05	5.36E+05	7.21E+05	8.81E+05	9.66E+05
3.63E+02	7.22E+02	3.08E+02	5.78E+02	2.62E+02	2.57E+02	2.45E+02	2.42E+02	2.54E+02	2.82E+02
6.02E+00	1.77E+01	3.79E+01	9.31E+01	1.23E+02	1.61E+02	2.17E+02	2.71E+02	3.17E+02	3.33E+02

RADON SOURCE CONCENTRATION IS 306.1 PCU/CC
 THE DIFFUSION COEFFICIENT IS 3.61E-02 CM²/SEC
 STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE R IS 3.56E+04
 THERE WERE 10 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
 A CPTS 1.0-M 26-JUL-81 10:51:02 A
 A J F F U S I O N C O R P
 AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TP-1 M=6.8%

INPUT DATA SUMMARY

DATA SET FOR THIS RUN IS CORN3.DAT
 DETECTOR REGION VOLUME IS 1952.03
 ILM SOURCE CONCENTRATION RANGE 175-525 PC1/CC.
 NUMBER OF TERMS FOR SUMMATIONS IS 50
 CONVERGENCE CRITERION FOR SUMS IS 0.00010
 COLUMN LENGTH IS 39.560 CM
 WELL TIME IS 10.0 MINUTES
 DRY DENSITY IS 2.070 GM/CC
 POROSITY IS 0.234
 FILLION CONTENT IS 41.5 PC1/GM
 FILLATION COEFFICIENT IS 0.230
 NUMBER OF DATA POINTS IS 10

POINT NO.	UNITS OF RT	COUNT RATE 1	COUNT RATE 2
1	20	2.00E+04	3.240E+04
2	30	3.49E+04	3.70E+04
3	40	6.13E+04	8.37E+04
4	50	1.03E+05	1.08E+05
5	60	1.36E+05	1.30E+05
6	80	1.70E+05	1.72E+05
7	100	2.05E+05	2.09E+05
8	150	2.93E+05	3.95E+05
9	200	3.77E+05	3.73E+05
10	250	4.23E+05	4.33E+05
R = 3.16E-03	C = 3.00E+02	ST DEV = 4.74E+04	
R = 3.83E-03	C = 2.35E+02	ST DEV = 3.10E+04	
R = 4.08E-03	C = 2.25E+02	ST DEV = 2.76E+04	

COUNTS DETECTED IN WELL TIME = 10. MINUTES

CHANNEL NUMBER	CHAN 1	CHAN 2	CHAN 3	CHAN 4	CHAN 5	CHAN 6	CHAN 7	CHAN 8	CHAN 9	CHAN 10
1	9.00E+01	3.74E+03	8.15E+01	1.71E+04	1.86E+04	2.36E+04	3.73E+04	5.37E+04	6.41E+04	7.13E+04
2	7.04E+03	8.03E+03	1.96E+04	2.19E+04	4.54E+04	7.01E+04	9.18E+04	1.32E+05	1.59E+05	1.76E+05
3	3.67E+03	4.49E+03	1.30E+04	2.43E+04	2.84E+04	6.50E+04	9.08E+04	1.34E+05	1.62E+05	1.82E+05
4	3.00E+04	3.50E+04	4.07E+04	6.93E+04	1.07E+05	1.64E+05	2.18E+05	3.20E+05	3.87E+05	4.30E+05
5	2.17E+02	1.52E+02	1.54E+02	1.05E+03	1.59E+03	1.70E+03	2.08E+03	3.94E+03	3.75E+03	4.63E+03
6	1.95E+00	8.09E+00	1.76E+01	3.81E+01	1.02E+01	1.12E+02	1.07E+02	4.60E+01	1.79E+02	1.54E+02

BADON SOURCE CONCENTRATION IS 225.0 PC1/CC
 THE DIFFUSION COEFFICIENT IS 1.176E-02 CM²/SEC +- 3.90E-01
 STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE B IS 3.76E+04
 THERE WERE 9 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT

AA
 A C E T T I N G 26-JUL-91 14:54:24 A
 A N I F U S I O N C O M E
 AA

TP-1 M=3.6%

INPUT DATA SUMMARY

DATA SET FOR THIS RUN IS CORN6.DAT
 DETECTOR REGION VOLUME IS 2410. CM³
 LHM SOURCE CONCENTRATION RANGE (1.5-5.5 PC/CC)
 NUMBER OF TERMS FOR SUMMATIONS IS 50
 CONCENTRATION CRITERION FOR SUMS IS 0.00010
 COLUMN LENGTH IS 20.110 CM
 WELL TIME IS 10.0 MINUTES
 DRY DENSITY IS 2.103 GM/CC
 POROSITY IS 0.231
 RANDOM COUNTS IS 41.5 PC/CM
 ENHANCEMENT COEFFICIENT IS 0.230
 NUMBER OF DATA POINTS IS 10

POINT NO.	UNITS OF DT	COUNT RATE 1	COUNT RATE 2
1	R	1.20E+04	2.28E+04
2	R	3.22E+04	6.16E+04
3	R	7.22E+04	9.74E+04
4	R	1.50E+05	1.98E+05
5	R	3.93E+05	3.38E+05
6	R	4.12E+05	3.05E+05
7	R	3.17E+05	2.63E+05
8	R	2.73E+05	2.27E+05
9	R	2.37E+05	2.07E+05
10	R	2.00E+04	2.28E+04
	C	3.77E+02	5.06E+04
	C	3.50E+02	1.42E+04
	C	3.56E+02	1.33E+04

COUNTS DETECTED IN WELL TIME = 10. MINUTES

CHANNEL NUMBER	CHAN 1	CHAN 2	CHAN 3	CHAN 4	CHAN 5	CHAN 6	CHAN 7	CHAN 8	CHAN 9	CHAN 10
PARON CALC.	3.49E+03	3.70E+01	1.73E+04	3.11E+04	4.43E+04	5.64E+04	7.05E+04	9.33E+04	1.16E+05	1.35E+05
PLUTONIUM CALC.	4.92E+03	1.22E+04	4.09E+04	7.39E+04	1.07E+05	1.37E+05	1.89E+05	2.47E+05	2.96E+05	3.40E+05
AMOUNT CALC.	4.06E+03	1.66E+03	1.37E+04	3.62E+04	6.72E+04	1.00E+05	1.51E+05	2.11E+05	2.82E+05	3.40E+05
TOTAL CALC.	7.92E+03	1.95E+04	7.07E+04	1.41E+05	2.18E+05	2.93E+05	4.26E+05	5.33E+05	6.74E+05	8.08E+05
TOTAL EXP.	1.70E+04	3.27E+04	8.77E+04	1.34E+05	2.24E+05	3.23E+05	4.16E+05	5.07E+05	6.01E+05	7.15E+05
DIFF. CORR.	3.66E+02	3.71E+02	3.47E+02	3.32E+02	3.23E+02	3.12E+02	3.06E+02	2.93E+02	2.81E+02	2.72E+02
RM CORR. PC/CC	3.39E+00	1.23E+01	3.79E+01	6.73E+01	9.59E+01	1.22E+02	1.67E+02	2.02E+02	2.31E+02	2.92E+02

PARON SOURCE CONCENTRATION IS 355.6 PC/CC
 THE DIFFUSION COEFFICIENT IS 3.22E-02 CM²/SEC. 1. 3.06E-01 9.5
 STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE R IS 1.24E+04
 THERE WERE 10 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT

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 A CPTS 1.0-R 26-JUL-91 14:53:08
 A P I F U S I O M C O R E
 AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TP-1 M=6.6%

INPUT DATA SUMMARY

DATA SET FOR THIS RUN IS COMB.DAT
 REFLECTOR REGION VOLUME IS 3410. CM3
 LOW SOURCE CONCENTRATION RANGE (25-523 PC1/CC)
 NUMBER OF TEPAS LUN SUMMATIONS IS 30
 CONVERGENCE CRITERION FOR SUMS IS 0.00010
 COLUMN LENGTH IS 20.11 CM
 DWELL TIME IS 10.0 MINUTES
 DRY DENSITY IS 2.103 GM/CC
 POROSITY IS 0.721
 PARTIAL CONTENT IS 41.5 PC1/CM
 EXAMINATION COEFFICIENT IS 0.210
 NUMBER OF DATA POINTS IS 10

POINT NO.	UNITS OF RT	COUNT RATE 1	COUNT RATE 2
1	10	6.720E+03	8.430E+03
2	15	1.773E+04	2.054E+04
3	20	3.201E+04	3.624E+04
4	30	7.128E+04	7.498E+04
5	40	1.069E+05	1.078E+05
6	50	1.22E+05	1.404E+05
7	60	1.908E+05	2.017E+05
8	100	2.786E+05	3.310E+05
9	150	3.924E+05	3.940E+05
10	300	4.673E+05	4.685E+05
P	1.50E-02	ST DEV = 4.471E+04	
P	3.62E-03	ST DEV = 1.038E+04	
P	5.81E-03	ST DEV = 1.723E+04	
P	5.82E-03	ST DEV = 1.762E+04	

COUNTS DETECTED IN DWELL TIME = 10. MINUTES

CHANNEL NUMBER	CHAN 4	CHAN 5	CHAN 6	CHAN 7	CHAN 8	CHAN 9	CHAN 10
10	4444444	4444444	4444444	4444444	4444444	4444444	4444444
15	9.23E+03	1.71E+04	2.43E+04	3.72E+04	5.13E+04	6.61E+04	7.43E+04
20	2.33E+04	4.12E+04	5.98E+04	9.13E+04	1.27E+05	1.64E+05	1.83E+05
30	1.36E+04	3.03E+04	3.00E+04	8.31E+04	1.26E+05	1.67E+05	1.90E+05
40	4.66E+04	8.89E+04	1.34E+05	7.14E+05	2.64E+05	3.97E+05	4.88E+05
50	7.13E+04	1.07E+05	1.37E+05	1.99E+05	2.79E+05	3.93E+05	4.67E+05
60	1.64E+05	1.67E+05	1.55E+05	1.41E+05	1.75E+05	1.44E+05	1.59E+05
70	3.11E+05	3.70E+05	3.30E+05	8.05E+05	1.11E+06	1.43E+06	1.61E+06
80	4444444	4444444	4444444	4444444	4444444	4444444	4444444
90	3.27E+03	7.53E+03	2.33E+04	3.72E+04	5.13E+04	6.61E+04	7.43E+04
100	2.61E+03	1.34E+04	1.34E+04	8.31E+04	1.26E+05	1.67E+05	1.90E+05
110	3.70E+04	2.70E+04	2.70E+04	1.99E+05	2.79E+05	3.93E+05	4.67E+05
120	7.09E+04	7.09E+04	7.09E+04	1.41E+05	1.75E+05	1.44E+05	1.59E+05
130	4444444	4444444	4444444	4444444	4444444	4444444	4444444
140	1.17E+03	2.59E+03	2.59E+03	3.72E+04	5.13E+04	6.61E+04	7.43E+04
150	6.21E+02	4.28E+02	4.28E+02	8.31E+04	1.26E+05	1.67E+05	1.90E+05
160	1.78E+04	1.78E+04	1.78E+04	1.99E+05	2.79E+05	3.93E+05	4.67E+05
170	3.28E+02	3.28E+02	3.28E+02	1.41E+05	1.75E+05	1.44E+05	1.59E+05
180	4.74E+01	4.74E+01	4.74E+01	8.05E+05	1.11E+06	1.43E+06	1.61E+06

LABON SOURCE CONCENTRATION IS 209.7 PC1/CC
 THE DIFFUSION COEFFICIENT IS 1.597E-02 CM2/SEC
 STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE R IS 1.56E+04
 THERE WERE 9 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT

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 A B I F F U S I O N C O R E A
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TP-10 M=17.6% (fines -#4)

INPUT DATA SUMMARY

DATA SET FOR THIS RUN IS TP10179
 LOW SOURCE CONCENTRATION RANGE (75-525 PC1/CC)
 NUMBER OF TERMS FOR SUMMATIONS IS 50
 CONVERGENCE CRITERION FOR SUMS IS 0.00010
 COLUMN LENGTH IS 10.160 CM
 WELL TIME IS 10.0 MINUTES
 DRY DENSITY IS 1.207 GM/CC
 POROSITY IS 0.553
 RADIUM CONCENTRATION IS 11.3 PC1/GM
 EXAMINATION COEFFICIENT IS 0.240
 NUMBER OF DATA POINTS IS 10

POINT NO.	UNITS OF DT	COUNT RATE 1	COUNT RATE 2
1	2	3.720E+04	0.040E+04
2	4	1.720E+03	1.610E+05
3	6	1.980E+05	1.720E+05
4	8	2.630E+05	2.920E+05
5	10	3.100E+05	3.440E+05
6	12	3.640E+05	3.840E+05
7	14	4.710E+05	4.790E+05
8	16	4.930E+05	5.030E+05
9	18	5.130E+05	5.130E+05
10	20	5.180E+05	5.190E+05

C = 2.25E+02 ST DEV = 5.684E+04
 C = 1.75E+02 ST DEV = 1.971E+04
 C = 1.83E+02 ST DEV = 0.363E+03
 C = 1.56E-02
 C = 1.55E-02
 C = 1.86E+02 ST DEV = 7.893E+03

COUNTS DETECTED IN WELL TIME = 10. MINUTES

CHANNEL NUMBER		CHAN 1	CHAN 2	CHAN 3	CHAN 4	CHAN 5	CHAN 6	CHAN 7	CHAN 8	CHAN 9	CHAN 10
AAAAAAAAAAAA		AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA	AAAAAAAA
BARON CALC.		9.03E+03	3.46E+04	5.25E+04	6.40E+04	7.15E+04	7.63E+04	8.36E+04	8.46E+04	8.50E+04	8.51E+04
FOLLOWUP CALC.		1.22E+04	7.56E+04	1.71E+05	1.53E+05	1.73E+05	1.86E+05	2.06E+05	2.09E+05	2.10E+05	2.10E+05
RISERUP CALC.		1.11E+02	4.78E+03	2.16E+04	4.82E+04	7.95E+04	1.10E+05	1.88E+05	2.07E+05	2.13E+05	2.18E+05
TOTAL CALC.		3.72E+04	1.72E+05	1.95E+05	2.63E+05	3.24E+05	3.72E+05	4.71E+05	5.01E+05	5.13E+05	5.18E+05
PIPEL. CORR.		7.12E-01	1.87E-01	1.67E-02	2.63E-02	3.18E-02	3.64E-02	4.71E-02	4.99E-02	5.13E-02	5.18E-02
IN COM PC1/CC		1.95E+01	7.48E+01	1.13E+02	1.35E+02	1.55E+02	1.65E+02	1.81E+02	1.83E+02	1.87E+02	1.84E+02

BARON SOURCE CONCENTRATION IS 186.1 PC1/CC
 THE DIFFUSION COEFFICIENT IS 2.741E-03 CM²/SEC
 STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE IS 2.89E+03
 THERE WERE 10 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT

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 A I F F U S I O N C O R P A
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TP-1 M=11.8% (fines -#4)

INPUT DATA SUMMARY

DATA SET FOR THIS RUN IS TP1121
 LOW SOURCE CONCENTRATION RANGE (25-525 PCI/CC)
 NUMBER OF TERMS FOR SUMMATIONS IS 50
 CONVERGENCE CRITERION FOR SUMS IS 0.00010
 COLUMN LENGTH IS 10.160 CM
 DUELL TIME IS 10.0 MINUTES
 DRY DENSITY IS 1.435 GM/CC
 POROSITY IS 0.469
 RADIUM CONTENT IS 126.0 PCI/GM
 RADIATION COEFFICIENT IS 0.230
 NUMBER OF DATA POINTS IS 10

POINT NO.	UNITS OF DT	COUNT RATE 1	COUNT RATE 2
1	2	7.20E+04	7.610E+04
2	4	1.150E+05	1.500E+05
3	6	1.880E+05	2.240E+05
4	8	2.580E+05	2.900E+05
5	10	3.210E+05	3.480E+05
6	12	3.760E+05	3.990E+05
7	14	4.230E+05	4.450E+05
8	16	4.620E+05	4.790E+05
9	18	4.930E+05	5.090E+05
10	20	5.200E+05	5.320E+05
P = 1.00E-02		SI DEV = 2.34E+04	
C = 2.00E+02		SI DEV = 1.355E+04	
B = 1.25E-02		SI DEV = 1.020E+04	
D = 1.28E-02		SI DEV = 4.740E+03	

COUNTS DETECTED IN DUELL TIME - 10. MINUTES

CHANNEL NUMBER	CHAN 1	CHAN 2	CHAN 3	CHAN 4	CHAN 5	CHAN 6	CHAN 7	CHAN 8	CHAN 9	CHAN 10
AAAAAAAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA	AAAAAAA
RADON CALC.	6.82E+03	2.14E+04	5.07E+04	6.41E+04	7.34E+04	7.98E+04	8.42E+04	8.72E+04	8.93E+04	9.08E+04
POLONIUM CALC.	0.85E+03	2.47E+04	1.16E+05	1.57E+05	1.77E+05	1.94E+05	2.06E+05	2.14E+05	2.20E+05	2.24E+05
RADIUM CALC.	7.29E+01	3.85E+03	1.90E+04	4.50E+04	7.64E+04	1.08E+05	1.37E+05	1.62E+05	1.87E+05	1.95E+05
TOTAL CALC.	1.57E+04	1.00E+05	1.86E+05	2.61E+05	3.27E+05	3.82E+05	4.27E+05	4.63E+05	4.91E+05	5.03E+05
TOTAL EXP.	3.70E+04	1.15E+05	1.88E+05	2.58E+05	3.21E+05	3.76E+05	4.22E+05	4.62E+05	4.93E+05	5.03E+05
DIFF. COEF.	3.36E-02	2.74E-02	2.60E-02	2.50E-02	2.44E-02	2.40E-02	2.38E-02	2.36E-02	2.36E-02	2.37E-02
RM CONC PCI/CC	1.47E+01	6.80E+01	1.10E+02	1.39E+02	1.59E+02	1.73E+02	1.82E+02	1.89E+02	1.91E+02	1.96E+02

RADON SOURCE CONCENTRATION IS 205.6 PCI/CC
 THE DIFFUSION COEFFICIENT IS 2.739E-02 CM²/SEC +- 3.69E-03
 STANDARD DEVIATION IN COUNT RATES FOR COMPOSITE D IS 9.74E+03
 THERE WERE 10 POINTS USED TO CALCULATE THE STANDARD DEVIATION OF THE DIFFUSION COEFFICIENT

MEMORANDUM

FROM: DGonzales, TAC *[initials]*
TO: PKChen, MK-ES
DATE: July 22, 1992
SUBJECT: Freeze/Thaw Impact on Radon Diffusion Characteristics of Soil

The following comments are prepared in support of radon diffusion modeling of frost protection soil for the Gunnison, CO disposal cell design.

A preliminary study was performed by the TAC (DGonzales, JMillard, and RRegar) to access the effects of freeze/thaw cycles on the radon diffusion coefficients for unsaturated radon cover soil. Typical radon barrier soil (Estes Gultch barrow source for Rifle, CO) was compacted, 95 percent compaction, in 4" diameter by 4" high cylindrical steel molds used for performing standard radon diffusion coefficient measurements (transient one-dimensional radon diffusion coefficient measurement technique developed by Rogers and Associates Engineering Corp. (RAE), Salt Lake City, Utah, and routine performed by RAE for the UMTRA Project). Samples were prepared at 4.4, 9.4, and 13.7 percent by weight moisture content, corresponding to 22, 46, and 68 percent moisture saturation, respectively.

The soil samples were sealed in the molds by spring loaded steel plates (see attached Figure 1), and the samples were subjected to 13 rapid, freeze/thaw cycles using the freezer compartment of a common domestic refrigerator: 15 hours freezing followed by 9 hours thawing. Soil temperatures cycled between - 12 to + 20 degrees centigrade. After 13 cycles, the diffusion coefficient for each sample was measured and compared with previously obtained results for the cover soil. Figure 2 displays the resultant comparison.

On the basis of this preliminary freeze/thaw experiment, one may reasonably conclude that freeze/thaw cycling of typical barrier soil, with moisture saturation less than 75 percent saturation, would not significantly alter the radon characteristics of soil. As an added element of conservatism, the frost protection soil for the Gunnison, CO disposal cell was designed at 83 percent compaction rather than 90 to 95 percent to simulate potential density changes produced by freeze/thaw events.

cc: MMiller
JMcBee

Diffusion Coefficient (cm²/s)

1×10^{-3}

Figure 2

JACOBS ENGINEERING GROUP INC., ALBUQUERQUE OPERATIONS

To: JMcBee *JK* *DL*
From: KKloc & DGonzales
Date: March 27, 1991

Re: Results of the DECHEM calculations for the Gunnison site

The Radiological/Toxicological Services group has completed the DECHEM screening calculation for post-remedial action concentrations of non-radiological hazardous constituents (NRHCs) for Gunnison site soils. The DECHEM analysis was carried out assuming that:

- Contaminated areas at the site will be excavated and backfilled with clean soil in order to comply with the 15 pCi/g Ra-226 standard for soils greater than 15 centimeters below land surface
- The alluvial aquifer will be restored as part of remedial action activities at the site; the screening analysis used initial concentrations of zero for site related NRHCs in groundwater
- Rural residences may be established onsite immediately after remediation
- Human receptors will be exposed to NRHCs predominantly via ingestion of alluvial groundwater. Because of backfilling, pathways involving inhalation of respirable dust derived from site soils, and the ingestion of meat, milk and vegetables grown on site soils are expected to be minimal

Three NRHCs that exceeded background levels in soil layers below the 15 pCi/g Ra-226 soil layer were chosen as indicators of the potential for adverse non-carcinogenic health effects: arsenic, molybdenum, uranium. The potential buildup of these constituents in the alluvial aquifer was calculated over time to determine if leaching of residual NRHCs could result in significant groundwater contamination subsequent to the planned aquifer restoration activities. Two exposure scenarios were analyzed: an onsite residence, and a residence 300 meters downgradient of the subpile.

For the onsite residence, drinking water reference values calculated up to 500 years into the future were less than 1.0. Reference values showed an increasing trend from 0 to approximately 0.6 within the first 7 years and then decreased steadily thereafter. A value less than 1.0 indicates a low potential for adverse non-carcinogenic health effects to residents drinking alluvial groundwater from this area.

Although reference values for the onsite scenario were below levels of concern, the DECHEMA groundwater model predicted onsite groundwater concentrations of uranium in excess of the proposed uranium MCL (0.044 mg/L). Assuming post-excavation uranium concentrations in subpile soils and no existing aquifer contamination, concentrations of uranium in groundwater are expected to increase from 0 to 0.053 mg/L within 7 years, and to decrease below the 0.044 mg/L MCL level sometime between 15 and 25 years. Because the groundwater model was implemented using a number of conservative assumptions, the actual time period for the buildup and dissipation of groundwater contamination may be less than calculated. Maximum concentration limits for arsenic and molybdenum will not be exceeded onsite.

For a resident 300 meters downgradient of the subpile, the total drinking water reference values also will not exceed 1.0 for uranium, arsenic, and molybdenum. Thus, adverse non-carcinogenic effects are not expected for residents in this scenario.

Offsite concentrations of arsenic and molybdenum are not expected to exceed MCLs since onsite concentrations were within these limits. Offsite transport and dispersion in the aquifer will result in NRHC concentrations lower than concentrations experienced onsite. Although the uranium MCL for an onsite well was exceeded for up to 25 years after remediation, the estimated uranium concentration for an offsite resident is expected to always be less than the MCL.

DECHEMA calculations were not carried out for post-remedial soil concentrations at the millyard and ore storage area, and the windblown tailings area. A qualitative assessment of contaminant transport processes in these areas indicates that residual NRHC concentrations should be lower than at the subpile area. Radiological remedial action requirements should reduce NRHCs in these areas nearly to background concentrations. This judgement is based upon the expectation that leaching of NRHCs at the millyard and ore storage area and windblown area, being largely the result of neutral rainwater infiltration, should have occurred to a lesser degree than leaching at the acidic sub-pile.

The results of the DECHEMA analysis at the Gunnison site indicate that excavation and backfilling required to achieve compliance with the radiological cleanup standard for sub-surface soils should be sufficient to protect against adverse non-carcinogenic health effects to potential off-site residents. For potential onsite residents residual subsoil uranium concentrations may produce an exceedance of the proposed uranium MCL for a limited period of up to 25 years after radiological remediation of the site. Aquifer restoration activities and/or institutional controls will be required as part of the overall remedial action program to mitigate an existing elevated groundwater uranium plume. If the aquifer restoration program is less than 25 years in duration, then the extension of institutional controls may be required for a short period to limit the use of the onsite aquifer.

The use of institutional controls up to 100 years for aquifer restoration is within UMTRA project guidelines, and in the case of Gunnison, a more practical approach when compared with the cost of deeper excavation, possibly into the saturated zone.

cc: PDarr
MMiller

CALCULATION COVER SHEET

CALC NO. GUNDECHEM #1 DISCIPLINE Rad. Services

NO. OF SHEETS 94

PROJECT:

GUNNISON DECHEM RISK ANALYSIS

SITE:

Gunnison, Colorado UMTRA Site.

FEATURE:

Pathway analysis to assess impacts of residual non-radiological hazardous constituents to determine additional excavation beyond that required for Ra-226/Th-230.

SOURCES OF DATA:

SOURCES OF FORMULAE & REFERENCES:

References on page 14.

PRELIMINARY CALC. ☐ FINAL CALC. ☒ SUPERSEDES CALC. NO. _____

<u>#1</u>	<u>GUNDECHEM #1</u>	<u>DGonzalez</u>	<u>3/15/91</u>	<u>K.K. Ke</u>	<u>3/15/91</u>	<u>M. Miller</u>	<u>3/27/91</u>
REV. NO.	REVISION	CALCULATION BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE

~~Q~~ 3/15/91
HK 3/15/91

DRAFT

DECHEM PATHWAY ANALYSIS
GUNNISON, COLORADO UMTRA SITE

MARCH, 1991

1.0 INTRODUCTION

3/15/91
KK 3/15/91

A pathway analysis is performed for UMTRA sites as part of the remedial action design to assess potential health impacts of residual concentrations of non-radiological hazardous constituents (NRHC's), such as heavy metals, and uranium that may reside in subsurface soil after compliance with the radium-226 (Ra-226) and thorium-230 (Th-230) cleanup standards have been met. Pathways considered are ingestion of groundwater, consumption of vegetables, meat and milk produced on the site, and the inhalation of particulates resuspended on the site. Each of these pathways is analytically modeled in the DECHEM computer code, which utilizes site-specific data and generic parameters to perform the analysis as a function of time for specified remedial action scenarios (DOE 1989, RAC 1990). The DECHEM evaluation serves as a screening process to indicate the potential need for additional excavation below the bulk radiological cleanup criteria to reduce non-radiological metal and uranium concentrations to safe, non-toxic levels.

2.0 CONTAMINATED AREAS

Extensive soil sampling of the site has been performed for radiological and non-radiological contaminants (ORNL 1980, FBDO 1981, BFEC 1984). A total of 68 acres has been identified as radiologically impacted, including the 35 acre tailings pile, and the limits and average subsurface depth of off-pile Ra-226 contamination are shown in Figure 1. The

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KK 3/15/91

Figure 1 Limits and average subsurface depth of off-pile contamination at the processing site near Gunnison, Colorado

KK 3/15/91

The structure of the foundation soil in the contaminated area consists of a thin topsoil layer up to 0.5 feet thick covering a cobble/gravel/sand subsoil, which, on average, consists of 70 percent cobbles/gravels larger than # 4 sieve by weight. Over 90 percent of the radiological and non-radiological contamination is associated with the fine size fraction less than # 4 sieve. Furthermore, the fluctuating groundwater table is shallow in the processing area, and is assumed to have an ambient depth of 5.5 feet, and flows in the southwesterly direction at about 3 feet per day.

3.0 RESIDUAL CONTAMINANTS OF CONCERN

Non-radiological contaminants of concern were identified by comparing hazardous metal concentrations in groundwater from domestic and monitor wells, the tailings source material and pore water, and background soil. The main non-radiological elements present in the ore and tailings are: As (greater than 10 times background), Mo, Cu, Ni, and Pb (4-7 times background). Concentrations of Se and V are typically elevated in uranium ore and tailings, however, samples from Gunnison indicate corresponding concentrations of these elements are at background levels in the ore, tailings, and tailings pile subsoil. In addition, the groundwater has not been impacted by these constituents. Although data is unavailable for Mn and Fe, for which secondary groundwater standards apply, these constituents are presumed to be significantly elevated in the source material. Pore water and groundwater directly beneath the tailings pile were elevated in As, Cd, Cu, Fe, Pb, Mn, and Ni, as well as

uranium.

Q 3/15/91
KK 3/15/91

Analysis of off-pile data indicates that the proposed excavation depths for Ra-226 cleanup would also reduce these non-radiological constituents and uranium to near background concentrations in the off-pile areas. Therefore, non-radiological impacts and the toxicity of uranium were only evaluated for the 35 acre pile area, and an additional 10 acres immediately north of the pile, which initially contained tailings.

The proposed radiological remediation of the tailings pile subsoils is estimated to be 2.5 feet to remove bulk Ra-226 exceeding background concentrations by more than 15 pCi/g. Since the excavation will be backfilled with clean soil, the pathway analysis will focus on the impacts of residual, elevated concentrations of relevant non-radiological constituents and uranium residing in subsoil layers in the interval below 2.5 feet and above the ambient water table at 5.5 feet. The proposed remedial action based on bulk Ra-226 will essentially remove any concentrations of Cu, Ni and Pb elevated above corresponding background values. Therefore, the DECHEMA code will only be applied to elevated residual concentrations of As, Mo and U in the 3.0 foot layer above the watertable, and below 2.5 feet of clean, compacted backfill.

4.0 INPUT PARAMETERS

KK 3/15/91

As a screening tool, DECHEMA employs conservative estimates to model pathway and uptake conditions. For example, values of non-site - specific parameters were obtained from the following sources:

- o Residential exposure assumptions and intake values were obtained from the U. S. Environmental Protection Agency's, Exposure Factors Handbook (EPA 1989). Factors were chosen to produce a reasonable conservative estimate for yearly intakes of groundwater, home grown foodstuffs, and air.
- o The atmospheric soil loading factors which determine the amount of respirable particulates available for intake, was also obtained from EPA guidance (42 CFR 60956-60959).
- o Factors for vegetable and animal uptake from soil were taken from the study of Baes et. al. (ORNL 1984).

A number of site-specific DECHEMA parameter values also are derived for the pathway analysis involving the NRHC area source, aquifer and soil matrix structures, and the geochemical properties and transport characteristics of the soil and aquifer. Excavation of the upper most 2.5 feet of contaminated soil is required to meet the Ra-226/Th-230 cleanup criteria. Clean, compacted backfill will be placed over a 3.0 foot thick marginally contaminated soil above the water table. Impact of this NRHC residual material left after radiological (Ra-226)

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cleanup criteria was evaluated from the time of remediation to 1000 years.

Soil profiles for U, As, and Mo were obtained from site characterization samples. Sample locations and analyzed results are given in Appendix A, and the constructed soil depth profiles and background soil concentrations for U, AS, and Mo are summarized in Tables 1 and 2, respectively.

Values for the soil to water partition function $K(d)$ were obtained from the MEPAS handbook (PNL 1989) assuming that the soil and aquifer matrices at the site have a clay content less than 10%, and that the pH of the soil and aquifer were between 5 and 9. A low value of $K(d)$ was selected in each case to conservatively maximize the mobility of each element, and the retardation of each element was assumed to be greater in the unsaturated zone above the water table relative to the saturated zone. Table 3 summarizes the $K(d)$ values selected.

The shallow alluvial aquifer at the Gunnison site is approximately 40 meters thick, has an ambient watertable of 5.5 feet below the ground surface, and groundwater flows from the northeast with an average linear velocity of 3 ft/day (1.38×10^{-5} m/s). The following values of aquifer parameters were chosen in consultation with the site hydrogeologist: 1) effective porosity of aquifer 0.1; 2) longitudinal and transverse dispersivity 5 m and 1 m, respectively; 3) aquifer soil density 1.9 g/cm^3 .

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Table 1 Post-remedial action average soil concentration profiles for U, As and Mo in the subpile area

Depth (ft)	Concentration (ppm)		
	U	As	Mo
0 - 1	3	5	5
1 - 2.5	3	5	5
2.5 - 4.5	55	45	15
4.5 - 5.5	28	23	8

Table 2 Average background soil concentrations of U, As, and Mo (0 - 0.5 feet)

Element	Concentration (ppm)
U	3
As	5
Mo	5

Table 3 Soil-pore water partition coefficient K(d) for NRHC's

Contaminant	K(d)	
	Soil	Aquifer
U	5	1
As	10	6
Mo	100	40

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The soils at the site consist of a well graded mixture of cobbles, pebbles and sand. The following values for soil parameters were used in the calculations: 1) soil bulk density 1.9 g/cm³; 2) effective soil porosity 0.3; 3) soil moisture content by volume 0.15.

5.0 ON-SITE OCCUPANCY AND FOOD PRODUCTION: ON-SITE WATER WELL

Separate uranium and sulfate plumes presently exist at the site. Therefore, natural flushing, or aquifer restoration activities will be required as part of the overall remedial action for the site to mitigate adverse health effects due to this groundwater contamination. It is assumed that either natural or restoration actions will effectively cleanup the aquifer. Accordingly, the pathway analysis will only evaluate the impact of the residual contamination layer on an otherwise clean aquifer.

The first exposure scenario considers a residence directly on remediated the processing site, 40 to 75 percent of the food produced on the site, and 100 percent of the water drawn from well drilled into shallow aquifer at the center of the site. Input parameters and associated output results are presented in Appendix B, and summarized as follows.

- o The reference value for the collective effect of all the contaminants does not exceed 1 for up to 1000 years. The total reference value increases from initial value of 0.35 to 0.87 in first 7 years, then steady decline with time. The main contribution to the total reference value in the first 15 years is due

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to the uptake of As and Mo contaminants from the surface rooting zone by vegetables and grasses (meat production) grown on the site, and leaching of uranium into the groundwater.

- o Vegetable pathway is an order of magnitude less important for As (0-7 years) than for Mo (0-15 years). The duration of the importance of the vegetable/meat pathways corresponding to the time required to leach the respective contaminants from the upper, 0-15 cm rooting layer. Since the rooting soil layer is clean backfill containing essentially background concentrations of As and Mo, the total reference value never exceeds one. Furthermore, the leaching of As and Mo into the groundwater do not significantly impact groundwater quality, and corresponding maximum concentration levels for As and Mo, 0.05 mg/l and 0.1 mg/l, respectively, are never exceeded. Therefore, health impacts due to residual As and Mo cannot be considered significant.
- o The leaching of uranium into the groundwater directly below the site produces the major impact on groundwater. Although the drinking water reference value is always less than one, it attains a maximum value of 0.556 seven years after remedial action, and then steadily declines. However, the estimated uranium concentration increases from 0 mg/l immediately after

OK 3/15/71
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remediation to a maximum of 0.0533 mg/l after 7 years, and then steadily decreases with time. The drinking water concentration of 0.044 mg/l is exceeded in the 7-15 year post-remedial action period, based on the conservative parameters assumed here. The existing uranium contamination plume would require remediation, and this activity would be concurrent with leaching of uranium from the residual layer between the groundwater table and the lower surface of the clean backfill layer. This restoration process could take up to 15 years to accomplish, and, therefore, after groundwater restoration, the impacts due to the residual NRHC's would be negligible. However, if the actual groundwater plume restoration or flushing took less than 15 years than uranium concentrations in groundwater directly under the site could exceed 0.044 mg/l for a limited time period after groundwater flushing, or restoration due to leaching from the residual layer. The combined effect of leaching and aquifer restoration/flushing would take less than 50 years, and be within EPA requirements for application of institutional controls.

6.0 ON-SITE OCCUPANCY AND FOOD PRODUCTION: OFF-SITE WATER WELL

The second exposure scenario considered has the same excavation/backfill structure as the first scenario, and food is grown and produced on the site. However, water is consumed from a well located 1000 meter downgradient from the site-center.

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Conclusions drawn from the analysis are as follows:

- o References values for As and Mo due to on-site food production are the same as calculated for the first scenario, and have a 0-15 year impact period through the vegetable/meat pathways. The total reference value for all As and Mo pathways does not exceed one. The calculated health impacts are essentially due to plant uptake and leaching of background concentrations for AS and Mo.
- o Off-site transport and dispersion of As, Mo and uranium leached from the subsoil into groundwater never produce groundwater concentrations that exceed MCL's for As and Mo at any location, and uranium concentrations do not exceeds 0.044 mg/l at any off-site location after remediation.

7.0 CONCLUSION

Residual uranium concentrations in a 3 foot layer above the water table, and below 2.5 feet of clean backfill could potentially elevated uranium concentrations in groundwater directly under the remediated site above 0.044 mg/l for a limited time between 7 and 15 years after remedial action. However, since natural aquifer flushing or active restoration will be required during this same time period to cleanup an existing uranium plume caused by leaching of uranium from the tailings pile, it is unlikely that additional excavation beyond that needed for Ra-226 will be

required to reduce the impact of residual uranium concentrations
above the water table and below clean backfill.

Q 3/15/91
KK 3/15/91

QA 3/15/91
dk 3/15/91

REFERENCES

- BFEC (Bendix Field Engineering Corp.), 1984. Radiological Characterization of the Gunnison, Colorado Uranium Mill Tailings Remedial Action Site, GJ14 Bendix Field Engineering Corporation, Grand Junction, Colorado
- DOE (U. S. Department of Energy), 1989. A Remedial Action Planning Tool for Metallic Contaminants in Soil at UMTRA Project Sites, Final Report and User's Guide, U. S. Department of Energy, Albuquerque Operations Office, UMTRA/DOE/AL 400655.0000.
- EPA (U.S. Environmental Protection Agency) 1989. Exposure Factors Handbook, U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, EPA/600/8-89/043.
- FBDU (Ford, Bacon and Davis, Utah, Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings, Gunnison, Site, DOE/UMT107, prepared by FBDU, Salt Lake City, Utah for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- ORNL (Oak Ridge National Laboratory) 1984. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture, Oak Ridge National Laboratory, Health and Safety Research Division, ORNL-5786.
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- PNL (Pacific Northwest Laboratory) 1989. Chemical Data Bases for the Multimedia Environmental Pollutant Assessment System (MEPAS); Version 1. PNL-7145 UC-602,603.
- RAC (Radiological Assessments Corporation, Neeses, SC 29107) 1990. DECHEM Version 3.02: An All-Pathways Assessment Procedure for Determining Acceptable Concentrations of Chemicals in Soil of Waste Sites.

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KK 3/15/91

APPENDIX A

SOIL SAMPLE DATA USED IN DECHEM ANALYSIS

JACOBS ENGINEERING GROUP INC.

ALBUQUERQUE OPERATIONS

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JEGA/UNC/0389-12

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

March 15, 1989

3/15/91
KK 3/15/91

Dr. Ron Chessmore
Manager, Chemistry Laboratory
UNC Geotech
P.O. Box 14000
2597 B 3/4 Road
Grand Junction, CO 81502-5504

Re: Analysis of Gunnison, CO
Archived Samples

Dear Ron:

Enclosed is a table of archived samples from the Gunnison, Colorado UMTRA Project site. The archived samples were initially analyzed and archived by Bendix.

As soon as your schedule permits, please analyze all samples listed in the table for the metals indicated. In addition to the metals analysis, 10 samples require analysis for Th-230 and 17 for uranium (as indicated in the table).

Please report all Th-230 concentrations in pCi/g and the remaining metal concentration in ppm. Also, please report the minimum detectable concentration for each analysis, if any samples are reported as less than the minimum.

Receipt of this letter is your authorization to perform the requested analysis. If any of the archived samples are not available for analysis, or if your records conflict with the data in the table, please contact me immediately so that we may select alternate samples for analysis or resolve the discrepancy. Please return all results to me.

If you have any questions, please contact Douglas Gonzales of our staff or me at (FTS) 846-1250.

Very truly yours,
JACOBS ENGINEERING GROUP INC.

Robert O. Murphy, Ph.D.
Health Physicist

ROM/DG/bj
Enclosures

cc: EBanks
DMann, DOE
DDubois
LLittle, GJPO
DGonzales

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 3/15/91
 KK 3/15/91

Gunnison NRT Characterization Soil Sample Location,
 Identification and Depth Increment

Map Key ^a	Location		Depth (feet)	Chemical Analysis Required						
	N	E		As	Mo	Se	V	Th	- 230 U	
<u>MILL YARD</u>										
38	1392	1809	0.0-0.5	X	X					
39	1193	1810	0.0-0.5	X	X					
40✓	1193	2010	0.0-0.5	X	X	X	X			X
41✓	1030	2140	0.0-0.5	X	X	X	X			X
42	1280	2270	0.0-0.5	X	X					
43	1630	2200	0.0-0.5	X	X					
<u>ORE STORAGE (SOUTHERN PORTION)</u>										
44 ✓	1080	1100	0.0-0.5	X	X	X	X		X	X
	1080	1100	0.5-1.0	X	X	X	X		X	X
	1080	1100	1.0-1.5	X	X	X	X		X	X
45a ✓	1020	1740	0.0-0.5	X	X	X	X		X	X
	1020	1740	0.5-1.0	X	X	X	X		X	X
	1020	1740	1.0-1.5	X	X	X	X		X	X
	1020	1740	1.5-2.0	X	X	X	X		X	X
45b	1010	2020	0.0-0.5	X	X	X	X		X	X
	1010	2020	0.5-1.0	X	X	X	X		X	X
	1010	2020	1.0-1.5	X	X	X	X		X	X
<u>ORE STORAGE (NORTHERN PORTION)</u>										
46	1460	1100	0.0-0.5	X	X					
47	1190	1424	0.0-0.5	X	X					
48	1388	1614	0.0-0.5	X	X	X	X			X
49	1557	1408	0.0-0.5	X	X	X	X			X
<u>BACKGROUND</u>										
50 ✓	BG - 1		0.0-0.5	X	X	X	X			X
51 ✓	BG - 3		0.0-0.5	X	X	X	X			X
52 ✓	BG - 4		0.0-0.5	X	X	X	X			X

^aJacobs Engineering internal reference only.

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Figure 5 Off-pile Sampling Locations

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1392 1889
TICKET ID: MAX 986

REQUESTOR: JACOBS-GARRISON
SAMPLE MATRIX: SOIL
UNC REQUISITION: 2289

DATE: 19-JUN-89

PROJECT NUMBER: SCP862000
DATE RECEIVED:
DATE COLLECTED:

#38
0 - 0.5

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	11	UG/G	18-MAY-89	156896	A-2 R02	
Molybdenum	5	UG/G	27-MAY-89	156896	AS-6 R03	

Raymond L. D. [Signature]
Q.C. COORDINATOR

19
3/15/91
3/15/91

3/15/91
3/15/91

#39
0 -0.5

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1193 1010
TICKET ID: MAX 903
REQUESTOR: JACOBS-GUNNISON
SAMPLE MATRIX: SOIL
UNC REQUISITION: 2289

DATE: 19-JUN-89
PROJECT NUMBER: SCPS02000
DATE RECEIVED:
DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	10	UG/G	10-MAY-89	156897	A-2 R02	
Molybdenum	5	UG/G	27-MAY-89	156897	AS-6 R03	

Donald Y. Dunlop
Q.C. COORDINATOR

UNC ANALYTICAL

CUSTOMER ID: 1280 2270
 TICKET ID: WMA 332
 REQUESTOR: JACOBS-SUMNISON
 SAMPLE MATRIX: SOIL
 UNC REQUISITION: 2289

DATE: 19-JUN-89

PROJECT NUMBER: SC9902000
 DATE RECEIVED:
 DATE COLLECTED:

#42
 0-0.5

ANALYTES REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	
					ANALYSIS	COMMENTS
Arsenic	27	UG/G	18-MAY-89	156898	A-2	R02
	12	UG/G	27-MAY-89	156898	AS-6	R03
Molybdenum						

Quell F. Dukat
 Q.C. COORDINATOR

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UNC ANALYTICAL RESULTS

CUSTOMER ID: 1630 2289
TICKET ID: MAX 901

REQUESTOR: JACOBS-CUNNISON
SAMPLE MATRIX: SOIL
UNC REQUISITION: 2289

DATE: 19-JUN-89

PROJECT NUMBER: SCP802000
DATE RECEIVED:
DATE COLLECTED:

43

0-0.5

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	9	ug/g	10-MAY-89	156899	A-2 R02	
Molybdenum	5	%g/g	27-MAY-89	156899	AS-6 R03	

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Gerald L. Derlost
Q.C. COORDINATOR

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1010 2020
 TICKET ID: WMA 336 0-6
 REQUESTOR: JACOBS-GUNNISON
 SAMPLE MATRIX: SOIL
 UNC REQUISITION: 2289

DATE: 19-JUN-89

PROJECT NUMBER: SC9802000
 DATE RECEIVED:
 DATE COLLECTED:

756

0 - 0.5

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	200	UG/G	10-MAY-89	156900	A-2 R02	
Molybdenum	72	UG/G	27-MAY-89	156900	AS-6 R03	
Selenium	3	UG/G	08-MAY-89	156900	A-2 R02	
Thorium 230	202.7	PCI/G	06-MAY-89	156900		
Uranium	457	UG/G	27-MAY-89	156900	AS-6 R03	
Vanadium	66	UG/G	13-JUN-89	156900	B-2 R02	

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Donald L. Dunlap
 Q.C. COORDINATOR

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1010 2020
 TICKET ID: NWA 349 "12"
 REQUESTOR: JACOBS-GUNNISON
 SAMPLE MATRIX: SOIL
 UNC REQUISITION: 2289

DATE: 19-JUN-89

PROJECT NUMBER: SC2862000
 DATE RECEIVED:
 DATE COLLECTED:

#45b
 0.5-1.0

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	250	UG/G	10-MAY-89	156901	A-2 R02	
Molybdenum	113	UG/G	27-MAY-89	156901	AS-6 R03	
Selenium	3	UG/G	08-MAY-89	156901	A-2 R02	
Thorium 230	550.2	PCI/G	06-MAY-89	156901		
Uranium	746	UG/G	27-MAY-89	156901	AS-6 R03	
Vanadium	99	UG/G	13-JUN-89	156901	B-2 R02	

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 24

General R. D. Cant
 G.C. COORDINATOR

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1010 2020 "12-18"
 TICKET ID: WMA 399
 REQUESTOR: JACOBS-CUMMISON
 SAMPLE MATRIX: SOIL
 UNC REQUISITION: 2289

DATE: 19-JUN-09

PROJECT NUMBER: 3CP902000
 DATE RECEIVED:
 DATE COLLECTED:

4SL
 1-0-1-3

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	330	UG/G	10-MAY-09	156902	A-2 R02	
Molybdenum	113	UG/G	27-MAY-09	156902	AS-6 R03	
Selenium	2	UG/G	08-MAY-09	156902	A-2 R02	
Thorium 230	705.0	PCI/G	06-MAY-09	156902	AS-6 R03	
Uranium	1520	UG/G	27-MAY-09	156902	B-2 R02	
Vanadium	97	UG/G	13-JUN-09	156902		

28 3/15/91
 t/k 3/15/91

25

Michael J. Dant
 Q.C. COORDINATOR

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1460 1100
TICKET ID: NWA 345

REQUESTOR: JACOBSON-GUNNISON
SAMPLE MATRIX: SOIL
UNC REQUISITION: 2289

DATE: 19-JUN-89

PROJECT NUMBER: SC9802000
DATE RECEIVED:
DATE COLLECTED:

#46
0-0.5

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	11	UG/G	10-MAY-89	156903	A-2 R02	
Molybdenum	7	UG/G	27-MAY-89	156903	AS-6 R03	

3/15/91 26
3/15/91

Donald L. Durlant
Q.C. COORDINATOR

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1190 1424
TICKET ID: MAX 911

REQUESTOR: JACOBS-CUMMISON
SAMPLE MATRIX: SOIL
UNC REQUISITION: 2289

DATE: 19-JUN-09

PROJECT NUMBER: SCPS02000
DATE RECEIVED:
DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	34	MG/G	18-MAY-09	156904	A-2 R02	
Molybdenum	22	MG/G	27-MAY-09	156904	AS-6 R03	

#43

0-0.5

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3/15/91

27

Ronald L. Durlant
Q.C. COORDINATOR

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1368 1614
TICKET ID: MAX 909

REQUESTOR: JACOBS-GUNNISON
SAMPLE MATRIX: SOIL
UNC REQUISITION: 2289

DATE: 19-JUN-89

PROJECT NUMBER: SCP862000
DATE RECEIVED:
DATE COLLECTED:

48

0-0.5

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Arsenic	200	UG/G	10-MAY-89	156905	A-2 R02	
Molybdenum	45	UG/G	27-MAY-89	156905	AS-6 R03	
Selenium	2	UG/G	08-MAY-89	156905	A-2 R02	
Strontium	104	UG/G	27-MAY-89	156905	AS-6 R03	
Vanadium	80	UG/G	13-JUN-89	156905	B-2 R02	

3/15/91 28
KK 3/15/91

Harold L. Dunlop
Q.C. COORDINATOR

UNC ANALYTICAL RESULTS

CUSTOMER ID: 1557 1400
 TICKET ID: MAX 913
 REQUESTOR: JACOBS-GUNNISON
 SAMPLE MATRIX: SOIL
 UNC REQUISITION: 2209

DATE: 19-JUN-89

PROJECT NUMBER: 9C9802000
 DATE RECEIVED:
 DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Atomic	200	UG/G	10-MAY-89	156906	A-2 R02	
Molybdenum	21	UG/G	27-MAY-89	156906	AS-6 R03	
Selenium	5	UG/G	08-MAY-89	156906	A-2 R02	
Strontium	163	UG/G	27-MAY-89	156906	AS-6 R03	
Vanadium	47	UG/G	13-JUN-89	156906	R-2 R02	

#49
 0-0.5

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29

Donald L. Durlant
 Q.C. COORDINATOR

DATE _____

SUBJECT _____

BY _____ CH'D. _____

3/15/91
3/15/91

SHEET NO. 30

JOB NO. _____

• Bendix data (31 samples) for Th-230 analysis

Th-230/Ra-226

Wind blown	0.50
One storage Area	1.04
Mill yard	0.90

Full composition
UNC ANALYTICAL RESULTS

TOTAL
DIGESTION

CUSTOMER ID: GUNNISON ROCK
TICKET ID:

DATE: 30-MAR-90
LAB ID: 173317

31

REQUESTOR: JACOBS, GUNN
SAMPLE MATRIX: SOIL
UNC REQUISITION: 4070

PROJECT NUMBER: SCP2000
DATE RECEIVED:
DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	METHOD OF ANALYSIS
Potassium 40	22.96	PCI/G	30-MAR-90	GAMMA
Radium 226	2.26	PCI/G	30-MAR-90	GAMMA
Thorium 230	2.7	PCI/G	22-MAR-90	C10 REV 02
Thorium 232	1.54	PCI/G	30-MAR-90	GAMMA

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3/15/91

COMMENTS:

UNC ANALYTICAL RESULTS

EXTRACTION
METHOD: 32

CUSTOMER ID: GUNNISON ROCK
TICKET ID:

DATE: 30-MAR-90
LAB ID: 173318

REQUESTOR: JACOBS, GUNN
SAMPLE MATRIX: SOIL
UNC REQUISITION: 4071

PROJECT NUMBER: SCP5G2000
DATE RECEIVED:
DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	METHOD OF ANALYSIS
Thorium 230	2.1	PCI/G	29-MAR-90	C10 REV 02

A Fraction > #4 Sieve.

1) Total digestion 2.7 pc/g
Extraction 2.1 "
=> precipitated / adsorbed on rocks

2) Ra-226 analysis (gamma spec.) 2.26 pc/g

B Fraction < #4 Sieve

3/15/91
3/15/91
KK

COMMENTS:

33

JACOBS ENGINEERING GROUP INC.

ALBUQUERQUE OPERATIONS

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

JEGA/UNC/0389-15

March 20, 1989

3/15/91
3/15/91
KK

Dr. Ron Chessmore
Manager, Chemistry Laboratory
UNC Geotech
P.O. Box 14000
2595 B 3/4 Road
Grand Junction, CO 81502-5504

Re: Analysis of Gunnison, CO
Archived Samples

Dear Ron:

Enclosed are two tables of archived samples from the Gunnison, CO UMTRA Project site. The archived samples were initially analyzed and archived by Bendix.

As soon as your schedule permits, please analyze all samples listed in Table 1 for the following metals: As, Ba, Cd, Cr, Pb, Hg, Se, Ag, Mo, Sb, Be, Co, Cu, Ni, Tl, Sn, U, V, Zn. We requested analyses for As, Mo, Se, V, Th-230, and U in the samples listed in Table 2 in our letter dated March 15, 1989. Therefore, please analyze the samples in Table 2 for all of the above metals in addition to the already requested As, Mo, Se, V, and U.

Please report all concentrations in ppm. Also, please report the detection limits and its standard deviation for each element. If any element is below the detection limit please report the numerical value whenever possible instead of less than the detection limit.

Receipt of this letter is your authorization to perform the requested analysis. If any of the archived samples are not available for analysis, or if your records conflict with the data in the table, please contact me immediately so that we may select alternate samples for analysis or resolve the discrepancy. Please return all results to me.

If you have any questions, please contact Bimal Mukhopadhyay of our staff or me at (FTS) 846-1250.

Very truly yours,
JACOBS ENGINEERING GROUP INC.

Robert Q. Murphy, Ph.D.
Health Physicist

ROM/BM/bj
Enclosures

cc: DManr, DOE
LLittle, GJPO
DDubois
EBanks
DGonzales

Table 1 Archived Gunnison Soil Samples^a

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3/15/91
KK 3/15/91

Map Key	Location N E		Sample Id.	Depth (feet)
SUBPILE				
1	2405	1250	A 011S01	1.0-2.9
	2405	1250	A 011S02	3.5-4.0
2	1950	1349	C 014S01	0.0-0.5
3	2766	1241	A 017S01	0.0-1.0
5	2465	1450	A 028S01	0.0-2.5
8	1902	1598	A 040S01	1.0-2.3
11	2932	1796	B 066S01	1.0-2.3
14	2848	1921	B 073S01	0.5-1.7
15	2729	1925	B 075S01	0.0-0.5
16	2489	1934	B 079S01	0.5-1.7
17	2404	2059	B 080S01	1.0-2.5
	2404	2059	B 080S02	2.5-3.0
18	2009	1953	D 084S01	0.0-0.5
19	2206	2203	D 090S01	0.5-1.0
20	3057	2211	D 091S01	0.0-1.0
21	2814	2209	D 094S01	0.2-1.3
22	2691	2205	D 095S01	1.0-2.0
WINDBLOWN (IMMEDIATELY NORTH OF PILE)				
23	3160	1620		0.0-0.5
	3160	1620		0.5-1.0
	3160	1620		1.5-2.0
26	3300	2200		0.0-0.5
	3300	2200		0.5-1.0
	3300	2200		1.0-1.5
WINDBLOWN (REMAINING AREA)				
33	3300	2318		0.0-0.5
34	3200	2480		0.0-0.5
36	2800	2400		0.0-0.5

^aAnalyze all samples for As, Ba, Cd, Cr, Pb, Hg, Se, Ag, Mo, Sb, Be, Co, Cu, Ni, Tl, Sn, U, V, and Zn.

Table 2 Archived Gunnison soil samples which require additional analyses^a

Map Key	Location		Depth (feet)
	N	E	
MILL YARD			
40 ✓	1193	2010	0.0-0.5
41 ✓	1030	2140	0.0-0.5
ORE STORAGE (SOUTHERN PORTION)			
44 ✓	1080	1100	0.0-0.5
	1080	1100	0.5-1.0
	1080	1100	1.0-1.5
45a ✓	1020	1740	0.0-0.5
	1020	1740	0.5-1.0
	1020	1740	1.0-1.5
	1020	1740	1.5-2.0
BACKGROUND			
50 ✓	BG-1		0.0-0.5
51 ✓	BG-3		0.0-0.5
52 ✓	BG-4		0.0-0.5

^aJEG letter dated March 15, 1989 requested analyses for As, Mo, Se, U, Th-230, and U on these samples. Also analyze these for Ba, Cd, Cr, Pb, Hg, Ag, Sb, Be, Co, Cu, Ni, Tl, Sn, and Zn.

JEY
KR
3/15/91
3/15/91

JACOBS ENGINEERING GROUP INC.

ALBUQUERQUE OPERATIONS

JEGA/UNC/0399-16

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

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March 23, 1989

Dr. Ron Chessmore
Manager, Chemistry Laboratory
UNC Geotech
P.O. Box 14000
2595 B 3/4 Road
Grand Junction, CO 81502-5504

Re: Analysis of Gunnison, CO
Archived Samples

Dear Ron:

As soon as your schedule permits, please analyze all samples brought in from the NAT site for the following metals: As, Ba, Cd, Cr, Pb, Hg, Se, Ag, Mo, Sb, Be, Co, Cu, Ni, Tl, Sn, U, V, Zn. Also, please analyze nitrate, cyanide, fluoride, and sulphide in the dionized water leachates of these samples, if possible, using your standard procedure.

Please report all concentrations in mg/l. Also, please report the detection limits and its standard deviation for each element. If an element is below the detection limit, please report the numerical value whenever possible instead of less than the detection limit.

Receipt of this letter is your authorization to perform the requested analysis.

If you have any questions, please contact Bimal Mukhopadhyay or me at (FTS) 846-1250.

Very truly yours,
JACOBS ENGINEERING GROUP INC.

Robert O. Murphy, Ph.D.
Health Physicist

ROM/BM/bj

cc: DMann, DOE
LLittle, GJPO
DDubois
EBanks
DGonzales

2624/3/15/91
KK 3/15/91

3/15/91
KK 3/15/91

CUMMINS 101 1020 1700 0-6				DATE: 20-JUN-89			
TICKET 101 1020 1700 0-6				PROJECT NUMBER: SC9901000			
SUBMITTER: JACOBS-COMMISSION				DATE RECEIVED:			
SAMPLE MATRIX: SOIL				DATE COLLECTED:			
CWC REQUISITION: 2209							
CWC ANALYTICAL RESULTS							
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS	
Aluminum	3	mg/g	27-MAY-89	156009	AS-6 R03		
Arsenic	300	mg/g	10-MAY-89	156009	A-2 R02		
Barium	213	mg/g	30-MAY-89	156009	B-2 R02		
Beryllium	-5	mg/g	12-JUN-89	156009	B-2 R02		
Cadmium	2	mg/g	27-MAY-89	156009	AS-6 R03		
Cobalt	-10	mg/g	12-JUN-89	156009	A-1 R02		
Chromium	-30	mg/g	12-JUN-89	156009	B-2 R02		
Copper	100	mg/g	10-JUN-89	156009	A-1 R02		
Mercury	.4	mg/g	25-MAY-89	156009	AS-3 R00		
Nickel	16	mg/g	27-MAY-89	156009	AS-6 R03		
Lead	37	mg/g	12-JUN-89	156009	A-1 R02		
Antimony	17	mg/g	27-MAY-89	156009	AS-6 R03		
Selenium	3	mg/g	08-MAY-89	156009	A-2 R02		
Zinc	215.7	mg/g	14-JUN-89	156009	A-2 R02		
Thorium 230	5	pc/g	08-MAY-89	156009	C-10 R02		
Thallium	407	mg/g	27-MAY-89	156009	AS-6 R03		
Vanadium	10	mg/g	27-MAY-89	156009	AS-6 R03		
Vanadium	10	mg/g	12-JUN-89	156009	B-2 R02		
Zinc	167	mg/g	10-JUN-89	156009	A-1 R02		

Pa-226 227 0-6"

James L. Doherty
S.C. COORDINATOR

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KK 3/15/91
3/15/91

WMC ANALYTICAL RESULTS

DATE: 20-JUN-89

PROJECT NUMBER: SC7001000
DATE RECEIVED:
DATE COLLECTED:

CUSTOMER ID: 1020 1700 "12-18"
TICKET ID: WMA 600
REQUESTOR: JACOBS-COMMISSION
SAMPLE MATRIX: SOIL
WMC REQUESTION: 1209

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	5	PPM	27-MAY-89	156001	AS-6 R03	
Artenio	270	PPM	10-MAY-89	156001	A-2 R02	
Berlio	603	PPM	30-MAY-89	156001	B-2 R02	
Berillium	-5	PPM	13-JUN-89	156001	B-2 R02	
Cadmium	2	PPM	27-MAY-89	156001	AS-6 R03	
Cobalt	12	PPM	12-JUN-89	156001	A-1 R02	
Chromium	-90	PPM	13-JUN-89	156001	B-2 R02	
Copper	172	PPM	10-JUN-89	156001	A-1 R02	
Mercury	-2	PPM	25-MAY-89	156001	AS-3 R00	
Molybdenum	19	PPM	27-MAY-89	156001	AS-6 R03	
Nickel	23	PPM	13-JUN-89	156001	A-1 R02	
Lead	46	PPM	27-MAY-89	156001	AS-6 R03	
Antimony	12	PPM	27-MAY-89	156001	AS-6 R03	
Selenium	2	PPM	08-MAY-89	156001	A-2 R02	
Tin	-3	PPM	14-JUN-89	156001	A-2 R02	
Thorium 230	160.4	PCT/0	06-MAY-89	156001	C-10 R02	
Thallium	5	PPM	27-MAY-89	156001	AS-6 R03	
Uranium	930	PPM	27-MAY-89	156001	AS-6 R03	
Vanadium	60	PPM	13-JUN-89	156001	B-2 R02	
Zinc	255	PPM	10-JUN-89	156001	A-1 R02	

Ra-226 12-18" 94pct

Shirley P. Dulant
S.C. COORDINATOR

40

3/15/91
3/13/91

CUSTOMER ID: 1000 1100 112"
TICKET ID: RMA 101 112"
REQUESTOR: JACQUES-JONSSON
SAMPLE MATRIX: SOIL
WPC ACQUISITION: 1100

DATE: 10-JUN-89
PROJECT NUMBER: 80001000
DATE RECEIVED:
DATE COLLECTED:

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WPC ANALYTICAL RESULTS

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYSED	LAD ID	METHOD OF ANALYSIS	COMMENTS
Silver	16	ppm	27-MAY-89	150007	AS-6 R03	
Alumina	1100	ppm	10-MAY-89	150007	AS-6 R03	
Boronic	5	ppm	10-MAY-89	150007	AS-6 R03	
Beryllium	2	ppm	13-JUN-89	150007	AS-6 R03	
Cadmium	45	ppm	27-MAY-89	150007	AS-6 R03	
Cobalt	50	ppm	12-JUN-89	150007	AS-6 R03	
Chromium	29	ppm	13-JUN-89	150007	AS-6 R03	
Copper	2	ppm	10-JUN-89	150007	AS-6 R03	
Mercury	5	ppm	13-JUN-89	150007	AS-6 R03	
Molybdenum	26	ppm	27-MAY-89	150007	AS-6 R03	
Nickel	2	ppm	27-MAY-89	150007	AS-6 R03	
Antimony	2	ppm	08-MAY-89	150007	AS-6 R03	
Selenium	5	ppm	14-JUN-89	150007	AS-6 R03	
Tin	100.7	ppm	08-MAY-89	150007	AS-6 R03	
Thorium 230	5	ppm	27-MAY-89	150007	AS-6 R03	
Thallium	254	ppm	27-MAY-89	150007	AS-6 R03	
Vanadium	116	ppm	13-JUN-89	150007	AS-6 R03	
Zinc	130	ppm	10-JUN-89	150007	AS-6 R03	

Ra-226 6-12" 210 pCi/g
12-18" 97 pCi/g
18"-24" 75 pCi/g

Donald P. Dault
S.C. COORDINATOR

H
L

CUSTOMER ID: 1000 1100
 TICKET ID: 000 101 2-6
 REQUESTOR: JACOBS-DEMIDON
 SAMPLE MATRIX: SOIL
 SPEC REQUESTION: 2189

QMC ANALYTICAL RESULTS

DATE: 20-JUN-89

PROJECT NUMBER: SC9962000
 DATE RECEIVED:
 DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	-	00/0	27-MAY-89	156000	AS-6 003	
Arsonic	0	00/0	10-MAY-89	156000	A-2 002	
Berium	0100	00/0	10-MAY-89	156000	B-2 002	
Beryllium	-5	00/0	13-JUN-89	156000	B-2 002	
Cadmium	-2	00/0	27-MAY-89	156000	AS-6 003	
Cobalt	35	00/0	12-JUN-89	156000	A-1 002	
Chromium	-50	00/0	13-JUN-89	156000	B-2 002	
Copper	19	00/0	10-JUN-89	156000	A-1 002	
Mercury	-2	00/0	27-MAY-89	156000	AS-6 003	
Molybdenum	5	00/0	27-MAY-89	156000	A-1 002	
Nickel	20	00/0	27-MAY-89	156000	AS-6 003	
Lead	20	00/0	27-MAY-89	156000	AS-6 003	
Antimony	-2	00/0	27-MAY-89	156000	A-2 002	
Selenium	-2	00/0	08-MAY-89	156000	A-2 002	
Vin	55.0	PC1/0	08-MAY-89	156000	C-10 002	
Thorium 230	5	00/0	27-MAY-89	156000	AS-6 003	
Thallium	111	00/0	27-MAY-89	156000	AS-6 003	
Strontium	44	00/0	13-JUN-89	156000	B-2 002	
Vanadium	115	00/0	10-JUN-89	156000	A-1 002	
Bioc						

Q-m 0-6
 756149

KK 3/15/91
 3/15/91

41

Quall P. Dink
 Q.C. COORDINATOR

3/15/91
3/15/91

1/

CUSTOMER ID: 1000 1100 " 12 17"

VEHICLE ID: MCA 076

REQUESTOR: JACOBS-COMMISSION

SAMPLE MATRIX: SOIL

WMC REGISTRATION: 2209

DATE: 20-JUN-09

PROJECT NUMBER: SC7901060

DATE RECEIVED:

DATE COLLECTED:

WMC ANALYTICAL RESULTS

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	5	ug/g	27-MAY-09	156000	AS-6 M03	
Arsenic	12	ug/g	30-MAY-09	156000	A-2 M02	
Barium	803	ug/g	30-MAY-09	156000	B-3 M02	
Beryllium	-5	ug/g	13-JUN-09	156000	B-3 M02	
Cadmium	2	ug/g	27-MAY-09	156000	AS-6 M03	
Cobalt	43	ug/g	13-JUN-09	156000	A-1 M02	
Chromium	-30	ug/g	13-JUN-09	156000	B-3 M02	
Copper	26	ug/g	10-JUN-09	156000	A-1 M02	
Mercury	-3	ug/g	25-MAY-09	156000	AS-6 M03	
Molybdenum	3	ug/g	27-MAY-09	156000	A-1 M02	
Nickel	31	ug/g	13-JUN-09	156000	AS-6 M03	
Lead	29	ug/g	27-MAY-09	156000	AS-6 M03	
Antimony	3	ug/g	27-MAY-09	156000	A-2 M02	
Selenium	-3	ug/g	08-MAY-09	156000	A-2 M02	
Tin	69.5	ug/g	08-MAY-09	156000	C-10 M02	
Thallium	5	ug/g	27-MAY-09	156000	AS-6 M03	
Vanadium	179	ug/g	27-MAY-09	156000	AS-6 M03	
Zinc	99	ug/g	13-JUN-09	156000	B-3 M02	
Bismuth	130	ug/g	10-JUN-09	156000	A-1 M02	

Pa-226 12"-18" 97

Quayle & Dunlop
S.C. COORDINATOR

3/15/91
3/15/91

45a

WMC ANALYTICAL RESULTS					DATE: 20-JUN-89		PROJECT NUMBER: SC7003000	
					DATE RECEIVED:		DATE COLLECTED:	
					DATE ANALYZED		LAB ID	
					RESULTS		METHOD OF ANALYSIS	
					UNITS		COMMENTS	
CUSTOMER ID: 1020 1700" 15-24"					-		1500-1	
VICKER ID: WMA 400 15-24"					190 mg/g		AS-6 R03	
REQUESTOR: JACOBO-DEWISSON					670 mg/g		A-2 R02	
SAMPLE MATRIX: SOIL					-5 mg/g		B-2 R02	
WMC REQUISITION: 2109					17 mg/g		AS-6 R03	
					12 mg/g		A-1 R02	
					-10 mg/g		B-2 R02	
					116 mg/g		A-1 R02	
					-12 mg/g		AS-6 R03	
					10 mg/g		A-1 R02	
					31 mg/g		AS-6 R03	
					37 mg/g		A-2 R02	
					7 mg/g		C-10 R02	
					-3 mg/g		AS-6 R03	
					85.9 PC1/g		A-2 R02	
					3 mg/g		C-10 R02	
					300 mg/g		AS-6 R03	
					65 mg/g		B-2 R02	
					277 mg/g		A-1 R02	

Ra-226 6.3 pic/y

Harold R. Dulek
S.C. COORDINATOR

11/13

WMC ANALYTICAL RESULTS

CUSTOMER ID: A 01001
TICKET ID:

DATE: 19-JUN-89

REQUESTOR: JACOB - COMMISSION
SAMPLE MATR: SOIL
WMC REGISTRATION: 2289

PROJECT NUMBER: OCT902000
DATE RECEIVED:
DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	5	PPM	27-MAY-89	156050	AS-6 003	
Artenic	35	PPM	10-MAY-89	156050	A-2 002	
Boron	757	PPM	10-MAY-89	156050	B-2 002	
Barium	-5	PPM	13-JUN-89	156050	B-2 002	
Cadmium	2	PPM	27-MAY-89	156050	AS-6 003	
Cobalt	11	PPM	12-JUN-89	156050	A-1 002	
Chromium	-30	PPM	13-JUN-89	156050	B-2 002	
Copper	30	PPM	10-JUN-89	156050	A-1 002	
Mercury	-2	PPM	27-MAY-89	156050	AS-3 000	
Molybdenum	20	PPM	27-MAY-89	156050	AS-6 003	
Nickel	17	PPM	12-JUN-89	156050	A-1 002	
Lead	39	PPM	27-MAY-89	156050	AS-6 003	
Antimony	1	PPM	27-MAY-89	156050	AS-6 003	
Selenium	-3	PPM	10-JUN-89	156050	A-2 002	
Tin	-3	PPM	10-JUN-89	156050	A-2 002	
Thallium	37	PPM	27-MAY-89	156050	AS-6 003	
Vanadium	55	PPM	13-JUN-89	156050	B-2 002	
Zinc	90	PPM	10-JUN-89	156050	A-1 002	

M1 1-2.9

3/15/91
3/15/91

Donald E. Daulton
P.C. COMBUSTION

3/15/91
3/15/91

#1
3.5-4.0

GMC ANALYTICAL RESULTS			
CUSTOMER ID: A 01802	DATE: 10-JUN-89	PROJECT NUMBER: 827802000	
TICKET ID:		DATE RECEIVED:	
ANALYST: JACQUES-GONNARD		DATE COLLECTED:	
SAMPLE MATRIX: SOIL			
GMC REGISTRATION: 2209			
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED
Aluminum	10	mg/g	27-MAY-89
Antimony	10	mg/g	10-MAY-89
Barium	165	mg/g	10-MAY-89
Beryllium	5	mg/g	13-JUN-89
Cadmium	2	mg/g	27-MAY-89
Cobalt	-10	mg/g	12-JUN-89
Chromium	-50	mg/g	13-JUN-89
Copper	20	mg/g	10-JUN-89
Mercury	2	mg/g	25-MAY-89
Molybdenum	9	mg/g	27-MAY-89
Nickel	12	mg/g	12-JUN-89
Lead	25	mg/g	27-MAY-89
Antimony	2	mg/g	27-MAY-89
Selenium	-2	mg/g	08-MAY-89
Vanadium	-3	mg/g	14-JUN-89
Zinc	5	mg/g	27-MAY-89
Thallium	15	mg/g	27-MAY-89
Strontium	47	mg/g	13-JUN-89
Vanadium	56	mg/g	10-JUN-89
Silicon			
Aluminum			
Antimony			
Barium			
Beryllium			
Cadmium			
Cobalt			
Chromium			
Copper			
Mercury			
Molybdenum			
Nickel			
Lead			
Antimony			
Selenium			
Vanadium			
Zinc			

James L. Dwyer
G.C. COORDINATOR

KK 3/15/91
3/15/91

#2
0-0.5

SNC ANALYTICAL RESULTS				DATE: 19-JUN-89	
CUSTOMER ID: C 010201				PROJECT NUMBER: SCT902000	
TICKET ID:				DATE RECEIVED:	
REQUESTOR: JACQUES-GUMISON				DATE COLLECTED:	
SAMPLE MATRIX: SOIL					
SNC REQUESTION: 2269					
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAS ID	METHOD OF ANALYSIS COMMENTS
Aluminum	3	ug/g	27-MAY-89	156000	AS-6 R03
Arsenic	370	ug/g	10-MAY-89	156000	A-2 R02
Barium	761	ug/g	10-MAY-89	156000	B-2 R02
Beryllium	-5	ug/g	13-JUN-89	156000	B-2 R02
Cadmium	21	ug/g	27-MAY-89	156000	AS-6 R03
Cobalt	21	ug/g	27-MAY-89	156000	A-1 R02
Chromium	-50	ug/g	13-JUN-89	156000	B-2 R02
Copper	83	ug/g	13-JUN-89	156000	A-1 R02
Mercury	2	ug/g	25-MAY-89	156000	AS-3 R00
Molybdenum	89	ug/g	27-MAY-89	156000	AS-6 R03
Nickel	160	ug/g	27-MAY-89	156000	A-1 R02
Lead	20	ug/g	27-MAY-89	156000	AS-6 R03
Antimony	2	ug/g	08-MAY-89	156000	A-2 R02
Selenium	8	ug/g	14-JUN-89	156000	A-2 R22
Zinc	11	ug/g	27-MAY-89	156000	AS-6 R03
Thallium	76	ug/g	27-MAY-89	156000	AS-6 R03
Vanadium	63	ug/g	13-JUN-89	156000	B-2 R02
Silica	106	ug/g	10-JUN-89	156000	A-1 R02

Gerald R. Daulton
S.C. COORDINATOR

WMC ANALYTICAL RESULTS				DATE: 19-JUN-89	
CUSTOMER ID: A 019001				PROJECT NUMBER: SCT002000	
TICKET ID:				DATE RECEIVED:	
REQUESTOR: JACOBS-COMMISION				DATE COLLECTED:	
SAMPLE MATRIX: SOIL					
WMC REQUESTION: 1209					
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS COMMENTS
Aluminum	9	PPM	27-MAY-89	156001	AS-6 R03
Arsenic	106	PPM	10-MAY-89	156001	A-2 R02
Barium	700	PPM	30-MAY-89	156001	B-2 R02
Beryllium	-5	PPM	13-JUN-89	156001	AS-6 R03
Cadmium	15	PPM	27-MAY-89	156001	A-2 R02
Cobalt	-50	PPM	13-JUN-89	156001	B-2 R02
Chromium	37	PPM	10-JUN-89	156001	A-1 R02
Copper	2	PPM	25-MAY-89	156001	AS-6 R03
Mercury	69	PPM	27-MAY-89	156001	A-1 R02
Molybdenum	21	PPM	13-JUN-89	156001	AS-6 R03
Nickel	163	PPM	27-MAY-89	156001	AS-6 R03
Lead	20	PPM	08-MAY-89	156001	A-2 R02
Antimony	-5	PPM	14-JUN-89	156001	AS-6 R03
Selenium	16	PPM	27-MAY-89	156001	A-2 R02
Tin	30	PPM	27-MAY-89	156001	AS-6 R03
Thallium	73	PPM	13-JUN-89	156001	B-2 R02
Vanadium	152	PPM	10-JUN-89	156001	A-1 R02
Zinc					

#3
0-1.0

47
3/15/91
3/15/91

D. Paul L. Daulton
O.C. COORDINATOR

17

CUSTOMER ID: A 01001
 TICKET ID:
 REQUESTOR: JACOBS-DEMISON
 SAMPLE MATRIX: SOIL
 UMC REQUISITION: 2209

DATE: 19-JUN-09

PROJECT NUMBER: SCP002000
 DATE RECEIVED:
 DATE COLLECTED:

UMC ANALYTICAL RESULTS

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Aluminum	5	mg/g	27-MAY-09	150002	AS-6 M03	
Antimony	02	mg/g	10-MAY-09	150002	A-2 M02	
Barium	800	mg/g	30-MAY-09	150002	B-2 M02	
Beryllium	-5	mg/g	13-JUN-09	150002	B-2 M02	
Cadmium	3	mg/g	27-MAY-09	150002	AS-6 M03	
Cobalt	-10	mg/g	12-JUN-09	150002	A-1 M02	
Chromium	-50	mg/g	13-JUN-09	150002	B-2 M02	
Copper	35	mg/g	10-JUN-09	150002	A-1 M02	
Mercury	-2	mg/g	25-MAY-09	150002	AS-3 M00	
Molybdenum	33	mg/g	27-MAY-09	150002	AS-6 M03	
Nickel	22	mg/g	12-JUN-09	150002	A-1 M02	
Lead	32	mg/g	27-MAY-09	150002	AS-6 M03	
Antimony	4	mg/g	27-MAY-09	150002	AS-6 M03	
Selenium	-2	mg/g	08-MAY-09	150002	A-2 M02	
Tin	-5	mg/g	14-JUN-09	150002	AS-6 M03	
Thallium	5	mg/g	27-MAY-09	150002	AS-6 M03	
Uranium	10	mg/g	13-JUN-09	150002	B-2 M02	
Vanadium	50	mg/g	13-JUN-09	150002	B-2 M02	
Zinc	71	mg/g	10-JUN-09	150002	A-1 M02	

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Handwritten Signature
 E.C. COORDINATOR

14

SNC ANALYTICAL RESULTS			
CUSTOMER ID: A 00001	DATE: 19-JUN-99	PROJECT NUMBER: 80000000	
TICKET ID:		DATE RECEIVED:	
REQUESTOR: JACOBS-Commission		DATE COLLECTED:	
SAMPLE MATRIS: SOIL			
SNC REQUESTION: 2109			
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED
Silver	3	ug/g	27-MAY-99
Arsonic	300	ug/g	10-MAY-99
Berium	700	ug/g	10-MAY-99
Beryllium	-3	ug/g	13-JUN-99
Cadmium	-3	ug/g	27-MAY-99
Cobalt	-10	ug/g	12-JUN-99
Chromium	-50	ug/g	13-JUN-99
Copper	30	ug/g	10-JUN-99
Mercury	-2	ug/g	25-MAY-99
Molybdenum	20	ug/g	12-JUN-99
Nickel	10	ug/g	27-MAY-99
Lead	3	ug/g	27-MAY-99
Antimony	-3	ug/g	08-MAY-99
Selenium	-3	ug/g	14-JUN-99
Tin	5	ug/g	27-MAY-99
Thallium	10	ug/g	27-MAY-99
Vanadium	50	ug/g	13-JUN-99
Zinc	63	ug/g	10-JUN-99
LAB ID	METHOD OF ANALYSIS	COMMENTS	
156003	AS-6 R03		
156003	A-2 R02		
156003	B-2 R02		
156003	B-2 R02		
156003	AS-6 R03		
156003	A-1 R02		
156003	B-2 R02		
156003	A-1 R02		
156003	AS-3 R00		
156003	AS-6 R03		
156003	A-1 R02		
156003	AS-6 R03		
156003	AS-6 R03		
156003	A-2 R02		
156003	AS-6 R03		
156003	AS-6 R03		
156003	B-2 R02		
156003	A-1 R02		

#8
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49
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Quell F. Dumbert
S.C. COORDINATOR

H

UNC ANALYTICAL RESULTS				DATE: 19-JUN-89			
CUSTOMER ID: 0 06001				PROJECT NUMBER: SC9001000			
TICEST ID:				DATE RECEIVED:			
DEPOSITION: JACOBS-COMMISSION				DATE COLLECTED:			
SAMPLE MATRIX: SOIL							
UNC ACQUISITION: 2209							
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS	
Silver	-	00/0	27-MAY-89	150000	AS-6 R03		
Artenic	102	00/0	10-MAY-89	150000	A-2 R02		
Berlon	1300	00/0	10-MAY-89	150000	B-2 R02		
Beryllium	-5	00/0	13-JUN-89	150000	B-2 R02		
Cadmium	2	00/0	27-MAY-89	150000	AS-6 R03		
Cobalt	-10	00/0	12-JUN-89	150000	A-1 R02		
Chromium	-50	00/0	13-JUN-89	150000	B-2 R02		
Copper	60	00/0	10-JUN-89	150000	A-1 R02		
Mercury	-2	00/0	24-MAY-89	150000	AS-3 R00		
Molybdenum	40	00/0	27-MAY-89	150000	AS-6 R03		
Nickel	13	00/0	13-JUN-89	150000	A-1 R02		
Lead	100	00/0	27-MAY-89	150000	AS-6 R03		
Antimony	20	00/0	27-MAY-89	150000	AS-6 R03		
Selenium	2	00/0	08-MAY-89	150000	A-2 R02		
Tin	-5	00/0	10-JUN-89	150000	AS-6 R03		
Tellurium	11	00/0	27-MAY-89	150000	AS-6 R03		
Vanadium	31	00/0	27-MAY-89	150000	AS-6 R03		
Zinc	81	00/0	13-JUN-89	150000	B-2 R02		
	70	00/0	10-JUN-89	150000	A-1 R02		

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3/15/91

Donald L. Dunlap
S.C. COORDINATOR

M

CUSTOMER ID: 0 075001			DATE: 19-JUN-89		
TICKET ID:			PROJECT NUMBER: 007001009		
REQUESTOR: JACOBS-COMMISSION			DATE RECEIVED:		
SAMPLE MATRIX: SOIL			DATE COLLECTED:		
WMC REQUISITION: 2289					
WMC ANALYTICAL RESULTS					
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS
Silver	-	5	27-MAY-89	156065	AS-6 R03
Artenale	35	00/0	10-MAY-89	156065	A-2 R02
Berlen	920	00/0	10-MAY-89	156065	0-2 R02
Boyllon	-5	00/0	13-JUN-89	156065	0-2 R02
Cadmon	2	00/0	27-MAY-89	156065	AS-6 R03
Cobalt	-10	00/0	12-JUN-89	156065	A-1 R02
Chroon	-50	00/0	13-JUN-89	156065	0-2 R02
Copper	42	00/0	10-JUN-89	156065	A-1 R02
Mercury	-2	00/0	25-MAY-89	156065	AS-3 R00
Molybdenum	14	00/0	27-MAY-89	156065	AS-6 R03
Nickel	14	00/0	12-JUN-89	156065	A-1 R02
Lead	29	00/0	27-MAY-89	156065	AS-6 R03
Antimony	3	00/0	27-MAY-89	156065	AS-6 R03
Selenium	-2	00/0	08-MAY-89	156065	A-2 R02
Tin	-5	00/0	14-JUN-89	156065	AS-6 R03
Vanadium	21	00/0	27-MAY-89	156065	AS-6 R03
Zinc	37	00/0	13-JUN-89	156065	0-2 R02
	40	00/0	10-JUN-89	156065	A-1 R02

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Gerald F. Dumbart
S.C. COORDINATOR

H

CWC ANALYTICAL RESULTS					DATE: 10-JUN-09		PROJECT NUMBER: SC9002000	
CUSTOMER ID: 0 075001					VICKET ID:		DATE RECEIVED:	
REQUESTOR: JCOOBS-COMMISSION					SAMPLE MATRIX: SOIL		DATE COLLECTED:	
CWC REQUESTION: 2109								
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS		
Aluminum	-	mg/g	27-MAY-09	150006	A5-6 R03			
Arsenic	49	mg/g	10-MAY-09	150006	A-2 R02			
Boron	550	mg/g	30-MAY-09	150006	B-2 R02			
Barium	-5	mg/g	13-JUN-09	150006	B-2 R02			
Beryllium	2	mg/g	27-MAY-09	150006	A5-6 R03			
Cadmium	-10	mg/g	12-JUN-09	150006	A-1 R02			
Cobalt	-30	mg/g	13-JUN-09	150006	B-2 R02			
Chromium	42	mg/g	16-JUN-09	150006	A-1 R02			
Copper	-2	mg/g	25-MAY-09	150006	A5-3 R00			
Mercury	17	mg/g	27-MAY-09	150006	A5-4 R03			
Nickel	21	mg/g	12-JUN-09	150006	A-1 R02			
Polychlorinated biphenyls	26	mg/g	27-MAY-09	150006	A5-6 R03			
Lead	6	mg/g	08-MAY-09	150006	A5-6 R03			
Antimony	3	mg/g	10-JUN-09	150006	A-2 R02			
Selenium	-5	mg/g	27-MAY-09	150006	A5-6 R03			
Vinyl Chloride	5	mg/g	27-MAY-09	150006	A5-6 R03			
Thallium	17	mg/g	13-JUN-09	150006	B-2 R02			
Vanadium	35	mg/g	10-JUN-09	150006	A-1 R02			
Zinc	49	mg/g	10-JUN-09	150006	A-1 R02			

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Donald E. Dwyer
S.C. COORDINATOR

H

CUSTOMER ID: 0 07001				DATE: 19-JUN-09			
VICTORY ID:				PROJECT NUMBER: SC9001000			
REQUESTED: JACOBS-GRIMMOND				DATE RECEIVED:			
SAMPLE MATRIX: SOIL				DATE COLLECTED:			
QMC REQUESTION: 2209							
QMC ANALYTICAL RESULTS							
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS	
Silver	5	PPM	27-MAY-09	156067	A-6 R03		
Arsenic	30	PPM	10-MAY-09	156067	A-2 R02		
Barium	700	PPM	30-MAY-09	156067	B-2 R02		
Beryllium	5	PPM	13-JUN-09	156067	B-2 R02		
Cadmium	2	PPM	27-MAY-09	156067	A-6 R03		
Cobalt	10	PPM	13-JUN-09	156067	A-1 R02		
Chromium	50	PPM	13-JUN-09	156067	B-2 R02		
Copper	30	PPM	10-JUN-09	156067	A-1 R02		
Mercury	2	PPM	25-MAY-09	156067	A-3 R00		
Molybdenum	10	PPM	27-MAY-09	156067	A-6 R03		
Nickel	10	PPM	12-JUN-09	156067	A-1 R02		
Lead	20	PPM	27-MAY-09	156067	A-6 R03		
Antimony	3	PPM	27-MAY-09	156067	A-6 R03		
Selenium	5	PPM	08-MAY-09	156067	A-2 R02		
Tin	5	PPM	16-JUN-09	156067	A-2 R02		
Thallium	32	PPM	27-MAY-09	156067	A-6 R03		
Uranium	40	PPM	13-JUN-09	156067	A-6 R03		
Vanadium	52	PPM	10-JUN-09	156067	A-1 R02		
Zinc	52	PPM	10-JUN-09	156067	A-1 R02		

#16
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53
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3/15/91

Shirley L. Durbert
S.C. COORDINATOR

H

CUSTOMER ID: 8 000001
TICKET ID:
REQUESTOR: JACOBSON-EDMONSON
SAMPLE MATRIX: SOIL
WMC REQUISITION: 2289

WMC ANALYTICAL RESULTS

DATE: 19-JUN-89

PROJECT NUMBER: SC9903000
DATE RECEIVED:
DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Aluminum	5	mg/g	27-MAY-89	156000	AS-6 R03	
Arsenic	55	mg/g	10-MAY-89	156000	A-2 R02	
Boron	866	mg/g	30-MAY-89	156000	B-2 R02	
Beryllium	-5	mg/g	13-JUN-89	156000	B-2 R02	
Cadmium	2	mg/g	27-MAY-89	156000	AS-6 R03	
Cobalt	11	mg/g	12-JUN-89	156000	A-1 R02	
Chromium	-90	mg/g	13-JUN-89	156000	B-2 R02	
Copper	24	mg/g	10-JUN-89	156000	A-1 R02	
Mercury	-2	mg/g	25-MAY-89	156000	AS-3 R00	
Nickel	13	mg/g	27-MAY-89	156000	AS-6 R03	
Phosphorus	37	mg/g	12-JUN-89	156000	A-1 R02	
Lead	4	mg/g	27-MAY-89	156000	AS-6 R03	
Antimony	-2	mg/g	08-MAY-89	156000	A-2 R02	
Selenium	-3	mg/g	14-JUN-89	156000	A-2 R02	
Tin	5	mg/g	27-MAY-89	156000	AS-6 R03	
Thallium	21	mg/g	27-MAY-89	156000	AS-6 R03	
Vanadium	47	mg/g	13-JUN-89	156000	B-2 R02	
Zinc	50	mg/g	10-JUN-89	156000	A-1 R02	

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Shirley L. Daulton
S.C. COORDINATOR

H

UNC ANALYTICAL RESULTS			DATE: 19-JUN-85		
CUSTOMER ID: 0 00002			PROJECT NUMBER: SCF002000		
TICKET ID:			DATE RECEIVED:		
DEPARTMENT: JACOBS-COMMIS			DATE COLLECTED:		
SAMPLE MATRIX: SOIL					
UNC REQUESTION: 2209					
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	RETURN OF ANALYSIS COMMENTS
Antimony	-	ppm	27-MAY-89	150069	AS-6 NO3
Arsenic	30	ppm	10-MAY-89	150069	A-2 NO2
Barium	300	ppm	10-MAY-89	150069	B-2 NO2
Beryllium	-	ppm	13-JUN-89	150069	B-2 NO2
Cadmium	-	ppm	27-MAY-89	150069	AS-6 NO3
Cobalt	-	ppm	12-JUN-89	150069	A-1 NO2
Chromium	-10	ppm	13-JUN-89	150069	B-2 NO2
Copper	-50	ppm	13-JUN-89	150069	A-1 NO2
Mercury	-2	ppm	25-MAY-89	150069	AS-3 NO0
Molybdenum	-	ppm	27-MAY-89	150069	AS-6 NO3
Nickel	13	ppm	12-JUN-89	150069	A-1 NO2
Lead	25	ppm	27-MAY-89	150069	AS-6 NO3
Antimony	-	ppm	27-MAY-89	150069	AS-6 NO3
Selenium	-	ppm	00-MAY-89	150069	A-2 NO2
Tin	-	ppm	14-JUN-89	150069	A-2 NO2
Thallium	5	ppm	27-MAY-89	150069	AS-6 NO3
Vanadium	12	ppm	27-MAY-89	150069	AS-6 NO3
Zinc	50	ppm	13-JUN-89	150069	B-2 NO2
	55	ppm	10-JUN-89	150069	A-1 NO2

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Shirley J. D. Lant
O.C. COORDINATOR

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3/15/91

#18
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QMC ANALYTICAL RESULTS				DATE: 19-JUN-89		PROJECT NUMBER: SCP002000	
TICRET ID:				DATE RECEIVED:		DATE COLLECTED:	
REQUESTOR: JACOBS-OWENSON							
SAMPLE MATRIX: FOIL							
QMC REGISTRATION: 2769							
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	REFERENCE OF ANALYSIS	COMMENTS	
Silver	-	94/g	27-MAY-89	156070	AS-6 R03		
Artenic		94/g	10-MAY-89	156070	A-2 R02		
Berium	823	94/g	10-MAY-89	156070	0-2 R02		
Beryllium	-5	94/g	13-JUN-89	156070	0-2 R02		
Cadmium	2	94/g	27-MAY-89	156070	AS-6 R03		
Cobalt	10	94/g	12-JUN-89	156070	A-1 R02		
Chromium	-50	94/g	13-JUN-89	156070	0-2 R02		
Copper	32	94/g	10-JUN-89	156070	A-1 R02		
Mercury	-2	94/g	25-MAY-89	156070	AS-3 R00		
Molybdenum	13	94/g	27-MAY-89	156070	AS-6 R03		
Nickel	10	94/g	12-JUN-89	156070	A-1 R02		
Lead	27	94/g	27-MAY-89	156070	AS-6 R03		
Antimony	3	94/g	27-MAY-89	156070	AS-6 R03		
Polonium	-2	94/g	08-MAY-89	156070	A-2 R02		
Tin	-5	94/g	14-JUN-89	156070	A-2 R02		
Tellurium	5	94/g	27-MAY-89	156070	AS-6 R03		
Vanadium	40	94/g	23-MAY-89	156070	AS-6 R03		
Zinc	57	94/g	13-JUN-89	156070	0-2 R02		
	74	94/g	10-JUN-89	156070	A-1 R02		

James L. D. ...
S.C. COORDINATOR

H

CUMC ANALYTICAL RESULTS				DATE: 19-JUN-89			
CUSTOMER ID: 0 090801				PROJECT NUMBER: SC7902000			
TICKET ID:				DATE RECEIVED:			
REQUESTOR: JACQUES-GUINISSON				DATE COLLECTED:			
SAMPLE MATRIX: SOIL							
CUMC REQUISITION: 2209							
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS	
Silver	-	94	27-MAY-89	156071	AS-6 R03		
Arsenic		94	10-MAY-89	156071	A-2 R02		
Barium	274	94	10-MAY-89	156071	B-2 R02		
Beryllium	-5	94	11-JUN-89	156071	B-2 R02		
Cadmium	2	94	27-MAY-89	156071	AS-6 R03		
Cobalt	14	94	12-JUN-89	156071	A-1 R02		
Chromium	-2	94	13-JUN-89	156071	B-2 R02		
Copper	34	94	10-JUN-89	156071	A-1 R02		
Mercury	-2	94	25-MAY-89	156071	AS-6 R03		
Molybdenum	7	94	27-MAY-89	156071	AS-6 R03		
Nickel	24	94	12-JUN-89	156071	A-1 R02		
Lead	23	94	27-MAY-89	156071	AS-6 R03		
Antimony	2	94	08-MAY-89	156071	A-2 R02		
Selenium	-5	94	14-JUN-89	156071	A-2 R02		
Tin	5	94	27-MAY-89	156071	AS-6 R03		
Thallium	51	94	27-MAY-89	156071	AS-6 R03		
Vanadium	36	94	13-JUN-89	156071	B-2 R02		
Zinc	118	94	10-JUN-89	156071	A-1 R02		

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Quell & D. L. St.
S.C. COORDINATOR

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#20
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UNC ANALYTICAL RESULTS				DATE: 19-JUN-89	
CUSTOMER ID: D 001801				PROJECT NUMBER: SCT001000	
TICKET ID:				DATE RECEIVED:	
REQUESTOR: JACOBSON-EDMONSON				DATE COLLECTED:	
SAMPLE MATRIX: SOIL					
UNC REQUESTION: 2209					
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS
Silver	5	PPM	27-MAY-89	156872	AS-6 R03
Arsonic	50	PPM	10-MAY-89	156872	A-2 R02
Barium	300	PPM	10-MAY-89	156872	0-2 R02
Beryllium	-5	PPM	13-JUN-89	156872	0-2 R02
Cadmium	2	PPM	27-MAY-89	156872	AS-6 R03
Cobalt	15	PPM	12-JUN-89	156872	A-1 R02
Chromium	-50	PPM	13-JUN-89	156872	0-2 R02
Copper	32	PPM	10-JUN-89	156872	A-1 R02
Mercury	-2	PPM	25-MAY-89	156872	AS-3 R00
Molybdenum	22	PPM	27-MAY-89	156872	AS-6 R03
Nickel	20	PPM	12-JUN-89	156872	A-1 R02
Lead	57	PPM	27-MAY-89	156872	AS-6 R03
Antimony	10	PPM	27-MAY-89	156872	AS-6 R03
Arsenic	-2	PPM	08-MAY-89	156872	A-2 R02
Tin	-5	PPM	14-JUN-89	156872	AS-6 R03
Thallium	6	PPM	27-MAY-89	156872	AS-6 R03
Tranilum	49	PPM	27-MAY-89	156872	AS-6 R03
Vanadium	77	PPM	13-JUN-89	156872	0-2 R02
Zinc	101	PPM	10-JUN-89	156872	A-1 R02

Shirley L. D. Hunt
O.C. COORDINATOR

H

WMC ANALYTICAL RESULTS						DATE: 19-JUN-89		PROJECT NUMBER: SC9062000	
						DATE RECEIVED:		DATE COLLECTED:	
CUSTOMER ID: D 004501									
TICKET ID:									
REQUESTOR: JACOBS-COMMISSION									
SAMPLE MATRIX: SOIL									
WMC REQUISITION: 2209									
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS			
Silver	-	00/G	27-MAY-89	156073	AS-6 R03				
Arsenic	300	00/G	10-MAY-89	156073	A-2 R02				
Boron	802	00/G	10-MAY-89	156073	0-2 R02				
Beryllium	-5	00/G	13-JUN-89	156073	0-2 R02				
Cadmium	12	00/G	27-MAY-89	156073	AS-6 R03				
Cobalt	12	00/G	13-JUN-89	156073	A-1 R02				
Chromium	-30	00/G	13-JUN-89	156073	0-2 R02				
Copper	30	00/G	10-JUN-89	156073	A-1 R02				
Mercury	-2	00/G	25-MAY-89	156073	AS-3 R00				
Molybdenum	30	00/G	27-MAY-89	156073	AS-6 R03				
Nickel	25	00/G	12-JUN-89	156073	A-1 R02				
Lead	44	00/G	27-MAY-89	156073	AS-6 R03				
Antimony	3	00/G	27-MAY-89	156073	AS-6 R03				
Selenium	-3	00/G	08-MAY-89	156073	A-2 R02				
Tin	-5	00/G	10-JUN-89	156073	A-2 R02				
Thallium	7	00/G	27-MAY-89	156073	AS-6 R03				
Uranium	50	00/G	27-MAY-89	156073	AS-6 R03				
Vanadium	72	00/G	13-JUN-89	156073	0-2 R02				
Zinc	86	00/G	10-JUN-89	156073	A-1 R02				

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J. Hall
S.C. COORDINATOR

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WMC ANALYTICAL RESULTS					
CUSTOMER NO: D 095001		DATE: 19-JUN-89			
TICKET ID:		PROJECT NUMBER: SC9002000			
REQUESTOR: JACOBS-GEORGE		DATE RECEIVED:			
SAMPLE MATRIX: SOIL		DATE COLLECTED:			
WMC REQUISITION: 2289					
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYSED	LAB ID	METHOD OF ANALYSIS
Silver	-	5	PPM	27-MAY-89	156074
Arsenic		30	PPM	10-MAY-89	156074
Barium		663	PPM	30-MAY-89	156074
Borates		-5	PPM	13-JUN-89	156074
Cadmium		-2	PPM	27-MAY-89	156074
Cobalt		-10	PPM	12-JUN-89	156074
Chromium		-30	PPM	13-JUN-89	156074
Copper		76	PPM	10-JUN-89	156074
Mercury		-2	PPM	25-MAY-89	156074
Molybdenum		9	PPM	27-MAY-89	156074
Nickel		15	PPM	12-JUN-89	156074
Lead		26	PPM	27-MAY-89	156074
Antimony		2	PPM	27-MAY-89	156074
Selenium		-2	PPM	08-MAY-89	156074
Tin		-5	PPM	14-JUN-89	156074
Thallium		11	PPM	27-MAY-89	156074
Vanadium		67	PPM	13-JUN-89	156074
Zinc		64	PPM	10-JUN-89	156074

Paul J. DeLoat
O.C. COORDINATOR

UNC ANALYTICAL RESULTS

CUSTOMER ID: 3100 1020 7-6
 TICKET ID: NMA 170
 REQUESTOR: JACOBS-DEWISON
 SAMPLE MATERIAL: SOIL
 UNC REQUESTION: 2209

DATE: 19-JUN-09
 PROJECT NUMBER: SC9801000
 DATE RECEIVED:
 DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	130	ug/g	27-MAY-09	156075	AS-6 R03	
Arsenic	620	ug/g	10-MAY-09	156075	A-2 R02	
Berilium	-5	ug/g	30-MAY-09	156075	B-2 R02	
Borillon	2	ug/g	13-JUN-09	156075	AS-6 R03	
Cadmium	17	ug/g	27-MAY-09	156075	A-1 R02	
Cobalt	-50	ug/g	12-JUN-09	156075	B-2 R02	
Chromium	32	ug/g	13-JUN-09	156075	A-1 R02	
Copper	70	ug/g	10-MAY-09	156075	AS-3 R00	
Mercury	18	ug/g	25-MAY-09	156075	AS-6 R03	
Polychlorinated	126	ug/g	12-JUN-09	156075	A-1 R02	
Nickel	35	ug/g	27-MAY-09	156075	AS-6 R03	
Lead	2	ug/g	27-MAY-09	156075	AS-6 R03	
Antimony	-5	ug/g	08-MAY-09	156075	A-2 R02	
Selenium	9	ug/g	10-JUN-09	156075	AS-6 R03	
Tin	63	ug/g	27-MAY-09	156075	AS-6 R03	
Thallium	92	ug/g	13-JUN-09	156075	B-2 R02	
Vanadium						
Zinc						

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David L. D. [Signature]
 Q.C. COORDINATOR

H

CUSTOMER ID: 3100 1620 " 6.1 L
 TICKET ID: MAX 195
 REQUESTER: JACOBS-CONMISSION
 SAMPLE MATRIX: SOIL
 WNC REQUESTION: 2289

WNC ANALYTICAL RESULTS

DATE: 19-JUN-89
 PROJECT NUMBER: SC9001000
 DATE RECEIVED:
 DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	5	PPM	27-MAY-89	156076	AS-6 R03	
Arsonic	118	PPM	10-MAY-89	156076	A-2 R02	
Berium	560	PPM	30-MAY-89	156076	B-2 R02	
Borillon	-5	PPM	13-JUN-89	156076	B-2 R02	
Cadmium	2	PPM	27-MAY-89	156076	AS-6 R03	
Cobalt	14	PPM	12-JUN-89	156076	A-1 R02	
Chromium	-50	PPM	13-JUN-89	156076	B-2 R02	
Copper	30	PPM	10-JUN-89	156076	A-1 R02	
Mercury	0.2	PPM	25-MAY-89	156076	AS-3 R00	
Molybdenum	74	PPM	27-MAY-89	156076	AS-6 R03	
Nickel	10	PPM	12-JUN-89	156076	A-1 R02	
Lead	150	PPM	27-MAY-89	156076	AS-6 R03	
Antimony	30	PPM	27-MAY-89	156076	AS-6 R03	
Selenium	-2	PPM	08-MAY-89	156076	A-2 R02	
Tin	-5	PPM	14-JUN-89	156076	A-2 R02	
Thallium	12	PPM	27-MAY-89	156076	AS-6 R03	
Vanadium	45	PPM	27-MAY-89	156076	AS-6 R03	
Zinc	73	PPM	13-JUN-89	156076	B-2 R02	

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Quail & Dunlop
 Q.C. COORDINATOR

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WMC ANALYTICAL RESULTS

CUSTOMER ID: 3160 1620
TICKET ID: WMA 196
REQUESTOR: JACOBS-COMWISON
SAMPLE MATRIX: SOIL
WMC REGISTRATION: 2286
DATE: 19-JUN-89
PROJECT NUMBER: SCT981000
DATE RECEIVED:
DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	-	ppb	27-MAY-89	156877	AS-6 R03	
Arsenic	132	ppb	18-MAY-89	156877	A-2 R02	
Berium	572	ppb	30-MAY-89	156877	B-2 R02	
Beryllium	-5	ppb	13-JUN-89	156877	B-2 R02	
Cadmium	2	ppb	27-MAY-89	156877	AS-6 R03	
Cobalt	14	ppb	12-JUN-89	156877	A-1 R02	
Chromium	-50	ppb	13-JUN-89	156877	B-2 R02	
Copper	23	ppb	10-JUN-89	156877	A-1 R02	
Mercury	.2	ppb	25-MAY-89	156877	AS-2 R00	
Molybdenum	82	ppb	27-MAY-89	156877	AS-6 R03	
Nickel	17	ppb	12-JUN-89	156877	A-1 R02	
Lead	100	ppb	27-MAY-89	156877	AS-6 R03	
Antimony	30	ppb	27-MAY-89	156877	AS-6 R03	
Selenium	2	ppb	08-MAY-89	156877	A-2 R02	
Tin	-5	ppb	14-JUN-89	156877	A-2 R02	
Thallium	13	ppb	27-MAY-89	156877	AS-6 R03	
Uranium	39	ppb	27-MAY-89	156877	AS-6 R03	
Vanadium	78	ppb	13-JUN-89	156877	B-2 R02	
Zinc	72	ppb	10-JUN-89	156877	A-1 R02	

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Donald L. Daulton
O.C. COORDINATOR

CUSTOMER ID: 3500 2200
 TICKET ID: WMA 093
 REQUESTOR: JACOBS-SONNISON
 SAMPLE MATRIX: SOIL
 WMC REQUISITION: 2209

WMC ANALYTICAL RESULTS

(C) 3/15/91

DATE: 19-JUN-89

PROJECT NUMBER: SC9002000
 DATE RECEIVED:
 DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Aluminum	-	ppm	27-MAY-89	156070	AS-6 R03	
Arsenic	12	ppm	10-MAY-89	156070	A-2 R02	
Boron	706	ppm	10-MAY-89	156070	B-2 R02	
Beryllium	-5	ppm	19-JUN-89	156070	B-2 R02	
Cadmium	2	ppm	27-MAY-89	156070	AS-6 R03	
Cobalt	-10	ppm	12-JUN-89	156070	A-1 R02	
Chromium	-50	ppm	12-JUN-89	156070	B-2 R02	
Copper	17	ppm	10-JUN-89	156070	A-1 R02	
Mercury	-2	ppm	25-MAY-89	156070	AS-3 R00	
Molybdenum	9	ppm	27-MAY-89	156070	AS-6 R03	
Nickel	14	ppm	12-JUN-89	156070	A-1 R02	
Lead	24	ppm	27-MAY-89	156070	AS-6 R03	
Antimony	2	ppm	27-MAY-89	156070	AS-6 R03	
Selenium	-2	ppm	10-MAY-89	156070	A-2 R02	
Tin	-5	ppm	10-JUN-89	156070	AS-6 R03	
Thallium	5	ppm	27-MAY-89	156070	AS-6 R03	
Vanadium	67	ppm	12-JUN-89	156070	B-2 R02	
Zinc	71	ppm	10-JUN-89	156070	A-1 R02	

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J. L. D. D. D.
 S.C. CONSULTING

WMC ANALYTICAL RESULTS

CUSTOMER ID: 1300 2200
 TICKET ID: WMA 176
 REQUESTOR: JACOBO-GONZALEZ
 SAMPLE MATRIX: SOIL
 WMC REGISTRATION: 2200

DATE: 19-JUN-99

PROJECT NUMBER: SCT9902000
 DATE RECEIVED:
 DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	-	ug/g	27-MAY-99	156079	AS-6 R03	
Arsonic	20	ug/g	10-MAY-99	156079	A-2 R02	
Barium	841	ug/g	10-MAY-99	156079	B-2 R02	
Beryllium	-5	ug/g	13-JUN-99	156079	B-2 R02	
Cadmium	2	ug/g	27-MAY-99	156079	AS-6 R03	
Cobalt	12	ug/g	12-JUN-99	156079	A-1 R02	
Chromium	-50	ug/g	13-JUN-99	156079	B-2 R02	
Copper	21	ug/g	10-JUN-99	156079	A-1 R02	
Mercury	-2	ug/g	25-MAY-99	156079	AS-3 R00	
Molybdenum	10	ug/g	27-MAY-99	156079	AS-6 R03	
Nickel	16	ug/g	27-JUN-99	156079	A-1 R02	
Lead	36	ug/g	27-MAY-99	156079	AS-6 R03	
Antimony	4	ug/g	27-MAY-99	156079	AS-6 R03	
Selenium	-2	ug/g	08-MAY-99	156079	A-2 R02	
Tin	-5	ug/g	16-JUN-99	156079	AS-6 R03	
Thallium	5	ug/g	27-MAY-99	156079	AS-6 R03	
Vanadium	17	ug/g	27-MAY-99	156079	AS-6 R03	
Zinc	50	ug/g	13-JUN-99	156079	B-2 R02	
	78	ug/g	10-JUN-99	156079	A-1 R02	

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Quall & Quall
 S.C. COORDINATOR

CUSTOMER ID: 3300 2200
 TICKET ID: 3300 2200
 REQUESTOR: JACOBS-GEORGE
 SAMPLE MATRIX: SOIL
 WMC REGISTRATION: 2200

DATE: 19-JUN-09
 PROJECT NUMBER: SCF002000
 DATE RECEIVED:
 DATE COLLECTED:

WMC ANALYTICAL RESULTS

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	REVISION OF ANALYSIS	COMMENTS
Silver	9	ppm	27-MAY-09	156000	AS-6 R03	
Arsenic	24	ppm	10-MAY-09	156000	A-2 R02	
Barium	839	ppm	10-MAY-09	156000	B-2 R02	
Beryllium	-5	ppm	13-JUN-09	156000	B-2 R02	
Cadmium	2	ppm	27-MAY-09	156000	AS-6 R03	
Cobalt	20	ppm	12-JUN-09	156000	A-1 R02	
Chromium	-50	ppm	13-JUN-09	156000	B-2 R02	
Copper	23	ppm	10-JUN-09	156000	A-1 R02	
Manganese	-2	ppm	25-MAY-09	156000	AS-6 R03	
Molybdenum	14	ppm	27-MAY-09	156000	A-1 R02	
Nickel	21	ppm	12-JUN-09	156000	AS-6 R03	
Lead	6	ppm	27-MAY-09	156000	A-2 R02	
Antimony	-2	ppm	08-MAY-09	156000	AS-6 R03	
Selenium	-5	ppm	14-JUN-09	156000	A-2 R02	
Tin	3	ppm	27-MAY-09	156000	AS-6 R03	
Thallium	23	ppm	13-JUN-09	156000	B-2 R02	
Vanadium	70	ppm	10-JUN-09	156000	A-1 R02	
Zinc	61	ppm	10-JUN-09	156000	A-1 R02	

Mercury	ND	ppm	27-MAY-09	156000	AS-6 R03	
Uranium	ND	ppm	27-MAY-09	156000	AS-6 R03	
Vanadium	ND	ppm	10-JUN-09	156000	A-1 R02	

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J. J. J. J. J.
 S.C. COORDINATOR

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CWC ANALYTICAL RESULTS				DATE: 19-JUN-89			
CUSTOMER ID: 3300 2310 TICKET ID: WMA 071				PROJECT NUMBER: SC9503000			
REQUESTOR: JACOB-GUNWISON				DATE RECEIVED:			
SAMPLE MATRIX: SOIL				DATE COLLECTED:			
CWC REQUESTION: 2289							
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS	
Silver	5	ug/g	27-MAY-89	156001	AS-6 R03		
Arsonic	30	ug/g	10-MAY-89	156001	A-2 R02		
Barium	041	ug/g	10-MAY-89	156001	B-2 R02		
Beryllium	-3	ug/g	11-JUN-89	156001	B-2 R02		
Cadmium	2	ug/g	27-MAY-89	156001	AS-6 R03		
Cobalt	-10	ug/g	12-JUN-89	156001	A-1 R02		
Chromium	-50	ug/g	13-JUN-89	156001	B-2 R02		
Copper	20	ug/g	10-JUN-89	156001	A-1 R02		
Mercury	-2	ug/g	25-MAY-89	156001	AS-3 R00		
Molybdenum	16	ug/g	27-MAY-89	156001	AS-6 R03		
Nickel	10	ug/g	11-JUN-89	156001	A-1 R02		
Lead	50	ug/g	27-MAY-89	156001	AS-6 R03		
Antimony	7	ug/g	27-MAY-89	156001	AS-6 R03		
Selenium	-2	ug/g	00-MAY-89	156001	A-2 R02		
Tin	-5	ug/g	10-JUN-89	156001	A-2 R02		
Thallium	5	ug/g	27-MAY-89	156001	AS-6 R03		
Bromine	45	ug/g	27-MAY-89	156001	AS-6 R03		
Vanadium	46	ug/g	11-JUN-89	156001	B-2 R02		
Zinc	30	ug/g	10-JUN-89	156001	A-1 R02		

Jacob G. Gunwison
S.C. COORDINATOR

H

CUSTOMER ID: 1200 2400
 TICKET ID: NMA 151
 REQUESTOR: JACOBS-OWENSON
 SAMPLE MATRIX: SOIL
 WPC REQUISITION: 1209

WPC ANALYTICAL RESULTS

DATE: 19-JUN-09

PROJECT NUMBER: SC9003000
 DATE RECEIVED:
 DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Aluminum	5	PPM	27-MAY-09	156002	AS-6 R03	
Arsenic	11	PPM	10-MAY-09	156002	A-2 R02	
Boron	174	PPM	30-MAY-09	156002	B-2 R02	
Beryllium	-5	PPM	13-JUN-09	156002	B-2 R02	
Cadmium	2	PPM	27-MAY-09	156002	AS-6 R03	
Cobalt	-10	PPM	12-JUN-09	156002	A-1 R02	
Chromium	-30	PPM	13-JUN-09	156002	B-2 R02	
Copper	21	PPM	10-JUN-09	156002	A-1 R02	
Mercury	-2	PPM	25-MAY-09	156002	AS-3 R00	
Molybdenum	5	PPM	27-MAY-09	156002	AS-6 R03	
Nickel	12	PPM	12-JUN-09	156002	A-1 R02	
Lead	34	PPM	27-MAY-09	156002	AS-6 R03	
Antimony	3	PPM	27-MAY-09	156002	AS-6 R03	
Selenium	-2	PPM	08-MAY-09	156002	A-2 R02	
Tin	-5	PPM	14-JUN-09	156002	A-2 R02	
Thallium	3	PPM	27-MAY-09	156002	AS-6 R03	
Vanadium	64	PPM	27-MAY-09	156002	AS-6 R03	
Zinc	95	PPM	13-JUN-09	156002	B-2 R02	
			10-JUN-09	156002	A-1 R02	

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Russell L. Dunlap
 V.C. COORDINATOR

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UNC ANALYTICAL RESULTS			
CUSTOMER ID: 2000 2400 VICKEY ID: NWA 104		DATE: 19-JUN-09	
REQUESTOR: JACOBS-EMERSON SAMPLE MATRIX: SOIL		PROJECT NUMBER: SC9901000	
UNC REQUISITION: 2209		DATE RECEIVED: DATE COLLECTED:	
ANALYSIS REQUESTED	RESULTS	DATE ANALYZED	LAB ID
Silver	5	17-MAY-09	156003
Arsonic	15	10-MAY-09	156003
Berlin	700	10-MAY-09	156003
Beryllium	5	13-JUN-09	156003
Cadmium	2	27-MAY-09	156003
Cobalt	-10	27-JUN-09	156003
Chromium	-10	13-JUN-09	156003
Copper	10	10-JUN-09	156003
Mercury	-2	25-MAY-09	156003
Nickel	5	27-MAY-09	156003
Polychlorinated Biphenyls	11	12-JUN-09	156003
Lead	30	27-MAY-09	156003
Antimony	3	27-MAY-09	156003
Selenium	-2	08-MAY-09	156003
Vinyl	-5	10-JUN-09	156003
Thallium	5	27-MAY-09	156003
Uranium	0	27-MAY-09	156003
Vanadium	60	13-JUN-09	156003
Zinc	64	10-JUN-09	156003

David L. Quilley
O.C. COORDINATOR

1007
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CUSTOMER ID: 1193 2010
TICKET ID: MAX 906
REQUESTOR: JACOBS-EMMISON
SAMPLE MATRIX: SOIL
WPC REQUISITION: 2289
WPC ANALYTICAL RESULTS
DATE: 19-JUN-89
PROJECT NUMBER: SCP001000
DATE RECEIVED:
DATE COLLECTED:

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	5	PPM	27-MAY-89	156004	AS-6 R03	
Arsonic	102	PPM	10-MAY-89	156004	A-2 R02	
Berium	760	PPM	10-MAY-89	156004	B-2 R02	
Beryllium	-5	PPM	13-JUN-89	156004	B-2 R02	
Cadmium	2	PPM	27-MAY-89	156004	AS-6 R03	
Cobalt	20	PPM	12-JUN-89	156004	A-1 R02	
Chromium	-50	PPM	13-JUN-89	156004	B-2 R02	
Copper	31	PPM	10-JUN-89	156004	A-1 R02	
Mercury	2	PPM	25-MAY-89	156004	AS-3 R00	
Molybdenum	20	PPM	27-MAY-89	156004	AS-6 R03	
Nickel	34	PPM	12-JUN-89	156004	A-1 R02	
Lead	59	PPM	27-MAY-89	156004	AS-6 R03	
Antimony	11	PPM	27-MAY-89	156004	AS-6 R03	
Selenium	3	PPM	00-MAY-89	156004	A-2 R02	
Tin	-5	PPM	16-JUN-89	156004	A-2 R02	
Thallium	5	PPM	27-MAY-89	156004	AS-6 R03	
Vanadium	426	PPM	27-MAY-89	156004	AS-6 R03	
Zinc	50	PPM	13-JUN-89	156004	B-2 R02	
	210	PPM	10-JUN-89	156004	A-1 R02	

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Donald E. Durlant
O.C. COORDINATOR

11

CUSTOMER ID: 1030 2140
 TICKET ID: MHA 335
 REQUESTOR: JACOBS-EDMUNSON
 SAMPLE MATRIX: SOIL
 UMC REGISTRATION: 2189

DATE: 19-JUN-09

PROJECT NUMBER: SC9001060
 DATE RECEIVED:
 DATE COLLECTED:

UMC ANALYTICAL RESULTS

ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS
Silver	-	ppb	27-MAY-09	156005	AS-6 R03	
Arsenic	10	ppb	10-MAY-09	156005	A-2 R02	
Barium	903	ppb	10-MAY-09	156005	B-2 R02	
Beryllium	-5	ppb	13-JUN-09	156005	B-2 R02	
Cadmium	2	ppb	27-MAY-09	156005	AS-6 R03	
Cobalt	11	ppb	12-JUN-09	156005	A-1 R02	
Chromium	-50	ppb	13-JUN-09	156005	B-2 R02	
Copper	26	ppb	10-JUN-09	156005	A-1 R02	
Mercury	-2	ppb	25-MAY-09	156005	AS-3 R00	
Molybdenum	5	ppb	12-JUN-09	156005	AS-6 R03	
Nickel	13	ppb	12-JUN-09	156005	A-1 R02	
Lead	133	ppb	27-MAY-09	156005	AS-6 R03	
Antimony	5	ppb	27-MAY-09	156005	AS-6 R03	
Selenium	-2	ppb	08-MAY-09	156005	A-2 R02	
Vanadium	-5	ppb	14-JUN-09	156005	AS-6 R03	
Zinc	5	ppb	27-MAY-09	156005	AS-6 R03	
Thallium	30	ppb	27-MAY-09	156005	AS-6 R03	
Uranium	50	ppb	13-JUN-09	156005	B-2 R02	
Vanadium	128	ppb	10-JUN-09	156005	A-1 R02	

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 0 - 0.5

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Donald L. Dunbar
 S.C. COORDINATOR

WMC ANALYTICAL RESULTS				DATE: 19-JUN-89	
CUSTOMER ID: 00-1 TICKET ID: WMA 437				PROJECT NUMBER: SC9802000	
REQUESTED: JACOB-COMMISSION				DATE RECEIVED:	
SAMPLE MATRIX: SOIL				DATE COLLECTED:	
WMC REGISTRATION: 2289					
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS, COMMENTS
Aluminum	-	ppm	27-MAY-89	156093	AS-6 R03
Antimony	4	ppm	10-MAY-89	156093	A-2 R02
Arsenic	691	ppm	10-MAY-89	156093	B-2 R02
Bismuth	-	ppm	13-JUN-89	156093	B-2 R02
Beryllium	-2	ppm	27-MAY-89	156093	AS-6 R03
Cadmium	-10	ppm	13-JUN-89	156093	A-1 R02
Cobalt	-50	ppm	13-JUN-89	156093	B-2 R02
Chromium	21	ppm	10-JUN-89	156093	A-1 R02
Copper	-2	ppm	25-MAY-89	156093	AS-3 R06
Mercury	-	ppm	13-JUN-89	156093	AS-6 R03
Molybdenum	10	ppm	13-JUN-89	156093	A-1 R02
Nickel	35	ppm	27-MAY-89	156093	AS-6 R03
Lead	-	ppm	27-MAY-89	156093	AS-6 R03
Antimony	-2	ppm	08-MAY-89	156093	A-2 R02
Selenium	-5	ppm	10-JUN-89	156093	A-2 R02
Tin	-	ppm	27-MAY-89	156093	AS-6 R03
Thallium	3	ppm	27-MAY-89	156093	AS-6 R03
Vanadium	61	ppm	13-JUN-89	156093	B-2 R02
Zinc	200	ppm	10-JUN-89	156093	A-1 R02

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Paul J. Dunlop
S.C. COORDINATOR

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3/15/91

B6-3

UWC ANALYTICAL RESULTS				DATE: 19-JUN-89			
CUSTOMER ID: 00-3 TICKET ID: NMA 009				PROJECT NUMBER: SC0002000 DATE RECEIVED: DATE COLLECTED:			
REQUESTOR: JACOBS-DEMISSION SAMPLE MATRIX: SOIL UWC REQUISITION: 3269							
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYZED	LAB ID	METHOD OF ANALYSIS	COMMENTS	
Silver	-	5	27-MAY-89	156094	AS-6 R03		
Arsonic	-	5	10-MAY-89	156094	A-2 R02		
Berlin	709	00/g	10-MAY-89	156094	B-2 R02		
Beryllium	-5	00/g	13-JUN-89	156094	B-2 R02		
Cadmium	-2	00/g	27-MAY-89	156094	AS-6 R03		
Cobalt	-10	00/g	12-JUN-89	156094	A-1 R02		
Copper	-30	00/g	13-JUN-89	156094	B-2 R02		
Chromium	20	00/g	10-JUN-89	156094	A-1 R02		
Mercury	-2	00/g	27-MAY-89	156094	AS-3 R00		
Niobium	-5	00/g	12-JUN-89	156094	AS-6 R03		
Nickel	20	00/g	27-MAY-89	156094	A-1 R02		
Lead	-2	00/g	27-MAY-89	156094	AS-6 R03		
Antimony	-2	00/g	08-MAY-89	156094	A-2 R02		
Barium	-5	00/g	16-JUN-89	156094	A-2 R02		
Tin	3	00/g	27-MAY-89	156094	AS-6 R03		
Thallium	-	00/g	27-MAY-89	156094	AS-6 R03		
Bromine	93	00/g	13-JUN-89	156094	B-2 R02		
Vanadium	143	00/g	10-JUN-89	156094	A-1 R02		
Zinc							

David L. Dwyer
S.C. COORDINATOR

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WMC ANALYTICAL RESU.YS				DATE: 19-JUN-89			
CUSTOMER ID: 00-4 TICKET ID: NMA 007				PROJECT NUMBER: SCP003000			
REQUESTOR: JACOBSON-GUNTERSON				DATE RECEIVED:			
SAMPLE MATRIX: SOIL				DATE COLLECTED:			
WMC REQUISITION: 2209							
ANALYSIS REQUESTED	RESULTS	UNITS	DATE ANALYSED	LAB ID	METHOD OF ANALYSIS	COMMENTS	
Silver	-	99/9	27-MAY-89	154095	A9-6 R03		
Artenic	3	99/9	10-MAY-89	154095	A-2 R02		
Barion	735	99/9	10-MAY-89	154095	B-2 R02		
Beryllion	-5	99/9	13-JUN-89	154095	B-2 R02		
Cadation	-2	99/9	27-MAY-89	154095	A9-6 R03		
Cobalt	-10	99/9	12-JUN-89	154095	A-1 R02		
Chromium	-50	99/9	13-JUN-89	154095	B-2 R02		
Copper	40	99/9	10-JUN-89	154095	A-1 R02		
Mercury	-2	99/9	25-MAY-89	154095	A9-3 R00		
Molybdenum	-2	99/9	27-MAY-89	154095	A9-6 R03		
Nickel	20	99/9	12-JUN-89	154095	B-1 R02		
Lead	10	99/9	27-MAY-89	154095	A9-6 R03		
Antimony	-2	99/9	08-MAY-89	154095	A-2 R02		
Selenium	-5	99/9	14-JUN-89	154095	A-2 R02		
Tin	5	99/9	27-MAY-89	154095	A9-6 R03		
Thallium	3	99/9	27-MAY-89	154095	A9-6 R03		
Uranium	07	99/9	11-JUN-89	154095	B-2 R02		
Vanadium	100	99/9	10-JUN-89	154095	A-1 R02		
Zinc							

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S.C. COORDINATOR

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APPENDIX B

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DECHEM COMPUTER CODE PRINTOUTS

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DECHEM (TM) -- RADIOLOGICAL ASSESSMENTS CORPORATION
Neeses, SC 29107

isk-based assessment of exposure of people to sites of chemical
ontamination in soil after remedial measures.

Site: GUNNISON SUBPILE/AFTER REMEDIAL ACTION
Date and time of analysis: Tue Jan 29 10:31:36 1991
Data file: A:GUNSUB6.TST
Print file: A:GUNSUB6.PRN

=====

SECTION I: PROBLEM DATA

Exposure pathways	In effect?
Food ingestion	Yes
Drinking water	Yes
Inhalation	Yes

Modifying (use) factors for exposure calculations	Percent
Percent of time that an individual spends on the decommissioned site:	100
Percentages of food types consumed by an individual that were produced on site:	
Produce	40
Leafy vegetables	40
Milk	75
Meat	75
Percent of an individual's drinking water that contains chemicals from the decommissioned site:	100

Food types	Included?
Produce	Yes
Leafy vegetables	Yes
Milk	Yes
Meat	Yes

Miscellaneous parameters that are not chemical-specific

Atmospheric soil loading by resuspension (g/m ³):	7E-005
Produce consumption by exposed individual (kg/year):	176
Leafy vegetable consumption by exposed individual (kg/year):	18
Milk consumption by exposed individual (L/year):	112
Meat consumption by exposed individual (kg/year):	94
Drinking water consumption by exposed individual (L/year):	511
Annual breathing rate of exposed individual (m ³ /year):	8030
Soil consumption by a cow (g/day):	500

Site parameters applicable to all chemicals

Site length (m):	425
Site width (m):	425
Net water input rate (cm/year)	

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(= rainfall + irrigation - evapotransp. - surf. runoff):

27.9

Layer (m)	Soil bulk density (g/cm ³)	Effective soil porosity (fraction)	Soil moisture content (fraction)
from -> To:			
0 -> 0.15	1.9	0.3	0.15
0.15 -> 0.3	1.9	0.3	0.15
0.3 -> 0.75	1.9	0.3	0.15
0.75 -> 1.35	1.9	0.3	0.15
1.35 -> 1.65	1.9	0.3	0.15

Parameters for the groundwater aquifer (drinking water pathway)

Distance of water source from decommissioned area (m):	0
Effective porosity of aquifer (cm ³ /cm ³):	0.1
Longitudinal dispersivity in aquifer (m):	5
Transverse dispersivity in aquifer (m):	1
Seepage velocity in aquifer (m/s):	1.38E-005
Thickness of aquifer (m):	40
Density of soil in aquifer (g/cm ³):	1.9

Pre-cleanup buildup of residual groundwater
contamination (years):

0

Chemical-specific profiles for U

Soil layers (m)	Initial post- cleanup concen- tration (ppm)	Soil/water K _d coefficient (mL/g)	Solubility in water (g/mL)
0 -> 0.15	3	5	6E-006
0.15 -> 0.3	3	5	6E-006
0.3 -> 0.75	3	5	6E-006
0.75 -> 1.35	55	5	6E-006
1.35 -> 1.65	28	5	6E-006
Aquifer	0 mg/L	1	

Chemical-specific profiles for AS

Soil layers (m)	Initial post- cleanup concen- tration (ppm)	Soil/water K _d coefficient (mL/g)	Solubility in water (g/mL)
0 -> 0.15	5	10	2E-007
0.15 -> 0.3	5	10	2E-007
0.3 -> 0.75	5	10	2E-007
0.75 -> 1.35	45	10	2E-007
1.35 -> 1.65	23	10	2E-007
Aquifer	0 mg/L	6	

Chemical-specific profiles for MO

Soil layers (m)	Initial post- cleanup concen- tration (ppm)	Soil/water K _d coefficient (mL/g)	Solubility in water (g/mL)
0 -> 0.15	5	100	1E-006
0.15 -> 0.3	5	100	1E-006
0.3 -> 0.75	5	100	1E-006
0.75 -> 1.35	15	100	1E-006

1.35 -> 1.65

8

100

1E-006

Aquifer

0 mg/L

40

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Chemical-specific parameters

	U	AS	MO
Intake limits for reference values (mg/year):			
Inhalation:	17	18.3	73
Ingestion:	49	73	73
n-octanol/water coefficient (organic chemicals only):	-----	-----	-----
Soil and groundwater loss-rate coefficient for physical, chemical and biological processes (1/year):	0	0	0
Bioconcentration factors referenced to dry soil:			
Pasture grass: (a)	0.0085	0.04	0.25
Crops: (b)	0.004	0.003	0.026
Milk (kg/L):	7.96E-005	3.74E-005	0.00585
Meat:	2.65E-005	0.00125	0.0234

(a) Dry weight. (b) Edible parts, wet weight.

(c) BCF calculated from n-octanol/water coefficient (K_{ow}).

SECTION II: PROBLEM RESULTS

Annual reference value for all chemicals over time

Time (years after cleanup)	Total: all chemicals	U	AS
0	0.346	0.0201	0.0272
7	0.865	0.561	0.0244
15	0.772	0.496	0.0171
50	0.405	0.213	0.00791
100	0.145	0.0233	0.00767
250	0.0396	0	0.00768
500	0.0132	0	0.00768

Annual reference value for all chemicals over time

Time (years after cleanup)	MO
0	0.299

7	0.28
15	0.259
50	0.184
100	0.114
250	0.0319
500	0.00557

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Annual reference value by pathway: All Chemicals

Time (years after cleanup)	Total: All Pathways	Vegetables	Milk	Meat	Drinking Water	Inhalation
0	0.346	0.167	0.0403	0.139	0	0.000292
7	0.865	0.141	0.0362	0.127	0.561	0.000173
15	0.772	0.124	0.0332	0.115	0.5	0.000108
50	0.405	0.082	0.0233	0.0783	0.222	2.57E-005
100	0.145	0.0501	0.0143	0.0479	0.0327	1.45E-005
250	0.0396	0.0129	0.00368	0.0124	0.0106	3.73E-006
500	0.0132	0.000996	0.000283	0.000951	0.011	2.87E-007

Annual reference value by pathway: U

Time (years after cleanup)	Total: All Pathways	Vegetables	Milk	Meat	Drinking Water	Inhalation
0	0.0201	0.0175	0.00195	0.000546	0	9.92E-005
7	0.561	0.00453	0.000505	0.000141	0.556	2.57E-005
15	0.496	0.00145	0.000162	4.54E-005	0.494	8.24E-006
50	0.213	1.13E-006	1.26E-007	3.51E-008	0.213	6.38E-009
100	0.0233	7.26E-011	8.11E-012	2.27E-012	0.0233	4.12E-013
250	0	0	0	0	0	0
500	0	0	0	0	0	0

Annual reference value by pathway: AS

Time (years after cleanup)	Total: All Pathways	Vegetables	Milk	Meat	Drinking Water	Inhalation
0	0.0272	0.0158	0.000388	0.0109	0	0.000154
7	0.0244	0.0114	0.000282	0.00788	0.00472	0.000112
15	0.0171	0.00679	0.000167	0.00467	0.00538	6.63E-005
50	0.00791	0.000216	5.31E-006	0.000149	0.00754	2.11E-005
100	0.00767	1.67E-006	4.1E-008	1.15E-006	0.00767	1.63E-008
250	0.00768	4.94E-011	1.21E-012	3.4E-011	0.00768	4.82E-013
500	0.00768	0	0	0	0.00768	0

Annual reference value by pathway: MO

Time (years after cleanup)	Total: All Pathways	Vegetables	Milk	Meat	Drinking Water	Inhalation
0	0.299	0.134	0.038	0.127	0	3.85E-005

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7	0.28	0.125	0.0355	0.119	0.00066	3.59E-005
15	0.259	0.115	0.0328	0.11	0.000766	3.33E-005
77	0.184	0.0818	0.0233	0.0781	0.00122	2.36E-005
100	0.114	0.0501	0.0143	0.0479	0.00177	1.45E-005
250	0.0319	0.0129	0.00368	0.0124	0.00294	3.73E-006
500	0.00557	0.000996	0.000283	0.000951	0.00334	2.87E-007

Chemical concentrations in and transfer rates among exposure media

Chemical: U

Time: 0 years since cleanup

Soil layer		Concentrations in Soil And Soil Water	
From ->	To (m):	Soil (ppm)	Water (mg/L)
0 ->	0.15	2.95	0.591
0.15 ->	0.3	2.95	0.591
0.3 ->	0.75	2.95	0.591
0.75 ->	1.35	54.5	6
1.35 ->	1.65	27.6	5.51

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.154

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 2.1E-007
Vapors 0
Milk (mg/L) 0.00114
Meat (mg/kg) 0.00038
Vegs. (mg/kg) 0.012
Pasture (mg/kg) 0.0255

Concentration in Groundwater at
Well (Receptor) (mg/L): 0

Chemical concentrations in and transfer rates among exposure media

Chemical: U

Time: 7 years since cleanup

Soil layer		Concentrations in Soil And Soil Water	
From ->	To (m):	Soil (ppm)	Water (mg/L)
0 ->	0.15	0.765	0.153
0.15 ->	0.3	1.8	0.36
0.3 ->	0.75	2.76	0.553
0.75 ->	1.35	45.2	6
1.35 ->	1.65	28.8	5.75

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.16

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 5.44E-008
Vapors 0
Milk (mg/L) 0.000295
Meat (mg/kg) 9.83E-005
Vegs. (mg/kg) 0.00311
Pasture (mg/kg) 0.0066

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0533

Chemical concentrations in and transfer rates among exposure media

Chemical: U

Time: 15 years since cleanup

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

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Concentrations in Soil And Soil Water		
Soil layer From -> To (m):	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.245	0.0491
0.15 -> 0.3	0.779	0.156
0.3 -> 0.75	2.09	0.418
0.75 -> 1.35	34.4	5.77
1.35 -> 1.65	29.3	5.85

Soil to Air:	
Diffusion	0
Evapotransp.	0
Soil to Groundwater:	
Leaching	0.162
Concentrations in Other Exposure Media	
Air Concentrations (mg/cm ³):	
Resusp. Part.	1.74E-008
Vapors	0
Milk (mg/L)	9.46E-005
Meat (mg/kg)	3.15E-005
Vegs. (mg/kg)	0.000997
Pasture (mg/kg)	0.00212

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0474

Chemical concentrations in and transfer rates among exposure media

Chemical: U
Time: 50 years since cleanup

Concentrations in Soil And Soil Water		
Soil layer From -> To (m):	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.00019	3.8E-005
0.15 -> 0.3	0.00202	0.000405
0.3 -> 0.75	0.265	0.053
0.75 -> 1.35	6.98	1.4
1.35 -> 1.65	12.1	2.41

Rates of Transfer from Soil To Other Media (mg/(cm ² y))	
Soil to Air:	
Diffusion	0
Evapotransp.	0
Soil to Groundwater:	
Leaching	0.0991
Concentrations in Other Exposure Media	
Air Concentrations (mg/cm ³):	
Resusp. Part.	1.35E-011
Vapors	0
Milk (mg/L)	7.33E-008
Meat (mg/kg)	2.44E-008
Vegs. (mg/kg)	7.72E-007
Pasture (mg/kg)	1.64E-006

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0204

Chemical concentrations in and transfer rates among exposure media

Chemical: U
Time: 100 years since cleanup

Concentrations in Soil And Soil Water		
Soil layer From -> To (m):	Soil (ppm)	Water (mg/L)
0 -> 0.15	1.23E-008	2.45E-009
0.15 -> 0.3	2.48E-007	4.96E-008
0.3 -> 0.75	0.0107	0.00213
0.75 -> 1.35	0.665	0.133
1.35 -> 1.65	1.29	0.258

Rates of Transfer from Soil To Other Media (mg/(cm ² y))	
Soil to Air:	
Diffusion	0
Evapotransp.	0
Soil to Groundwater:	
Leaching	0.0115
Concentrations in Other Exposure Media	
Air Concentrations (mg/cm ³):	
Resusp. Part.	8.72E-016
Vapors	0

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Milk (mg/L)	4.73E-012
Meat (mg/kg)	1.58E-012
Vegs. (mg/kg)	4.98E-011
Pasture (mg/kg)	1.06E-010

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.00223

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Chemical concentrations in and transfer rates among exposure media

Chemical: U

Time: 250 years since cleanup

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	0	0
0.15 -> 0.3	0	0
0.3 -> 0.75	8.58E-006	1.72E-006
0.75 -> 1.35	0.00279	0.000558
1.35 -> 1.65	0.00556	0.00111

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.00363

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 0
Vapors 0
Milk (mg/L) 0
Meat (mg/kg) 0
Vegs. (mg/kg) 0
Pasture (mg/kg) 0

Concentration in Groundwater at
Well (Receptor) (mg/L): 0

Chemical concentrations in and transfer rates among exposure media

Chemical: U

Time: 500 years since cleanup

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	0	0
0.15 -> 0.3	0	0
0.3 -> 0.75	7.22E-014	1.44E-014
0.75 -> 1.35	2.89E-009	5.78E-010
1.35 -> 1.65	5.65E-009	1.13E-009

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 4.02E-009

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 0
Vapors 0
Milk (mg/L) 0
Meat (mg/kg) 0
Vegs. (mg/kg) 0
Pasture (mg/kg) 0

Concentration in Groundwater at
Well (Receptor) (mg/L): 0

Chemical concentrations in and transfer rates among exposure media

Chemical: AS

Time: 0 years since cleanup

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

		Concentrations in Soil And Soil Water	
Soil layer			
From -> To (m):		Soil (ppm)	Water (mg/L)
> 0.15		4.98	0.2
0.15 -> 0.3		4.98	0.2
0.3 -> 0.75		4.98	0.2
0.75 -> 1.35		45	0.2
1.35 -> 1.65		23	0.2

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Soil to Air:
 Diffusion 0
 Evapotransp. 0
 Soil to Groundwater:
 Leaching 0.00559

 Concentrations in Other
 Exposure Media

 Air Concentrations (mg/cm³):
 Resusp. Part. 3.5E-007
 Vapors 0
 Milk (mg/L) 0.000337
 Meat (mg/kg) 0.0112
 Veggies. (mg/kg) 0.015
 Pasture (mg/kg) 0.2

Concentration in Groundwater at
 Well (Receptor) (mg/L): 0

Chemical concentrations in and transfer rates among exposure media

Chemical: AS
 Time: 7 years since cleanup

		Concentrations in Soil And Soil Water	
Soil layer			
From -> To (m):		Soil (ppm)	Water (mg/L)
-> 0.15		3.61	0.2
0.15 -> 0.3		4.98	0.2
0.3 -> 0.75		4.98	0.2
0.75 -> 1.35		45	0.2
1.35 -> 1.65		23	0.2

Rates of Transfer from Soil
 To Other Media (mg/(cm² y))

Soil to Air:
 Diffusion 0
 Evapotransp. 0
 Soil to Groundwater:
 Leaching 0.00559

 Concentrations in Other
 Exposure Media

 Air Concentrations (mg/cm³):
 Resusp. Part. 2.54E-007
 Vapors 0
 Milk (mg/L) 0.000245
 Meat (mg/kg) 0.00815
 Veggies. (mg/kg) 0.0109
 Pasture (mg/kg) 0.145

Concentration in Groundwater at
 Well (Receptor) (mg/L): 0.000674

Chemical concentrations in and transfer rates among exposure media

Chemical: AS
 Time: 15 years since cleanup

		Concentrations in Soil And Soil Water	
Soil layer			
From -> To (m):		Soil (ppm)	Water (mg/L)
0 -> 0.15		2.14	0.163
0.15 -> 0.3		4.89	0.2
0.3 -> 0.75		4.98	0.2
0.75 -> 1.35		45	0.2
1.35 -> 1.65		23	0.2

Rates of Transfer from Soil
 To Other Media (mg/(cm² y))

Soil to Air:
 Diffusion 0
 Evapotransp. 0
 Soil to Groundwater:
 Leaching 0.00559

 Concentrations in Other
 Exposure Media

 Air Concentrations (mg/cm³):
 Resusp. Part. 1.51E-007
 Vapors 0

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Milk (mg/L)	0.000145
Meat (mg/kg)	0.00484
Vegs. (mg/kg)	0.00646
Pasture (mg/kg)	0.0861

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.000769

Chemical concentrations in and transfer rates among exposure media

Chemical: AS
Time: 50 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.0679	0.00679
0.15 -> 0.3	0.807	0.0807
0.3 -> 0.75	4.76	0.2
0.75 -> 1.35	45	0.2
1.35 -> 1.65	23	0.2

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.00559

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 4.79E-009
Vapors 0
Milk (mg/L) 4.61E-006
Meat (mg/kg) 0.000154
Vegs. (mg/kg) 0.000205
Pasture (mg/kg) 0.00274

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.00108

Chemical concentrations in and transfer rates among exposure media

Chemical: AS
Time: 100 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.000524	5.24E-005
0.15 -> 0.3	0.00879	0.000879
0.3 -> 0.75	1.79	0.179
0.75 -> 1.35	45	0.2
1.35 -> 1.65	23	0.2

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.00559

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 3.7E-011
Vapors 0
Milk (mg/L) 3.56E-008
Meat (mg/kg) 1.19E-006
Vegs. (mg/kg) 1.59E-006
Pasture (mg/kg) 2.11E-005

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0011

Chemical concentrations in and transfer rates among exposure media

Chemical: AS
Time: 250 years since cleanup

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
-> 0.15	1.55E-008	1.55E-009
0.15 -> 0.3	4.15E-007	4.15E-008
0.3 -> 0.75	0.0365	0.00365
0.75 -> 1.35	39	0.2
1.35 -> 1.65	23	0.2

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0011

Chemical concentrations in and transfer rates among exposure media

Chemical: AS
Time: 500 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
-> 0.15	0	0
0.15 -> 0.3	0	0
0.3 -> 0.75	4.19E-006	4.19E-007
0.75 -> 1.35	26.7	0.2
1.35 -> 1.65	23	0.2

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0011

Chemical concentrations in and transfer rates among exposure media

Chemical: MO
Time: 0 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	5	0.05
0.15 -> 0.3	5	0.05
0.3 -> 0.75	5	0.05
0.75 -> 1.35	15	0.15
1.35 -> 1.65	7.99	0.0799

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0011

Soil to Air: 3/15/91
Diffusion 0
Evapotransp. 0
Soil to Groundwater: 85
Leaching 0.00559

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 1.1E-015
Vapors 0
Milk (mg/L) 1.06E-012
Meat (mg/kg) 3.52E-011
Vegs. (mg/kg) 4.7E-011
Pasture (mg/kg) 6.26E-010

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.00559

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 0
Vapors 0
Milk (mg/L) 0
Meat (mg/kg) 0
Vegs. (mg/kg) 0
Pasture (mg/kg) 0

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.00223

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 3.5E-007
Vapors 0

Milk (mg/L) 0.033
 Meat (mg/kg) 0.132
 Veggies. (mg/kg) 0.13
 Pasture (mg/kg) 1.25

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Concentration in Groundwater at
 Well (Receptor) (mg/L): 0

Chemical concentrations in and transfer rates among exposure media

Chemical: MO
 Time: 7 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	4.66	0.0466
0.15 -> 0.3	4.98	0.0498
0.3 -> 0.75	5	0.05
0.75 -> 1.35	14.8	0.148
1.35 -> 1.65	8.23	0.0823

Rates of Transfer from Soil
 To Other Media (mg/(cm² y))

Soil to Air:
 Diffusion 0
 Evapotransp. 0
 Soil to Groundwater:
 Leaching 0.00229

Concentrations in Other Exposure Media

Air Concentrations (mg/cm³):
 Resusp. Part. 3.27E-007
 Vapors 0
 Milk (mg/L) 0.0308
 Meat (mg/kg) 0.123
 Veggies. (mg/kg) 0.121
 Pasture (mg/kg) 1.17

Concentration in Groundwater at
 Well (Receptor) (mg/L): 9.43E-005

Chemical concentrations in and transfer rates among exposure media

Chemical: MO
 Time: 15 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	4.32	0.0432
0.15 -> 0.3	4.94	0.0494
0.3 -> 0.75	5	0.05
0.75 -> 1.35	14.6	0.146
1.35 -> 1.65	8.47	0.0847

Rates of Transfer from Soil
 To Other Media (mg/(cm² y))

Soil to Air:
 Diffusion 0
 Evapotransp. 0
 Soil to Groundwater:
 Leaching 0.00232

Concentrations in Other Exposure Media

Air Concentrations (mg/cm³):
 Resusp. Part. 3.03E-007
 Vapors 0
 Milk (mg/L) 0.0285
 Meat (mg/kg) 0.114
 Veggies. (mg/kg) 0.112
 Pasture (mg/kg) 1.08

Concentration in Groundwater at
 Well (Receptor) (mg/L): 0.000109

Chemical concentrations in and transfer rates among exposure media

Chemical: MO
 Time: 50 years since cleanup

Rates of Transfer from Soil
 To Other Media (mg/(cm² y))

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Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	3.06	0.0306
0.15 -> 0.3	4.56	0.0456
0.3 -> 0.75	4.97	0.0497
0.75 -> 1.35	13.8	0.138
1.35 -> 1.65	9.38	0.0938

Soil to Air:
 Diffusion 0
 Evapotransp. 0
 Soil to Groundwater:
 Leaching 0.00256

 Concentrations in Other
 Exposure Media

 Air Concentrations (mg/cm³):
 Resusp. Part. 2.14E-007
 Vapors 0
 Milk (mg/L) 0.0202
 Meat (mg/kg) 0.0809
 Veggies. (mg/kg) 0.0797
 Pasture (mg/kg) 0.766

Concentration in Groundwater at
 Well (Receptor) (mg/L): 0.000174

Chemical concentrations in and transfer rates among exposure media

Chemical: MO
 Time: 100 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	1.88	0.0188
0.15 -> 0.3	3.71	0.0371
0.3 -> 0.75	4.85	0.0485
0.75 -> 1.35	12.8	0.128
1.35 -> 1.65	10.2	0.102

Rates of Transfer from Soil
 To Other Media (mg/(cm² y))

 Soil to Air:
 Diffusion 0
 Evapotransp. 0
 Soil to Groundwater:
 Leaching 0.00282

 Concentrations in Other
 Exposure Media

 Air Concentrations (mg/cm³):
 Resusp. Part. 1.31E-007
 Vapors 0
 Milk (mg/L) 0.0124
 Meat (mg/kg) 0.0496
 Veggies. (mg/kg) 0.0488
 Pasture (mg/kg) 0.469

Concentration in Groundwater at
 Well (Receptor) (mg/L): 0.000252

Chemical concentrations in and transfer rates among exposure media

Chemical: MO
 Time: 250 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.484	0.00484
0.15 -> 0.3	1.56	0.0156
0.3 -> 0.75	3.89	0.0389
0.75 -> 1.35	10.2	0.102
1.35 -> 1.65	10.7	0.107

Rates of Transfer from Soil
 To Other Media (mg/(cm² y))

 Soil to Air:
 Diffusion 0
 Evapotransp. 0
 Soil to Groundwater:
 Leaching 0.00294

 Concentrations in Other
 Exposure Media

 Air Concentrations (mg/cm³):
 Resusp. Part. 3.39E-008
 Vapors 0

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Milk (mg/L) 0.0032
Meat (mg/kg) 0.0128
Vegs. (mg/kg) 0.0126
Pasture (mg/kg) 0.121

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(Concentration in Groundwater at
well (Receptor) (mg/L): 0.000419

Chemical concentrations in and transfer rates among exposure media

Chemical: MO
Time: 500 years since cleanup

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.0373	0.000373
0.15 -> 0.3	0.22	0.0022
0.3 -> 0.75	2.06	0.0206
0.75 -> 1.35	6.84	0.0684
1.35 -> 1.65	8.91	0.0891

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.00275

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 2.61E-009
Vapors 0
Milk (mg/L) 0.000246
Meat (mg/kg) 0.000985
Vegs. (mg/kg) 0.00097
Pasture (mg/kg) 0.00933

Concentration in Groundwater at
all (Receptor) (mg/L): 0.000477

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DECHEM (TM) -- RADIOLOGICAL ASSESSMENTS CORPORATION
Neeses, SC 29107

(Site-based assessment of exposure of people to sites of chemical contamination in soil after remedial measures.

Site: GUNNISON SUBPILE/AFTER REMEDIAL ACTION
Date and time of analysis: Tue Jan 29 16:19:22 1991
Data file: B:GUNSUB10.TST
Print file: B:GUNSUB10.PRN

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SECTION I: PROBLEM DATA

Exposure pathways	In effect?
Food ingestion	Yes
Drinking water	Yes
Inhalation	Yes

Modifying (use) factors for exposure calculations	Percent
Percent of time that an individual spends on the decommissioned site:	100
Percentages of food types consumed by an individual that were produced on site:	
Produce	40
Leafy vegetables	40
Milk	75
Meat	75
Percent of an individual's drinking water that contains chemicals from the decommissioned site:	100

Food types	Included?
Produce	Yes
Leafy vegetables	Yes
Milk	Yes
Meat	Yes

Miscellaneous parameters that are not chemical-specific

Atmospheric soil loading by resuspension (g/m ³):	7E-005
Produce consumption by exposed individual (kg/year):	176
Leafy vegetable consumption by exposed individual (kg/year):	18
Milk consumption by exposed individual (L/year):	112
Meat consumption by exposed individual (kg/year):	94
Drinking water consumption by exposed individual (L/year):	511
Annual breathing rate of exposed individual (m ³ /year):	8030
Soil consumption by a cow (g/day):	500

Site parameters applicable to all chemicals

Site length (m):	425
Site width (m):	425
Net water input rate (cm/year)	

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(= rainfall + irrigation - evapotransp. - surf. runoff):

27.9

Layer depths (m)	Soil bulk density (g/cm ³)	Effective soil porosity (fraction)	Soil moisture content (fraction)
From -> To:			
0 -> 0.15	1.9	0.3	0.15
0.15 -> 0.3	1.9	0.3	0.15
0.3 -> 0.75	1.9	0.3	0.15
0.75 -> 1.35	1.9	0.3	0.15
1.35 -> 1.65	1.9	0.3	0.15

Parameters for the groundwater aquifer (drinking water pathway)

Distance of water source from decommissioned area (m):	300
Effective porosity of aquifer (cm ³ /cm ³):	0.1
Longitudinal dispersivity in aquifer (m):	5
Transverse dispersivity in aquifer (m):	1
Seepage velocity in aquifer (m/s):	1.38E-005
Thickness of aquifer (m):	40
Density of soil in aquifer (g/cm ³):	1.9

Pre-cleanup buildup of residual groundwater contamination (years):

0

Chemical-specific profiles for U

Soil layers (m)	Initial post-cleanup concentration (ppm)	Soil/water K _d coefficient (mL/g)	Solubility in water (g/mL)
0 -> 0.15	3	5	6E-006
0.15 -> 0.3	3	5	6E-006
0.3 -> 0.75	3	5	6E-006
0.75 -> 1.35	55	5	6E-006
1.35 -> 1.65	28	5	6E-006
Aquifer	0 mg/L	1	

Chemical-specific parameters

U

Intake limits for reference values

(mg/year):

Inhalation: 17

Ingestion: 49

n-octanol/water coefficient (organic chemicals only): -----

Soil and groundwater loss-rate coefficient for physical, chemical and biological processes (1/year): 0

Bioconcentration factors referenced

to dry soil:

Pasture grass: (a) 0.0085
Crops: (b) 0.004
Milk (kg/L): 7.96E-005
Meat: 2.65E-005

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(a) Dry weight. (b) Edible parts, wet weight.

(c) BCF calculated from n-octanol/water coefficient (K_{ow}).

SECTION II: PROBLEM RESULTS

Annual reference value for all chemicals over time

Time (years after cleanup)	Total: all chemicals	U
0	0.0201	0.0201
7	0.233	0.233
15	0.311	0.311
50	0.206	0.206
100	8.34E-011	8.34E-011
250	7.36E-026	7.36E-026
500	0	0

Annual reference value by pathway: All Chemicals

Time (years after cleanup)	Total: All Pathways	Vegetables	Milk	Meat	Drinking Water	Inhalation
0	0.0201	0.0175	0.00195	0.000546	0	9.92E-005
7	0.233	0.00453	0.000505	0.000141	0.228	2.57E-005
15	0.311	0.00145	0.000162	4.54E-005	0.309	8.24E-006
50	0.206	1.13E-006	1.26E-007	3.51E-008	0.206	6.38E-009
100	8.34E-011	7.26E-011	8.11E-012	2.27E-012	5.97E-024	4.12E-013
250	7.36E-026	0	0	0	7.36E-026	0
500	0	0	0	0	0	0

Annual reference value by pathway: U

Time (years after cleanup)	Total: All Pathways	Vegetables	Milk	Meat	Drinking Water	Inhalation
0	0.0201	0.0175	0.00195	0.000546	0	9.92E-005
7	0.233	0.00453	0.000505	0.000141	0.228	2.57E-005
15	0.311	0.00145	0.000162	4.54E-005	0.309	8.24E-006
50	0.206	1.13E-006	1.26E-007	3.51E-008	0.206	6.38E-009
100	8.34E-011	7.26E-011	8.11E-012	2.27E-012	5.97E-024	4.12E-013
250	7.36E-026	0	0	0	7.36E-026	0
500	0	0	0	0	0	0

Chemical concentrations in and transfer rates among exposure media

Chemical: U

Rates of Transfer from Soil

3/13/91

Time: 0 years since cleanup

Concentrations in Soil And Soil Water		
Soil layer From -> To (m):	Soil (ppm)	Water (mg/L)
0 -> 0.15	2.95	0.591
0.15 -> 0.3	2.95	0.591
0.3 -> 0.75	2.95	0.591
0.75 -> 1.35	54.5	6
1.35 -> 1.65	27.6	5.51

To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.154

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Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 2.1E-007
Vapors 0
Milk (mg/L) 0.00114
Meat (mg/kg) 0.00038
Vegs. (mg/kg) 0.012
Pasture (mg/kg) 0.0255

Concentration in Groundwater at
Well (Receptor) (mg/L): 0

Chemical concentrations in and transfer rates among exposure media

Chemical: U

Time: 7 years since cleanup

Concentrations in Soil And Soil Water		
Soil layer From -> To (m):	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.765	0.153
0.15 -> 0.3	1.8	0.36
0.3 -> 0.75	2.76	0.553
0.75 -> 1.35	45.2	6
1.35 -> 1.65	28.8	5.75

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.16

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 5.44E-008
Vapors 0
Milk (mg/L) 0.000295
Meat (mg/kg) 9.83E-005
Vegs. (mg/kg) 0.00311
Pasture (mg/kg) 0.0066

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0218

Chemical concentrations in and transfer rates among exposure media

Chemical: U

Time: 15 years since cleanup

Concentrations in Soil And Soil Water		
Soil layer From -> To (m):	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.245	0.0491
0.15 -> 0.3	0.779	0.156
0.3 -> 0.75	2.09	0.418
0.75 -> 1.35	34.4	5.77
1.35 -> 1.65	29.3	5.85

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.162

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):

3/13/91

Resusp. Part. 1.74E-008
Vapors 0
Milk (mg/L) 9.46E-005
Meat (mg/kg) 3.15E-005
Vegs. (mg/kg) 0.000997
Pasture (mg/kg) 0.00212

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Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0297

Chemical concentrations in and transfer rates among exposure media

Chemical: U
Time: 50 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	0.00019	3.8E-005
0.15 -> 0.3	0.00202	0.000405
0.3 -> 0.75	0.265	0.053
0.75 -> 1.35	6.98	1.4
1.35 -> 1.65	12.1	2.41

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.0991

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 1.35E-011
Vapors 0
Milk (mg/L) 7.33E-008
Meat (mg/kg) 2.44E-008
Vegs. (mg/kg) 7.72E-007
Pasture (mg/kg) 1.64E-006

Concentration in Groundwater at
Well (Receptor) (mg/L): 0.0197

Chemical concentrations in and transfer rates among exposure media

Chemical: U
Time: 100 years since cleanup

Soil layer From -> To (m):	Concentrations in Soil And Soil Water	
	Soil (ppm)	Water (mg/L)
0 -> 0.15	1.23E-008	2.45E-009
0.15 -> 0.3	2.48E-007	4.96E-008
0.3 -> 0.75	0.0107	0.00213
0.75 -> 1.35	0.665	0.133
1.35 -> 1.65	1.29	0.258

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.0115

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 8.72E-016
Vapors 0
Milk (mg/L) 4.73E-012
Meat (mg/kg) 1.58E-012
Vegs. (mg/kg) 4.98E-011
Pasture (mg/kg) 1.06E-010

Concentration in Groundwater at
Well (Receptor) (mg/L): 5.72E-025

Chemical concentrations in and transfer rates among exposure media

Chemical: U

Rates of Transfer from Soil

KK 3/15/91

Time: 250 years since cleanup

		Concentrations in Soil And Soil Water	
Soil layer		-----	
From ->	To (m):	Soil (ppm)	Water (mg/L)
-----		-----	
0 ->	0.15	0	0
0.15 ->	0.3	0	0
0.3 ->	0.75	8.58E-006	1.72E-006
0.75 ->	1.35	0.00279	0.000558
1.35 ->	1.65	0.00556	0.00111

To Other Media (mg/(cm² y))

Soil to Air: 94
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 0.00363

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 0
Vapors 0
Milk (mg/L) 0
Meat (mg/kg) 0
Vegs. (mg/kg) 0
Pasture (mg/kg) 0

Concentration in Groundwater at
Well (Receptor) (mg/L): 7.06E-027

Chemical concentrations in and transfer rates among exposure media

Chemical: U
Time: 500 years since cleanup

		Concentrations in Soil And Soil Water	
Soil layer		-----	
From ->	To (m):	Soil (ppm)	Water (mg/L)
-----		-----	
0 ->	0.15	0	0
0.15 ->	0.3	0	0
0.3 ->	0.75	7.22E-014	1.44E-014
0.75 ->	1.35	2.89E-009	5.78E-010
1.35 ->	1.65	5.65E-009	1.13E-009

Rates of Transfer from Soil
To Other Media (mg/(cm² y))

Soil to Air:
Diffusion 0
Evapotransp. 0
Soil to Groundwater:
Leaching 4.02E-009

Concentrations in Other
Exposure Media

Air Concentrations (mg/cm³):
Resusp. Part. 0
Vapors 0
Milk (mg/L) 0
Meat (mg/kg) 0
Vegs. (mg/kg) 0
Pasture (mg/kg) 0

Concentration in Groundwater at
Well (Receptor) (mg/L): 0

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 4 1992

Mr. Albert R. Chernoff, Project Manager
Uranium Mill Tailings Remedial Action
Project Office
U.S. Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. Chernoff:

We have reviewed the procedure on "Bulk Radionuclide Determination, Excavation Control, and Site Verification For Cobbly Soils" sent with your letter of March 26, 1992, and supplemented by a revised Page 12 sent by facsimile on March 30, 1992. We hereby concur with its use on U.S. Department of Energy Uranium Mill Tailings Remedial Action Project sites containing a high percentage of cobbly subsoil. This procedure, designated RAC-OP-003, should be referenced in the specific Remedial Action Plans for those sites where it will be used.

One item of note concerns the section of the procedure discussing authority (Section 1.3). This section should be revised to reference this letter of concurrence rather than the September 17, 1991, letter cited, which agreed with the concept but did not concur with the procedure.

Any questions should be addressed to Allan Mullins of my staff at FTS 964-2578.

Sincerely,

John J. Surmeier, Chief
Uranium Recovery Branch
Division of Low-Level Waste Management
and Decommissioning, NMSS

cc: D. Metzler, DOE Alb
P. Mann, DOE Alb
D. Gonzalez, TAC

Health Physics Standard Operating Procedures

Title: SOIL VERIFICATION USING COBBLES-TO-FINES CORRECTION

Procedure No.: OP-003-4

Rev. No.: 0

Page 1 of 15

APPROVAL HP CONTROLLED COPY 101

APPROVED:

4-17-92
Project Director, Remedial Actions Contractor, UMTRA Project

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4/17/92
Health Physics and Environment Manager, Remedial Actions Contractor, UMTRA Project

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4-17-92
Health Physics Operations Manager, Remedial Actions Contractor, UMTRA Project

Soil Verification Using Cobbles-To-Fines Correction

1.0 SCOPE

1.1 Purpose

This procedure will be used for determining and verifying average bulk radionuclide concentrations for radium-226 (Ra-226), thorium-230 (Th-230), and, if necessary, thorium-232 (Th-232) at locations where the subsoil consists of a percentage of cobbles in the bulk sample sufficient to affect measurement of the total radionuclide concentration. Excavation control and verification will be based on bulk concentrations determined by this procedure.

1.2 Applicability

This procedure may be applied in areas designated for routine soil excavation and verification (see RAC-OP-003) where the subsoil media contains a high percentage of cobbles.

1.3 Authority

Letter to A.R. Chernoff, DOE/UMTRA from J.J. Surmeier, NRC dated April 4, 1992.

2.0 REFERENCES

- 2.1 RAC Health Physics Procedure RAC-RP-005 - Radiological Instrumentation.
- 2.2 RAC Health Physics Procedure RAC-OP-002 - Excavation Control Procedure
- 2.3 RAC Health Physics Procedure RAC-OP-003

3.0 DEFINITIONS

- 3.1 Cobbles - The portion of a composite soil sample which will not pass through a #4 mesh sieve.
- 3.2 Fines - The portion of a composite soil sample which will pass through a #4 mesh sieve.
- 3.3 Mass partition function, f , of a cobbly soil sample - the ratio of the dry mass of the cobbles (M_{cob}), to the dry mass of the fines (M_{fin}):

$$f = M_{cob}/M_{fin} \text{ (cobble to fine ratio),}$$

where the total dry mass of the sample, M_T , is

$$M_T = M_{>.5} + M_{<.5}$$

3.4 Radiological concentration (Ra-226, Th-230, or Th-232), in picocuries per gram (pCi/g), for the fines or cobbles, are designated by $C_{<.5}$ and $C_{>.5}$, respectively.

3.5 Bulk radionuclide concentration (Ra-226, Th-230, or Th-232), in pCi/g, is designated by C_s , and calculated using

$$C_s = \text{Total Sample Radioactivity (pCi)} / \text{Total Dry Mass of Sample (g)}$$

$$C_s = (C_{<.5} \times M_{<.5} + C_{>.5} \times M_{>.5}) / (M_{<.5} + M_{>.5})$$

$$C_s = C_{<.5} (1/(1+f)) + C_{>.5} (f/(1+f)).$$

3.6 Student t distribution (t) - the mathematical quantity used to define the distribution of test statistics for small sample populations; used herein to determine the lower and upper 95 percent confidence values for mass partition function and cobble radionuclide concentrations respectively.

3.7 Running Average - The determination of statistical quantities based on the available data and recalculated as more data becomes available.

3.8 Statistical Mass Partition Function (f_L) - The mass partition function (f), at the lower 95 percent confidence value calculated from test pit or running average data.

3.9 Statistical Cobble Radionuclide Concentration ($C_{>.5U}$) - The cobble radionuclide concentration ($C_{>.5}$) at the upper 95 percent confidence value calculated from test pit or running average data.

4.0 REQUIREMENTS

4.1 Prerequisites

4.1.1 All instruments used under this procedure shall have valid calibration.

4.1.2 Backup data (correlations, etc.) must be acquired, retained on-site, and made available for audit, on all methods and analyses used for excavation control and verification measurements.

4.2 Tools, Material, Equipment

- 4.2.1 Buckets, wheelbarrows, #4 mesh sieves or screens (4.8 millimeter), shovels or backhoe, weighing scale up to 200 lbs., drying oven, and other materials, as necessary, to obtain representative bulk soil samples. It should be noted that a 1/4 inch hardware cloth is approximately equivalent to a #4 mesh sieve, and may be used in lieu of a #4 mesh sieve.

4.3 Precautions/Limits

N/A

4.4 Acceptance Criteria

N/A

5.0 PROCEDURE

5.1 Site Evaluation

- 5.1.1 This guidance applies to processing sites and vicinity property areas. If the work area under consideration is less than 0.5 acre, the mass partition function (f) will be based on soil sampling from one centrally located test pit.
- 5.1.2 The statistical mass partition function (f_L) and statistical cobble radionuclide concentration (C_{50}) may be determined by analysis of samples collected from test pits prior to construction. The purpose for developing a statistical mass partition function is only to obtain an estimate of the excavation depth required for compliance with radiological cleanup standards.
- 5.1.3 Approximately 30 uniformly distributed sampling locations (test pits) will be used for the entire site. Fewer test pits may be used on small sites with prior approval from the HP & E Manager.
- 5.1.4 If test pit excavation activities are performed during remedial action, the statistical mass partition function (f_L) shall be obtained by calculating a running average of the corresponding parameters obtained as test pit work progresses across the site.

5.2 Test Pit Soil Sampling and Analysis

- 5.2.1 Dig each test pit to the estimated depth of contamination at the location, and record the test pit surface elevation and maximum depth of each test pit.
- 5.2.2 Collect one composite sample from each test pit. The composite soil sample shall be comprised of all the material contained in a standard shovel from each one foot increment (no material shall be discarded). Sampling shall begin at the cobbly soil surface or tailings/cobbly soil interface and continue through a minimum of 5 feet of cobbly material or all the cobbly material (whichever is less).
- 5.2.3 Sieve the composite sample through a #4 mesh sieve, collecting the fines and cobbles in separate buckets of known weight. Weigh both fractions separately. Thoroughly mix the fine fraction and extract two (2) representative 500 gram can samples.
- 5.2.4 Determine the percent moisture content by weight of one of the can samples and calculate the adjusted dry weight of the fines. Calculate the adjusted dry weight of the cobbles assuming a moisture content of 1.5 percent. Record all pertinent information on the Cobbles to Fines Calculation Sheet (Attachment 1). Calculate the mass partition function (f) for the test pit using the adjusted dry weight of the fines and cobbles in the relation defined in Definition 3.3.
- 5.2.5 The second can shall be analyzed by the site laboratory for Ra-226 (and Th-232 if necessary) and sent to the vendor laboratory for Ra-226 and Th-230 analysis (and Th-232 if necessary). Record on-site and vendor analysis results on Attachment 1.

Note: Analysis for Th-232 shall only be performed if the site characterization indicates Th-232 is present.

- 5.2.5.1 Using the initial on-site analysis results and the vendor analysis results for all test pit or running average samples, a Ra-226 correction factor shall be established using the following equation:

$$Ra-226 \text{ C.F.} = \frac{R_1 + R_2 + \dots R_n}{n}$$

where, C.F. = correction factor,
 R_n = Vendor results (pCi/g) divided by
initial OCS results (pCi/g) for the
 n^{th} sample (i.e., 1, 2, ...n), and
 n = number of ratios.

5.2.5.2 The correction factor shall be updated using the pertinent analyses results from QA samples (section 5.10).

5.2.6 Ship the fraction retained on the #4 sieve from each test pit to the vendor laboratory, in the 5-gallon bucket. This material shall be cleaned, crushed, and analyzed for Ra-226, Th-230 and, if necessary, Th-232. Record vendor analysis results on Attachment 1.

5.2.7 Calculate the bulk radionuclide concentration (C_b) for the test pit using the mass partition function (f) for the test pit (section 5.2.4), the vendor radiological concentration of the fines ($C_{<.44}$), and the radiological concentration of the cobbles ($C_{>.44}$) in the equation defined in Definition 3.5. Bulk radionuclide concentrations should be calculated for Ra-226, Th-230, and Th-232 (if necessary).

5.3 Establish background bulk radionuclide concentrations for Ra-226, Th-230, and, if necessary, Th-232, by the sampling and analyses detailed in steps 5.2.1 through 5.2.6 at three uncontaminated background locations containing cobbly subsoil.

5.4 Statistical Mass Partition Function - Alternative 1 (Test Pits)

5.4.1 Upon completion of test pit sampling, pertinent data shall be compiled on the Statistical Data Sheet (Attachment 2), and the statistical mass partition function shall be calculated using the following equation:

$$f_L = \bar{f} - t(s/\sqrt{n})$$

where, f_L = statistical average mass partition function at the
lower 95 percent confidence value,
 $\bar{f}$ = mean mass partition functions of n samples,
 s = sample standard deviation for the n samples,
 t = t from Attachment 3, and
 n = number of observations.

5.4.2 The mean of the sample population is determined as follows:

$$\bar{f} = \frac{f_1 + f_2 + \dots + f_n}{n}$$

where, $f_{1,2 \dots n}$ = the value of f for sample 1, 2, or n ; and
 n = the number of samples.

5.4.3 The standard deviation is calculated as follows:

$$S = \frac{\sqrt{\sum_{n=1}^n (f_n - \bar{f})^2}}{n - 1}$$

where, S = sample standard deviation,
 f_n = value of f for sample n ,
 $\bar{f}$ = mean of f for n samples, and
 n = number of samples.

5.4.4 The statistical cobble radionuclide concentration for Ra-226, Th-230 and Th-232 (if necessary) shall be calculated using the following equation:

$$C_{>u} = \bar{C} + t(s/\sqrt{n})$$

where, $C_{>u}$ = The statistical cobble radionuclide concentration at the upper 95 percent confidence value,
 $\bar{C}$ = mean radionuclide concentration of the n samples,
 s = standard deviation of the 30 samples,
 t = t from Attachment 3, and
 n = number of samples.

5.5 Statistical Mass Partition Function - Alternative 2 (Running Average)

5.5.1 The statistical mass partition function (f_L) and the statistical cobble radionuclide concentration ($C_{>u}$) may be obtained by calculating a running average of the corresponding parameters using the equations

in sections 5.4.1 and 5.4.4 respectively. Compile data on the Statistical Data Sheet and recalculate f_L and $C_{>u}$ as data is obtained from each new test pit.

5.6 The statistical mass partition function and statistical cobble radionuclide concentration for alternative 1 or 2, will only be used for excavation control to obtain an estimate of the final excavation depth to comply with EPA's radiological cleanup standards. Final excavation depths and verification will be determined as described in section 5.7 through 5.9.

5.6.1 By solving the equation in section 3.5 for $C_{<#4}$ and using the statistical mass partition function (f_L) and the statistical cobble radionuclide concentration ($C_{>u}$) an estimate of the allowable fines radionuclide concentration may be obtained as follows:

$$C_{<#4} = \frac{C_B - C_{>u} [f_L / (1 + f_L)]}{[1 / (1 + f_L)]}$$

where, $C_{<#4}$ = The estimated fines radionuclide concentration,
 C_B = the applicable limit (i.e., 5 or 15 pCi/g for Ra-226 or Th-232 or 35 pCi/g for Th-230),
 f_L = statistical mass partition function, and
 $C_{>u}$ = statistical cobble radionuclide concentration.

5.7 Verification Soil Sampling & Analysis

5.7.1 Grid the entire site into squares of 100 yd² (-100 m²). Grids shall be uniformly distributed over the site so as to obtain representative data. Record location and elevation for each 100 yd² grid.

5.7.2 Further subdivide each grid where excavation control is being performed into approximately 10 x 10 foot squares (see below). Subdividing grids may normally be done visually by the technician performing the survey. Soil sample extraction will be performed at each of the nine 10 x 10 foot squares within the grid. Each soil plug should consist of all the material contained in a standard shovel. This will include soil, rock, and small/large gravel. No material is to be discarded. The soil plug will be taken to a depth of 15 centimeters (cm). Sample collection shall be random (non-biased).

	(30')		
	0	0	0
	0	0	0
(30')	0	0	0
	0	0	0

0 = sample location

5.7.3 The nine soil plugs (80-100 lbs combined weight) comprise a composite sample.

5.7.4 Sieve the composite sample through a #4 mesh sieve, collecting the fines and cobbles in separate buckets of known weight. Thoroughly mix the fine fraction.

5.8 Site Verification Alternative 1 (Grid Specific)

5.8.1 For verification alternative 1, weigh both fractions separately and record information on Attachment 1.

5.8.2 Extract two (2) 500g can samples of the fine fraction for moisture content and radiological analysis.

5.8.3 Determine the moisture content of the fines and calculate the adjusted dry weight. Calculate the adjusted dry weight of cobbles assuming a moisture content of 1.5 percent. Calculate and record the mass partition function for the grid (Attachment 1).

5.8.4 Analyze the second can sample of fines for Ra-226 and, if necessary, Th-232 with the on-site OCS. Calculate the corrected radionuclide concentration using the site Ra-226 correction factor determined in section 5.2.5.1.

5.8.5 Calculate the bulk radionuclide concentration C_b for the grid using the grid specific mass partition function, radionuclide concentration of the fines (the initial corrected concentration shall be used for calculating the Ra-226 bulk radionuclide concentration) and the statistical cobbles

radionuclide concentration ($C_{>u}$) in the formula in section 3.5. All data shall be recorded on Form F1-OP-003-4.

5.8.6 Dry, seal and store the sample for 20 day on-site analysis.

5.8.7 After a minimum of 20 days, reanalyze the sample and calculate the final bulk radionuclide concentration (C_B) for the grid.

5.9 Site Verification Alternative 2 (Statistical)

5.9.1 For each 100 m² grid, a 9-plug composite soil sample of the fines soil will be obtained following the technique outlined in Section 5.7.

5.9.2 Extract a 500g can sample of the fine fraction for radiometric analysis. Discard the larger size soil fraction.

5.9.3 Analyze the can sample for Ra-226 and, if necessary, Th-232 with the on-site OCS. Calculate the corrected radionuclide concentration using the site correction factor determined in section 5.2.5.1.

5.9.4 Calculate the bulk radionuclide concentration for the grid using the radionuclide concentration of the fines (the initial corrected concentration shall be used for calculating the Ra-226 bulk radionuclide concentration), the statistical mass partition function (f_L) and the statistical cobble radionuclide concentration ($C_{>u}$) in the formula from section 3.5 modified below.

$$C_B = C_{<4} [1/(1 + f_L)] + C_{>u} [f_L/(1 + f_L)]$$

Record the pertinent data on the Alternative 2 Bulk Concentration Data Sheet (Attachment 4).

5.8.6 Dry, seal and store the sample for 20 day on-site analysis.

5.8.7 After a minimum of 20 days, reanalyze the sample and calculate the final bulk radionuclide concentration (C_B) for the grid.

5.10 The verification sample from the 25th 100 m² grid of each block will be sent to an outside Vendor laboratory for independent Ra-226, Th-230, and, if necessary, Th-232 analyses in accordance with Quality Assurance requirements.

6.0 RECORDS/REPORTS/NOTIFICATIONS

6.1 All data shall be recorded on the appropriate data sheet.

7.0 ATTACHMENTS

7.1 Attachment 1 - Cobble to Fines Calculation Sheet (F1-OP-003-4)

7.2 Attachment 2 - Statistical Data Sheet (F2-OP-003-4)

7.3 Attachment 3 - Critical Values of t.

7.4 Attachment 4 - Alternative 2 Bulk Concentration Data Sheet (F4-OP-003-4)

COBBLES TO FINES CALCULATION SHEET

Site: _____

Sheet _____ of _____

Sample/Grid I.D. _____

Date: _____

Fines	Cobbles	Moisture Content Fines
Wt. Sample & Bucket _____	Wt. Sample & Bucket _____	Wet Wt. Sample/Pan _____
Wt. Bucket _____	Wt. Bucket _____	Dry Wt. Sample/Pan _____
Wt. Sample _____	Wt. Sample _____	Tare Wt. Pan _____
Adjusted _____	Adjusted _____	Wt. Water* _____
Dry Wt. (M _{ced})* _____	Dry Wt. (M _{sed})** _____	Wt. Soil** _____
		Percent Water(*/**) _____

* Adjusted Dry Wt. of the Fines = Wt. Sample x (1 - % water)

** Adjusted Dry Wt. of the Cobbles = Wt. Sample x (1 - .015)

Mass Partition function (f) = M_{sed}/M_{ced} = _____

Radiological Analysis	²²⁶ Ra (pCi/g)	²³⁰ Th (pCi/g)	²³² Th (pCi/g)	COMMENTS
Cobbles (C _{sed})				
On-Site Analysis Fines (C _{ced})	• •• ••••	N/A		
Vendor Analysis Fines (C _{ced})				
Bulk Radionuclide Concentration (C _g)	# ## ###			

* Initial;

** Initial Corrected;

*** 20 day (N/A for Test Pit or Running AVE.)

Using Vendor;

Using Initial Corrected;

*** Using 20 day (N/A for Test Pits or Running AVE.)

²²⁶Ra Correction Factor: _____

Reviewed By: _____

Date: _____

F1-OP-003-4

Appendix:

OP-003-4

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STATISTICAL DATA SHEET

Date: _____ Sheet ____ of ____

[illegible]

Statistical Mass Partition Function (I_1) =

Statistical Cobble Radionuclide Concentration ($C_{s,u}$) = ^{226}Ra Correction Factor (C.F.) =

Reviewed By:

Date:

F2.OP.003.4

CRITICAL VALUES OF t

$n-1$	$t_{.050}$
1	6.314
2	2.920
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.860
9	1.833
10	1.812
11	1.796
12	1.782
13	1.771
14	1.761
15	1.753
16	1.746
17	1.740
18	1.734
19	1.729
20	1.725
21	1.721
22	1.717
23	1.714
24	1.711
25	1.708
26	1.706
27	1.703
28	1.701
29	1.699
inf.	1.645

DATE:

BITE:

[illegible]

Bulk Concentration $C_2 = C_{2,0} (1/(1 + t)) + C_{2,\infty} (1/(1 + t))$

Statistical Cobble Radionuclide Concentration C_c Statistical Mass Partition Function q

Reviewed By:

Date: _____

F4-0P-003.4

END

**DATE
FILMED**

5 / 26 / 93