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February 7, 2006

Mr. William von Till, Project Manager
Fuel Cycle Facilities Branch
Division of Fuel Cycle Safety and Safeguards
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Two White Flint North, 11545 Rockville Pike
Rockville, Maryland 20852-2738

Subject: **Final Design and Reclamation Plan for GHP No. 2/Mill Area: Request for Deviation from Ra-226 Frost Protection and Exposure Rate Criteria**
Reference: **License SUA-648, Docket No. 40-0299, License Condition 61**

Dear Mr. von Till:

Umetco Minerals Corporation (Umetco) is requesting a license amendment to License Condition 61, U.S. Nuclear Regulatory Commission (NRC) Materials License Number SUA-648, for Umetco's Gas Hills Uranium Mill Site (Applicable Amendments: 38, 44, 52). The purpose of this amendment request is to:

1) allow the average Ra-226 content in cover materials used for placement on GHP-2 to exceed the 10 pCi/g criterion specified in the Final Design and Reclamation Plan for GHP No. 2/Mill Area, and establish a new limit of 15 pCi/g; and

2) adjust the exposure limit for GHP-2 from 30 μR/hr to 40 μR/hr to reflect the increase in cover soils Ra-226 content and better reflect the range of exposure rates observed in background soils.

The data and rationales supporting this request are documented in the enclosed report entitled *Report Amending Final Design and Reclamation Plan for GHP No. 2/Mill Area.* This report demonstrates that the deviations requested above will not adversely impact health, safety, or the environment. Furthermore, public access will be limited because GHP-2 is located within the site transfer boundary. Replacement pages for those portions of the September 2003 *Final Design and Reclamation Plan* that would be affected by this license amendment request are provided in Attachment 1 of the enclosed report.

If you or your staff has any questions or need additional information, please contact me at (970) 256-8889 or by e-mail at gieckte@dow.com.

Sincerely,

Ralph B. Bowen for

Thomas E. Gieck
Remediation Leader

TEG/SDK/jfc

Enclosure: As stated

REPORT AMENDING FINAL DESIGN AND RECLAMATION PLAN GHP NO. 2/MILL AREA

Gas Hills, Wyoming Site

February 2006

Amending Revision 1, September 2003

UMETCO Minerals Corporation
2754 Compass Drive, Suite 280
Grand Junction, CO 81506

REPORT AMENDING FINAL DESIGN AND RECLAMATION PLAN FOR GHP NO. 2/MILL AREA

Gas Hills, Wyoming Site

Docket No. 40-0299
License No. SUA-648

Umetco Minerals Corporation
2754 Compass Drive, Suite 280
Grand Junction, Colorado 81506

February 2006

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Definition of Terms

Acronym	Definition
11e.(2)	11e.(2) byproduct material, defined under 10 CFR 40 Appendix A
ALARA	As Low As Reasonably Achievable
AML	State of Wyoming Abandoned Mine Lands (program)
cpm	counts per minute
DCGL	Derived Concentration Guideline Level, analogous to SRSG (below)
DOE	Department of Energy
EPA	Environmental Protection Agency (U.S.)
FSS	Final Status Survey
GHP-2	Gas Hills Pond No. 2 (also referred to as GHP No. 2)
GIS	Geographic Information System
IBR	Incidental Boundary Revision
LC	License Condition
NORM	Naturally Occurring Radioactive Material
NRC	U. S. Nuclear Regulatory Commission
pCi/g	picoCuries per gram
$pCi/m^2/s$	picoCuries per meter squared per second
Ra-226	Radium-226
SRSG	Single Radionuclide Soil Guideline (as derived by the NRC RESRAD code)
TER	Technical Evaluation Report (NRC 2001, NRC 2004)
Th-232	Thorium-232
UCC	Union Carbide Corporation

1.0 INTRODUCTION

Umetco Minerals Corporation (Umetco) is requesting a modification to License Condition 61 as contained in License SUA-648. As such, this report amends certain requirements set forth in the report entitled *Final Design and Reclamation Plan for GHP No.2/Mill Area*—herein referred to as the GHP-2 Reclamation Plan—submitted to the U.S. Nuclear Regulatory Commission (NRC) by Umetco on September 11, 2003 (Umetco 2003a).

1.1 Objectives of this License Amendment Request – Specific Areas of Deviation

Based on the data and rationales presented herein, Umetco is requesting alternate criteria or a deviation from the approved *Final Status Survey Plan* (Umetco 2000a) and the *Final Design and Reclamation Plan for GHP No.2/Mill Area* (Umetco 2003a). The specific areas of deviation are:

1) to change the allowable average radium-226 (Ra-226) content in cover (frost protection) materials for placement on GHP-2 from 10 pCi/g to 15 pCi/g; and

2) to adjust the exposure rate limit for GHP-2 from 30 μR/hr to 40 μR/hr to reflect the increase in cover soils Ra-226 content requested above and—equally important—to better reflect exposure rates characteristic of the background areas coinciding with borrow material sources.

As Umetco will demonstrate herein, the deviations requested above will not adversely impact health, safety, or the environment. Furthermore, public access will be limited because GHP-2 is located within the site transfer boundary (Figure 1). Based on the latter findings and the additional analyses documented herein, Umetco believes that an optimal radon barrier and frost protection cover is in place at GHP-2 and that erosion protection can commence in Spring 2006.

1.2 Background

To satisfy the objectives and criteria set forth in the 2000 *Final Status Survey Plan* (FSS Plan) and the 2003 GHP-2 Reclamation Plan, the following numerical criteria for radiological conditions were previously established for reclamation of GHP-2:

- The average Ra-226 content of clay soils used to construct the radon barrier is less than or equal to 2 pCi/g.

- The exit radon flux calculated using the RADON model and verified by NESHAPS sampling must be below the 20 pCi/m^2-s exit flux limit established in 10 CFR 40, Appendix A, Criterion 6.

- The average Ra-226 measured for samples collected from the 0-1 and 1-2 ft portions of the frost protection layer must not exceed 10 pCi/g.

- The average gamma exposure rate measured on the GHP-2 cover is less than or equal to 30 μR/hr, the site-wide background exposure rate previously established for site repositories.

As documented in the following section, the first two criteria—radon barrier meeting the 2 pCi/g criterion and updated radon model and NESHAPS sampling results less than the 20 pCi/m^2-s radon flux limit—have been satisfied at GHP-2. However, based on sampling and gamma measurements conducted to date, the latter two criteria—Ra-226 $\leq$10 pCi/g for the frost protection layer and exposure rates $\leq$30 µR/hr—have not been met. This is because Umetco has excavated nearly all soils containing low Ra-226 (< 10 pCi/g) from existing borrow areas and—most important—the background levels on which these criteria were based have since been demonstrated to be unrealistically conservative. The following sections discuss historical issues and more recent data supporting this finding.

1.2.1 Borrow Area Sources and Incidental Boundary Revision

Since 1997, Umetco has conducted mining activities in search of suitable cover soils for completion of the Above Grade, Heap Leach, A-9, and GHP-2 repositories. These materials were sorted from reclaimed mining areas to the east and south of the site within Umetco's Mine Permit boundaries. In 2004 it became evident that the supply of suitable cover materials was diminishing. Therefore, Umetco submitted a request for an Incidental Boundary Revision (IBR) encompassing approximately 82.5 acres in two areas west of the present Gas Hills 349C Mine Permit Boundary (Umetco 2004b). This area is shown in Figure 1. The northern 60-acre portion includes the Moore Ranch Borrow Area, a mine pit previously reclaimed by the Wyoming Department of Environmental Quality, Abandoned Mine Lands Division (AML). The southern 22.5-acre portion is designated for regrading of the North-South Evaporation Ponds.

To date, approximately 36 acres of soil from the Moore Ranch Borrow Area have been excavated and placed as cover materials at the Gas Hills site repositories. This leaves only 24 acres—or 29 percent of the 82.5 acre IBR—remaining for use as a borrow source. To meet the radiological criteria above (10 pCi/g Ra-226 and 30 µR/hr exposure rate), Umetco anticipates disturbing an additional 30 to 40 acres of previously undisturbed ground to yield the required volume – more than the borrow material available within our mine permit boundaries. This forecast/assumption is based on Umetco's experience placing 10 pCi/g cover on site repositories—corresponding to a total excavation volume of approximately 1.5 million cubic yards. Additionally, based on recent gamma surveys conducted in the remaining borrow areas, the radium content of undisturbed background soils remaining within the IBR may not meet the 10 pCi/g Ra-226 criterion. This is because the lower radium content soils have already been excavated for use as cover materials.

1.2.2 Final Status Survey Results and Background Reassessment

As documented extensively in the approved *Final Status Survey Report* (FSS Report, Umetco 2003b) and corresponding Addendum 1 (Umetco 2004a), the previously determined background levels for soil Ra-226 and exposure rates—which formed the basis for the requirements set forth in the 2003 GHP-2 Reclamation Plan—did not adequately account for the prevalence and magnitude of naturally occurring radioactive material (NORM) at and surrounding the Gas Hills site.

For example, at GHP-1, excavation of byproduct material resulted in exposure of underlying low-level ore exhibiting Ra-226 levels higher than those previously measured in affected soils. Umetco therefore proposed alternate criteria to demonstrate cleanup of GHP-1 using the B5 pit

as a local reference area. Based upon the results of extensive scientific and geochemical evaluation, supporting a site-wide background level notably higher than the previously determined 10 pCi/g, Umetco demonstrated that final status survey objectives for GHP-1 had been attained. Even though criteria previously established for the windblown and pond areas had not been achieved (due to extensive NORM presence and highly variable background conditions), the NRC approved the Final Status Survey Report in their September 2004 Technical Evaluation Report (TER). In this report, NRC staff concluded that the criteria set forth in 10 CFR Part 40, Appendix A, Criterion 6(6) had been met for the areas evaluated and that "minor deviations from the Final Status Survey Plan do not impact health, safety, or the environment."

It is important to note that at the time the (Umetco 2000b) background report was developed—the original basis for both the 10 pCi/g and 30 μR/hr criteria—Umetco did not have the data visualization and Geographic Information System (GIS) capabilities that we have today. These techniques have since allowed a much more spatially representative characterization of radiological conditions. Additionally, during that period and the ensuing discussions with the NRC, both parties believed it possible to derive a single number that was representative of background conditions for the heterogeneous Gas Hills vicinity. But after extensive remediation and additional site characterization, it is evident that this is not case (Umetco 2003b, 2004a, NRC 2001, NRC 2004). In fact, in the 2004 TER, the NRC states:

> *"Background Ra-226 and uranium values are difficult to quantify because the site is on land containing natural deposits of uranium, open pit uranium mines are on and adjacent to the site, and the Wyoming Abandoned Mines Program has used mine overburden (spoils) to fill some adjacent open pit mines so that surface soil contains up to 20 pCi/g Ra-226."*

This conclusion is germane to GHP-2, as the Moore Ranch borrow area is on AML reclaimed land. In summary, the deviations requested herein are consistent with the conclusions drawn for the Final Status Survey efforts conducted to date (Umetco 2003b, 2004a) and corresponding NRC approvals (NRC 2001, 2004). If approved, these deviations will also prevent any further unnecessary disturbance of borrow area soils.

1.2.3 Organization and Contents

Following this introduction, Section 2 discusses the status of the GHP-2 pond reclamation. Section 3 documents the rationales supporting the deviation from the 10 pCi/g average Ra-226 cover criterion. Section 4 presents data supporting the requested increase in the allowable average exposure rate. References are provided in Section 5. Appendix A presents detailed soil sampling results for both subgrade and radon barrier sampling. Appendix B and Appendix C document the radon attenuation model re-runs and the supporting ALARA (As Low as Reasonably Achievable) analysis, respectively. Attachment 1 includes replacement pages for those portions of the September 2003 *Final Design and Reclamation Plan* that would be affected by this license amendment request.

2.0 GHP-2 RECLAMATION STATUS

Except for additional sampling scheduled for Spring 2006 and construction of the erosion protection layer, reclamation of the GHP-2 pond is nearly complete. In fact, Umetco can proceed with rock placement if the deviations requested herein are agreed to by the NRC. Table 2.1 summarizes the status of the GHP-2 pond reclamation.

2.1 Radon Barrier

The radon barrier was placed August through October 2005 in accordance with Section 5.4 of the Reclamation Plan. In accordance with the plan, soil samples were collected during radon barrier construction at a frequency of 1 sample per 800 cubic yards, or approximately 1 sample per acre per lift of soils. Laboratory analysis of these samples verified that the average Ra-226 content of the radon barrier soils meets the 2 pCi/g criterion. For the 26 composite samples collected, the average Ra-226 is 2 pCi/g (2.36 pCi/g rounded to 1 significant figure). Detailed results are provided in Appendix A.

2.2 Soil Verification Samples – Frost Protection

The frost protection layer of the GHP-2 cover was constructed with soils obtained primarily from the Moore Ranch Borrow Area. In accordance with the Reclamation Plan, frost protection cover materials were continuously gamma surveyed and the upper two feet sampled and analyzed for Ra-226 content. Eleven of the proposed 15 grids were sampled in December 2005; the remaining four grids will be sampled in Spring 2006. Site analysis of these verification samples indicates an average Ra-226 content of 13.8 pCi/g for the 0-1 foot depth profile and 14 pCi/g for the 1-2 foot profile.

These results exceed the previously approved 10 pCi/g criterion. The reason for this exceedance is twofold. First, as discussed in Section 1, there appears to be a diminishing supply of lower radium content cover soils in the borrow areas. Second, the meter cut-off historically used by Umetco to estimate soil radium content ultimately resulted in an underestimation of frost protection material radium content for GHP-2. This finding is discussed further below.

Based on Umetco's experience with placement of site cover materials at the C-18 and other repositories, a meter cut-off limit of 16,000 counts per minute (cpm) was applied to GHP-2 as well. Historically, this limit had been a reliable indicator that the 10 pCi/g cover criterion would be achieved. Samples collected during the early phase of frost protection placement on GHP-2 (October 2005) indicated that this was the case, but this material was from the A-9 Highwall borrow source, not Moore Ranch which was ultimately used for the majority of the GHP-2 cover placement. Later analysis of samples collected from Moore Ranch indicated that this material has a different radiological footprint from that of cover materials previously placed. For example, because there was no apparent thorium-232 (Th-232) contribution, the gamma being observed was primarily from the Ra-226 609 kev energy peak. As such, utilizing the previously valid 16,000 cpm cut-off limit resulted in an underestimation of cover material radium content for GHP-2.

Table 2.1. Summary of GHP-2 Reclamation Status

GHP Task/ Pond Layer	Status	Comment
Solidification, liner removal, and pond regrading	Complete	This phase included solidifying remaining liquids and evaporative residue, removal and disposal of the pond liner, and pond re-grading — 24,570 cubic yards of the liner soil was used to construct the radon barrier (see below)
Radon Barrier	Completed in October 2005	Results of recent collimated field gamma surveys conducted in 2005 verify that that clay soils excavated from the GHP-2 liner and used for construction of the radon barrier had an average Ra-226 content of 2 pCi/g.
Frost Protection	Layer placed in December 2005, sampling complete at 11 of proposed 15 grids	In the Sep-03 *Reclamation Plan*, Umetco stated that "The radium activity input for the frost protection layer assumes the approved ^{226}Ra site-wide background value of 10 pCi/g." Although not complete (4 grids scheduled for sampling in Spring 2006), sampling conducted in December 2005 yielded higher values than this (10.8-16.4 pCi/g), averaging approximately 14 pCi/g in both 0-1 and 1-2 ft depth profiles. As such, and a key factor driving this amendment, Umetco is requesting deviation from the previous 10 pCi/g standard.
Radon Attenuation Design/Model	Revised version included in this submittal	Given the increased Ra-226 content in frost protection cover material cited above, and also to reflect more recent subgrade soil sampling results, the radon model used for the radon attenuation design for the GHP-2 cover was rerun. As documented in Section 3 and Appendix B, the model results are still below the 20 pCi/m^2-s radon flux limit criterion.
NESHAPS Sampling	58 of the scheduled 100 locations have been sampled	NESHAPS sample locations are shown in Figure 2. The current average based on the 58 samples collected to date is 6.8 pCi/m^{2}/s. This value is well below the 20 pCi/m^2-s criterion. The remaining 42 locations will be sampled in Spring 2006.
Gamma Exposure Survey	Majority completed on 10/24/05, remainder scheduled for Spring 2006	As shown on Plate 1, two areas remain to be surveyed (these have not been graded) Of the 6,961 exposure rate data points, only 2 are below the current 30 μR/hr exposure rate criterion. The majority are between 30 and 40 μR/hr, and the average is 38 μR/hr. These results—coupled with the conservatism of the 30 μR/hr background exposure rate—underlie the second area of deviation requested herein.
Erosion Protection	Scheduled for April 2006	The schedule for rock placement is contingent upon NRC approval of this license amendment.

Table 2.2 GHP-2 Frost Verification Samples: 0-1 and 1-2 ft Depths

GHP-2 Grid	Depth	Count Date	Ra-226 (pCi/g)	Error Term
1	0-1 ft	12/6/05	14.6	± 0.60
	1-2 ft	12/6/05	12.2	± 0.52
3	0-1 ft	12/9/05	11.8	± 0.53
	1-2 ft	12/9/05	16.4	± 0.66
5	0-1 ft	12/7/05	12.3	± 0.50
	1-2 ft	12/7/05	11.2	± 0.47
7	0-1 ft	12/8/05	14.0	± 0.60
	1-2 ft	12/8/05	13.1	± 0.57
8	0-1 ft	12/6/05	14.8	± 0.60
	1-2 ft	12/6/05	13.6	± 0.57
9	0-1 ft	12/5/05	14.2	± 0.56
	1-2 ft	12/5/05	15.7	± 0.60
10	0-1 ft	12/8/05	10.8	± 0.45
	1-2 ft	12/8/05	13.2	± 0.54
11	0-1 ft	12/9/05	14.7	± 0.61
	1-2 ft	12/9/05	15.0	± 0.64
12	0-1 ft	12/6/05	15.3	± 0.61
	1-2 ft	12/6/05	14.7	± 0.58
13	0-1 ft	12/9/05	16.2	± 0.64
	1-2 ft	12/9/05	15.2	± 0.62
14	0-1 ft	12/6/05	14.2	± 0.59
	1-2 ft	12/6/05	13.8	± 0.56

Average Ra-226 0-1 ft = 13.8 pCi/g; average Ra-226 1-2 ft = 14 pCi/g (results reflect ingrowth after 21 days).
Note that within each grid, 0-1 ft and 1-2 ft samples were *not* collocated.
Grids 2, 4, 6, and 15 (not listed above) will be sampled in Spring 2006.

2.3 NESHAPS Soil Sampling

Radon emissions from uranium mill tailings are regulated by the NRC under generally applicable standards set by the Environmental Protection Agency (EPA). In accordance with these guidelines, Radon-222 emissions from uranium mill tailings are limited to an average of 20 picoCuries per meter squared per second (pCi/m2-s) for each region. NESHAPS sampling is required to demonstrate that this criterion is met.

A partial sampling of NESHAPS conducted at 58 locations on the soils used as cover for GHP-2 indicates the repository will meet the Radon Flux rate as specified in 10 CFR 40, Appendix A, Criterion 6 of 20 pCi/m^2s with the present cover materials utilized. The average Radon Flux rate for the sample locations collected to date indicate the average radon flux rate for GHP-2 is 6.8 pCi/m^2-s which is well below the standard as specified in 10 CFR 40. The remaining 42 sample locations for GHP-2 are scheduled to be sampled as weather permits in early 2006. As shown in Table 2.3, only 3 of the 58 locations sampled to date exceed the 20 pCi/m^2-s standard. Given these results, the majority of the remaining 42 sample locations would have to exceed the standard in order for the GHP-2 repository average to fail the radon flux limit criterion.

Table 2.3 GHP-2 NESHAPS Sampling Results, October 2005

Point Location	Sample ID	Radon Flux Rate (pCi/m^2s)
GHP2 NS-4	G4	20
GHP2 NS-05	G05	1.5
GHP2 NS-10	G10	17.2
GHP2 NS-11	G11	42.7
GHP2 NS-12	G12	2.8
GHP2 NS-17	G17	2.9
GHP2 NS-18	G18	1.1
GHP2 NS-19	G19	2.2
GHP2 NS-23	G23	3.6
GHP2 NS-24	G34	9.4
GHP2 NS-25	G25	21.8
GHP2 NS-29	G29	7.6
GHP2 NS-30	G30	2.7
GHP2 NS-31	G31	2
GHP2 NS-33	G33	0.9
GHP2 NS-34	G34	1.6
GHP2 NS-35	G35	17.1
GHP2 NS-36	G36	8.7
GHP2 NS-40	G40	1.5
GHP2 NS-41	G41	1.4
GHP2 NS-42	G42	1.4
GHP2 NS-43	G43	1.2
GHP2 NS-44	G44	1.2
GHP2 NS-45	G45	6.3
GHP2 NS-46	G46	8.7
GHP2 NS-51	G51	4.6
GHP2 NS-52	G52	3.8
GHP2 NS-53	G53	14.8
GHP2 NS-54	G54	12.9
GHP2 NS-55	G55	1.2
GHP2 NS-56	G56	3.7
GHP2 NS-57	G57	1.2
GHP2 NS-59	G59	4.4
GHP2 NS-60	G60	1.4
GHP2 NS-61	G61	2.4
GHP2 NS-62	G62	4.4
GHP2 NS-63	G63	2.2
GHP2 NS-64	G64	5.4

Point Location	Sample ID	Radon Flux Rate (pCi/m^2s)
GHP2 NS-65	G65	1.9
GHP2 NS-69	G69	5.6
GHP2 NS-70	G70	1.3
GHP2 NS-71	G71	7.9
GHP2 NS-72	G72	15.4
GHP2 NS-73	G73	4.3
GHP2 NS-74	G74	2.1
GHP2 NS-75	G75	3.8
GHP2 NS-76	G76	4
GHP2 NS-77	G77	12.3
GHP2 NS-78	G78	11.5
GHP2 NS-79	G79	27.5
GHP2 NS-80	G80	9.4
GHP2 NS-81	G81	8
GHP2 NS-82	G82	13.6
GHP2 NS-86	G86	3.2
GHP2 NS-87	G87	5.3
GHP2 NS-88	G88	6.1
GHP2 NS-89	G89	1.1
GHP2 NS-90	G90	1

All samples collected on 10/24/05.
Average flux rate: 6.8 pCi/m^2s
58 of 100 proposed sampling locations collected
Remaining locations to be sampled in Spring 2006

2.4 GHP-2 Exposure Survey

Direct gamma radiation exposure rates for GHP-2 were determined by conducting RMGPS scans over the frost protection layer on October 24, 2005. All data were from scintillation measurements using a bare detector held one meter above the repository cover surface. Calibration of the radiation survey instruments was performed utilizing a Pressurized Ionization Chamber (PIC). Scans were conducted utilizing an ATV on approximately parallel offsetting traverses of the cover approximately 10 meters apart, while moving along the traverse at a rate not exceeding 0.5 meters per second. Results of the gamma radiation exposure survey for GHP-2 are shown on Plate 1.

Of the 6,961 survey data points, only 2 are below the current 30 μR/hr exposure rate criterion. The majority are between 30 and 40 μR/hr, and the average is 38 μR/hr. As such, most results exceed the previously established site-wide background exposure rate of 30 μR/hr. This conservative background value had been used historically by Umetco to demonstrate that gamma exposure levels for the tailings repositories meet the requirements set forth in 10 CFR 40, Appendix A, Criterion 6(1). The higher exposure rates measured over GHP-2 (relative to the A-9 for example) are not unexpected, as there is typically a correlation between soil Ra-226 content and gamma exposure rates. Given the higher radium content measured in frost protection cover soils, it is not surprising that exposure rates were higher as well.

3.0 REQUEST FOR ALTERNATE CRITERIA: COVER SOIL RA-226 CONTENT

As discussed in the preceding section, the Ra-226 content of frost protection cover materials in place at GHP-2 exceeds the previously established 10 pCi/g criterion. This criterion was based on a conservatively derived background value which did not adequately account for the prevalence and magnitude of naturally occurring radioactive material (NORM) at and surrounding the Gas Hills site. Even the NRC (in their 2004 TER) later acknowledged the difficulty in quantifying background Ra-226, along with the fact that the adjacent AML lands, some of which coincide with Umetco's borrow area sources, have surface soils containing up to 20 pCi/g Ra-226. Given these findings, Umetco is requesting that the allowable average Ra-226 content in cover (frost protection) soils be changed from 10 pCi/g to 15 pCi/g.

Section 3.1 reiterates the rationales use to justify this deviation, initially discussed in Section 1.2.2. To verify that this request would be health-protective, the radon model used to evaluated the radon attenuation design for GHP-2 was re-run using a higher radium content (15 pCi/g vs. 10 pCi/g) for the frost protection layer (Section 3.2). An ALARA analysis was also performed to assess the costs and benefits associated with removal and replacement of cover soils to meet the 10 pCi/g criterion (Section 3.3).

3.1 Rationales for Deviation from the 2003 GHP-2 Reclamation Plan

The primary rationales supporting revising the average allowable Ra-226 content in frost protection (cover) materials for GHP-2 are follows:

- Background as originally established and forming the basis for the 10 pCi/g cover criterion is too low. Difficulties related to the derivation of representative background values for the highly heterogeneous and mineralized Gas Hills region are discussed at great length in the FSS Report and, as discussed previously, were corroborated by the NRC.

- 10 CFR Part 40, Appendix A, Criterion 6(6) requires that the soil radium concentration resulting from byproduct material, averaged over areas of 100 square meters, does not exceed background levels by more than 5 pCi/g of Ra-226 averaged over the first 15 cm (6 inches), or 15 pCi/g for 15-cm thick layers at underlying depths. Although not directly comparable to GHP-2 because a different averaging area is used to demonstrate that the cover meets criteria, it is worth noting that the 15 pCi/g deviation requested herein is consistent with the soil cleanup criteria applied at other site areas, e.g., GHP-1.

- Based on recent gamma surveys and historical data, most of the lower radium content borrow area soils have already been excavated. Therefore, the 10 pCi/g criterion may be difficult to meet without extensive disturbance of remaining borrow area soils.

3.2 Effects on Radon Flux Model

The radon attenuation design for the GHP-2 cover was evaluated using the RADON computer code, Version 1.2, February 2, 1989. Model runs were conducted using the input parameters documented in the 2003 *Final Design and Reclamation Plan* and assuming an average radium

activity for the frost protection layer of 10 pCi/g Ra-226. Because of the deviation requested herein—increasing the allowable average Ra-226 in frost protection soils from 10 pCi/g to 15 pCi/g—it was necessary to re-run this model. Additionally, based on recent sampling, the Ra-226 input initially assumed for subgrade layers is also no longer valid. As documented in Appendix A (Table A.1), the layer-specific subgrade Ra-226 averages have decreased—essentially halved for Layers 1 through 4.

To account for these differences, two model runs were performed. The first retained all input parameters used in the September 2003 model RUN 2* (see note below) except for the frost protection layer (Layer 6), for which the Ra-226 content was increased from 10 to 15 pCi/g. The second was run to provide a more representative case, accounting for the increased radium in Layer 6, but the decreased radium in subgrade layers documented in Appendix A. Results of the radon attenuation design model reruns are documented in Appendix B and summarized in Table 3.1 (below). For comparison purposes, this table also lists the radium values assumed in the original September 2003 model run.

Table 3.1 January 2006 RADON Model Results

Layer No.	Sep-03 RUN 2* Ra-226 (pCi/g)	Jan-06 Run 1 Ra-226 (pCi/g)	Jan-06 Run 2 Ra-226 (pCi/g)
Layer 1 – Waste	62	62	29
Layer 2 – Waste	55	55	31
Layer 3 – Waste	62	62	28
Layer 4 – Waste	69	69	21
Layer 5 - Radon Barrier	2	2	2
Layer 6 - Frost Protection	10	15	15
Model Results: Calculated Exit Flux	14.30 pCi/m^2-s	18.7 pCi/m^2-s	14.60 pCi/m^2-s

* *Most site-specific (realistic) run performed for the September 2003 radon attenuation design.*

The RADON models run to support this license amendment resulted in an exit flux of 18.7 pCi/m^2-s and 14.6 pCi/m^2-s for model runs 1 and 2, respectively. Both results are below the 20 pCi/m^2-s exit flux limit established in 10 CFR 40, Appendix A, Criterion 6.

3.3 ALARA Analysis

Based on the detailed analysis provided in Appendix C of this License Amendment, this section evaluates the potential costs and benefits of not implementing the deviations requested in this license amendment—i.e.: What would be the effect on public dose and associated reclamation costs if Umetco proceeded with removal and replacement of frost protection cover soils to meet the 10 pCi/g average Ra-226 cover criterion?

To address this question, an ALARA analysis was performed consistent with NRC guidance (NUREG-1727, NRC 2000). A similar evaluation was undertaken for the approved FSS Addendum 1 to support a no further action alternative for cleanup of GHP-1 and the windblown

area (Umetco 2004a). The following analysis uses the same approach and most of the same assumptions as those used in the 2004 ALARA evaluation. The only exceptions are the costs (see below) and the expected Ra-226 reduction. For this analysis, the expected reduction is 5 pCi/g—equivalent to 15 pCi/g, the deviation in allowable radium content for cover materials requested herein, minus the current 10 pCi/g criterion. This section is a brief summary of the detailed analysis provided in Appendix C.

3.3.1 ALARA Cost Estimate

Cost implications of placing an additional two feet of 10 pCi/g material over GHP-2 are documented in Appendix C, Table C.1 and summarized here as follows[†]:

- Removal of 120,000 cubic yards of frost protection currently in place that exceeds the 10 pCi/g Ra-226 criterion (estimated $2.60 per cubic yard or $313,000)
- Replacement of 120,000 cubic yards of 10 pCi/g material obtained from borrow area reclamation (estimated $2.75 per cubic yard or $331,000)
- Assuming likely rejection of a percentage of excavated material based on historical observations (30 percent assumed herein), additional costs of $94,000
- Disturbance of an additional 30 to 40 acres of previously undisturbed borrow material (Umetco has already disturbed 36 acres or approximately 42 percent of the 82.5-acre boundary revision), corresponding to revegetation and topsoil removal and replacement costs of approximately $167,000

[†] Total volumes and costs summarized above are rounded to 2 to 3 significant figures – see Appendix C (ALARA Analysis), Table C.1 calculation sheet for detailed costs.

The above estimates yield a total cost of approximately $905,000 to meet the 10 pCi/g cover standard which has already been demonstrated to be well within the established background range for the Gas Hills site. Additional factors not accounted for in this estimate include a likely increase in the riprap and cover size and also potential impacts on the diversion channel design.

The rejection rate noted above requires further explanation. To date, Umetco has excavated and placed approximately 1.5 million cubic yards of 10 pCi/g Ra-226 material in the repositories. Although difficult to quantify because rejection rates have varied historically depending on the borrow source (8 to 50%), the amount of material disturbed but rejected due to elevated Ra-226 content must be accounted for. In this case, to yield another 120,000 cubic yards of frost protection material soil meeting the 10 pCi/g criterion, Umetco might have to disturb twice that amount. The above cost estimate assumes a rejection rate of 30 percent, which is likely an underestimate given the recent difficulty in finding lower radium content borrow soils.

3.3.2 ALARA Results

As documented in Appendix C, two scenarios were evaluated. This was done to be consistent with the ALARA analysis undertaken for the FSS Addendum 1 Report. The first scenario represents a best-estimate exposure scenario, and the second—considered an upper bound or worst-case scenario—assumes a greater outdoor exposure fraction. Results of the ALARA calculations for both these scenarios are documented in Appendix C (Tables C.3 and C.4) and summarized in Table 3.2 below.

Table 3.2 Summary of GHP-2 License Amendment ALARA Analysis Results

Scenario	Model Permutation	Scenario Description	$PW(AD_{collective})$, in person-rem	B_{AD}	Cost per person-rem
1	Best Estimate	Ra-226 DCGL=141 pCi/g: most realistic exposure scenario	0.29	$586	$3,088,000 (rounded)
2	Upper Bound Exposure Scenario	Ra-226 DCGL=26.9 pCi/g: worst-case scenario	1.54	$3,073	$589,000 (rounded)

Interpretation of Results:

$PW(AD_{collective})$ is the present worth of the future collective averted dose. B_{AD} represents the benefit from averted dose for a remediation action—or $PW(AD_{collective})$ * $2000/person-rem. According to NRC guidance (NUREG-1727, NRC 2000), any future corrective action that costs more than the calculated B_{AD} value does not support a concomitant benefit. In this case, $905,000—the estimated costs of removal and replacement of GHP-2 cover soils—far exceeds both $586 and $3,073, the B_{AD} values calculated herein for best estimate and upper bound scenarios.

As shown above, costs per person-rem for the worst-case and most realistic exposure scenarios are $589,000 and $3,088,000, respectively. These costs are substantially higher than the $20,000 cost per person-rem considered "prohibitively expensive" by the NRC (NUREG-1727).

Summary

Radiation protection regulations mandate that doses be ALARA, taking into account the economics of improvement in relation to benefits to public health and safety as well as other factors. License termination, or site decommissioning, requires that the licensee demonstrate that the applicable dose criteria have been met and that doses are ALARA. The results of the Appenix C ALARA analysis demonstrate that removal and replacement of GHP-2 cover soils to meet a 10 pCi/g (vs. 15 pCi/g) Ra-226 criterion is not justified.

4.0 REQUEST FOR ALTERNATE CRITERIA: EXPOSURE RATE REVISION

An increase in the allowable average Ra-226 content of cover soils necessitates a concomitant increase in the allowable exposure rate, as the two endpoints are usually correlated. As discussed in Section 2.4, the October 2005 gamma exposure survey of the top portion of GHP-2 after cover placement yielded an average exposure rate of 38 μR/hr—in fact, all but 2 of the 6,961 survey data points exceed the current 30 μR/hr criterion. Given these findings, Umetco is requesting a revision in the allowable average exposure rate from 30 μR/hr to 40 μR/hr. The rationales supporting this request are documented below.

4.1 Factors Underlying the 30 μR/hr Background Exposure Rate Derivation

The site-wide background exposure rate of 30 μR/hr was established based on the data presented in Appendix A of the *Final Background Characterization Report* (Umetco 2000b). This conservative background value has since been used by Umetco to demonstrate that gamma exposure levels for the tailings repositories meet the requirements set forth in 10 CFR 40, Appendix A, Criterion 6(1).

As was the case for the windblown area background value, the 30 μR/hr background exposure rate was established after extensive discussion with the NRC, and was essentially a negotiated value. In early 2000, the NRC requested a conservative value representing central tendency rather than accounting for the well-established variability in background exposure rates. Also, because the data set was not normally distributed, the NRC requested that the geometric mean of 30.5 μR/hr be used instead of the arithmetic mean of 33.5 μR/hr.

This conservatism in the exposure rate background has not been an issue to date, because for most areas Umetco has met the 30 μR/hr criterion (an exception is the shine noted for the A-9 as documented in Addendum 2 of the FSS Report). However, it does require re-evaluation for GHP-2, as the criterion will be difficult to meet. Several aspects of the 30 μR/hr background rate derivation warrant reassessment. First, irrespective of the distribution of the original data set, it may not be valid to compare an average exposure rate (e.g., for the GHP-2 cover) with a criterion that was based on a more conservative geometric mean.

Second, recent increased capabilities in data mapping and visualization techniques have allowed Umetco to better assess the geographic distribution of data. For example, Figure 4 maps the exposure rate data used as the basis for the 30 μR/hr criterion. As shown on this map, a clear spatial pattern is evident. The lower (< 30 μR/hr) background rates are found east of the site, but in the area west of the site, corresponding to the Moore Ranch Borrow Area (the source of GHP-2 cover material), the exposure rates are clearly higher, with virtually all exceeding 30 μR/hr.

4.2 Exposure Rates in Adjacent Mining Regions

In addition to the factors discussed above, the 35 μR/hr exposure rate is consistent with levels measured for the NRC commissioned 1981 EG&G aerial radiological survey of the Gas Hills Mining District (EG&G 1982). The results of this survey, shown in Figure 5, indicate terrestrial exposure rates ranging from 30-45 μR/hr in the mining regions west and south of the Gas Hills site.

5.0 REFERENCES

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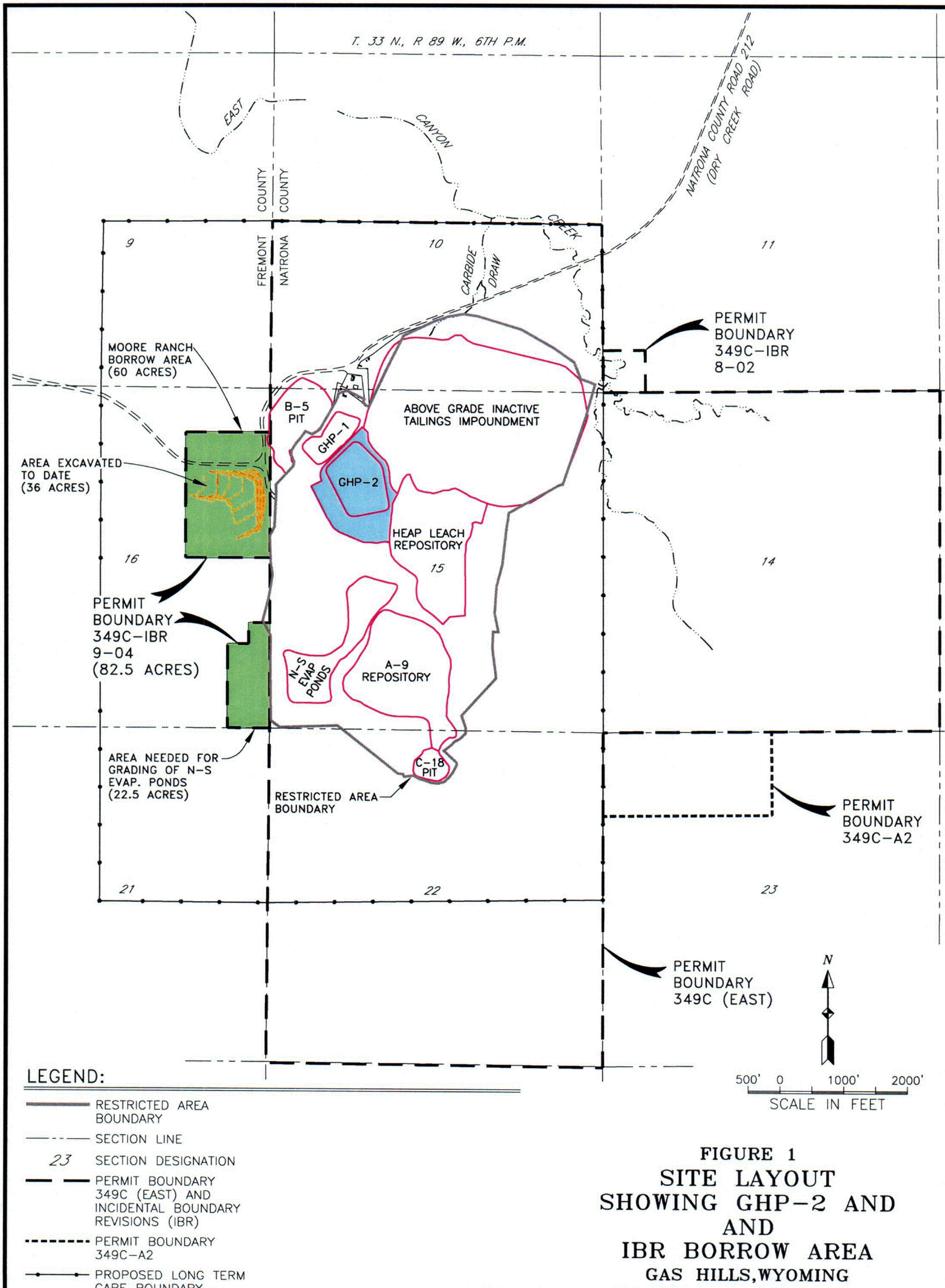


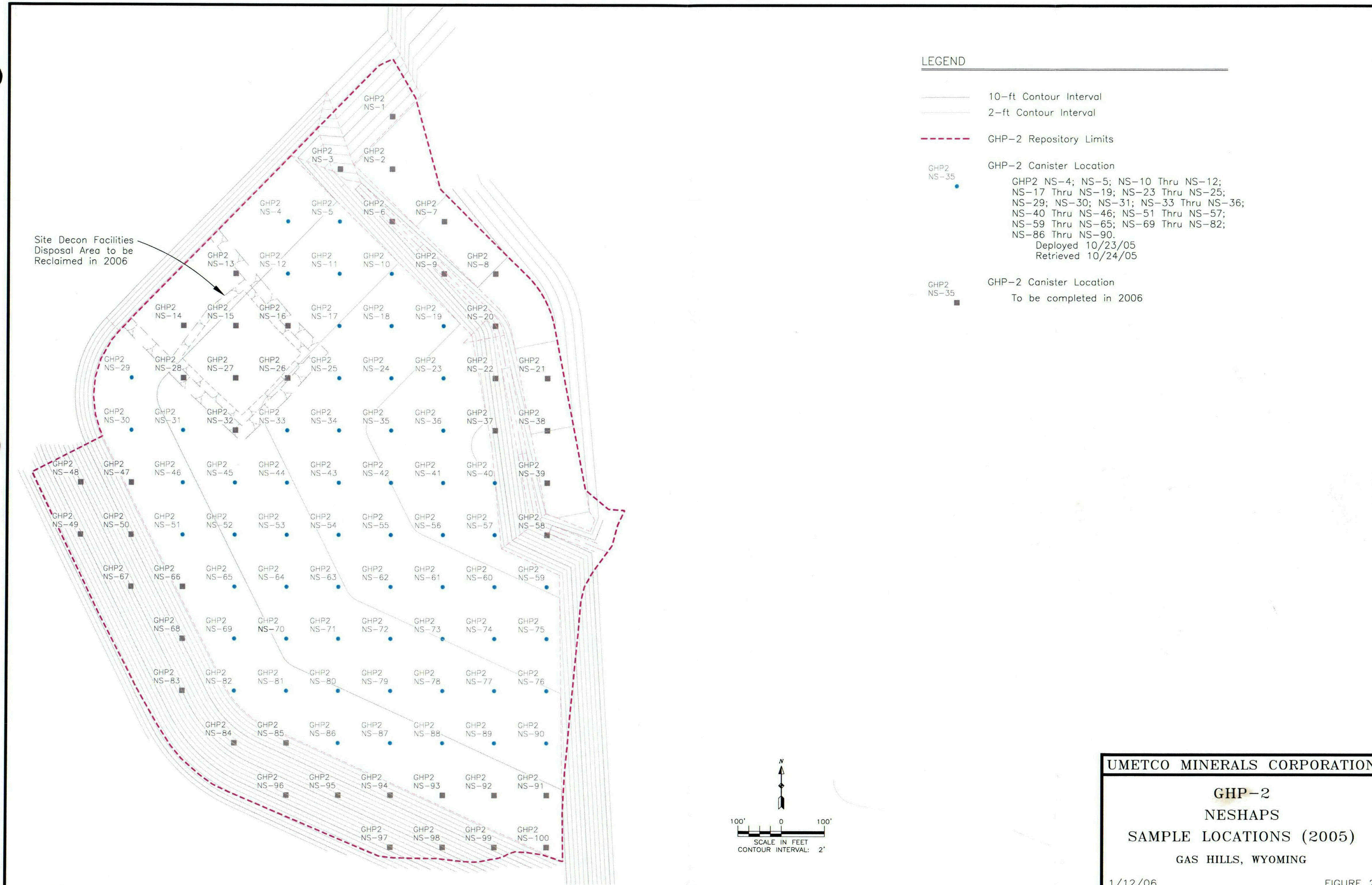
FIGURE 1

SITE LAYOUT SHOWING GHP–2 AND AND IBR BORROW AREA

GAS HILLS, WYOMING

GH–SITE–ACRES.DWG

C01



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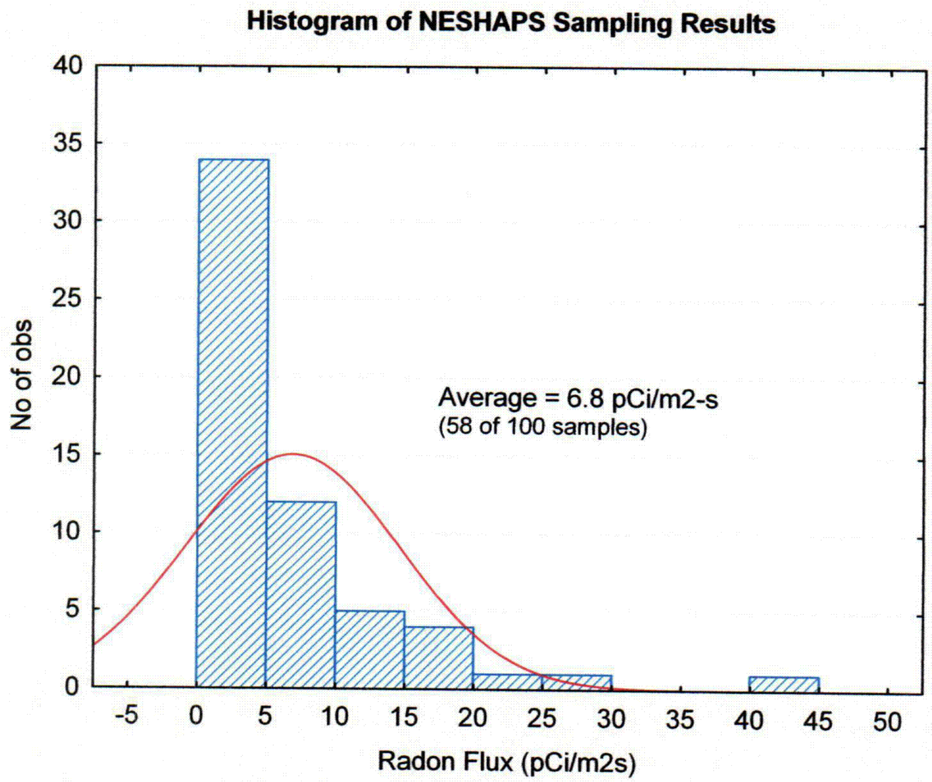
GHP-2
NESHAPS
SAMPLE LOCATIONS (2005)
GAS HILLS, WYOMING

1/12/06 FIGURE 2

GHP2-Neshaps-2005.dwg

CO2



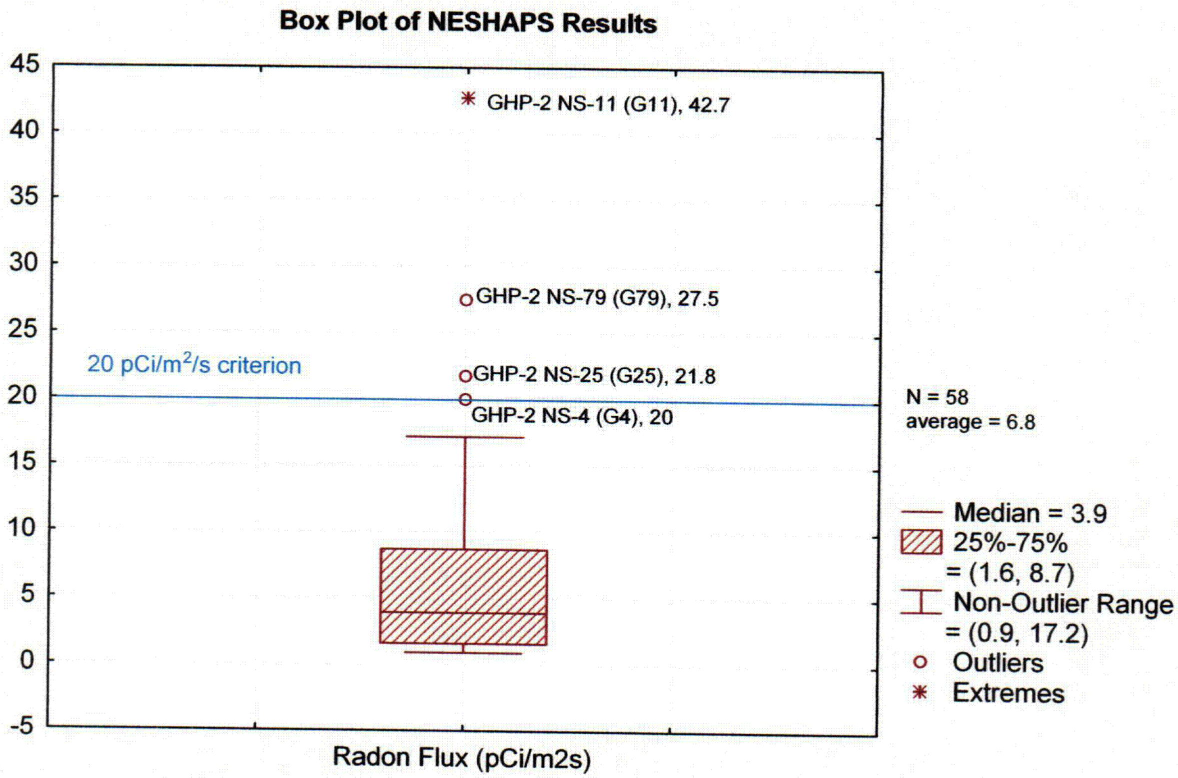
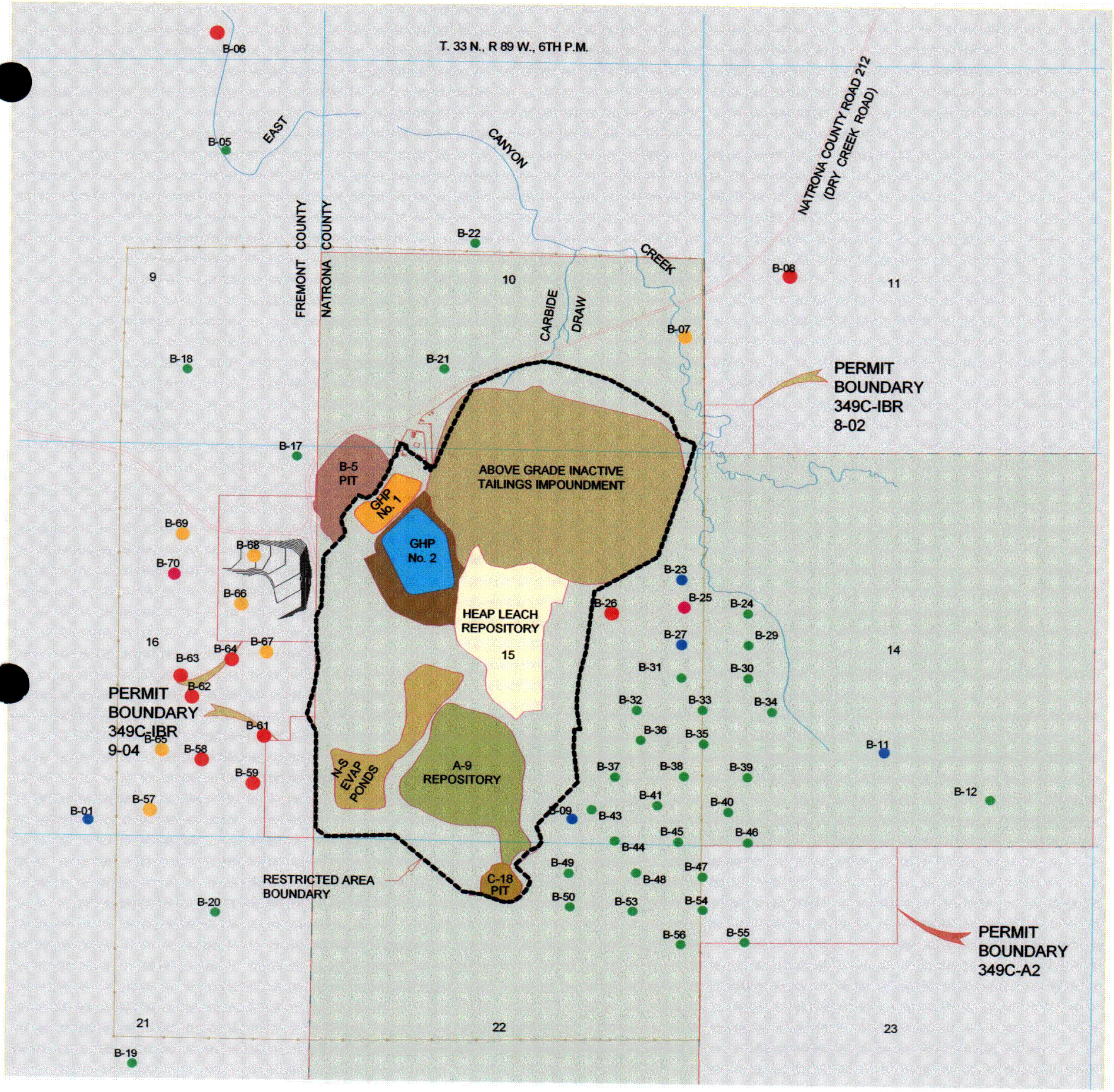


Figure 3. Plot of October 24, 2005 NESHAPS Sampling Results for GHP-2 Gas Hills Site, Wyoming

C03

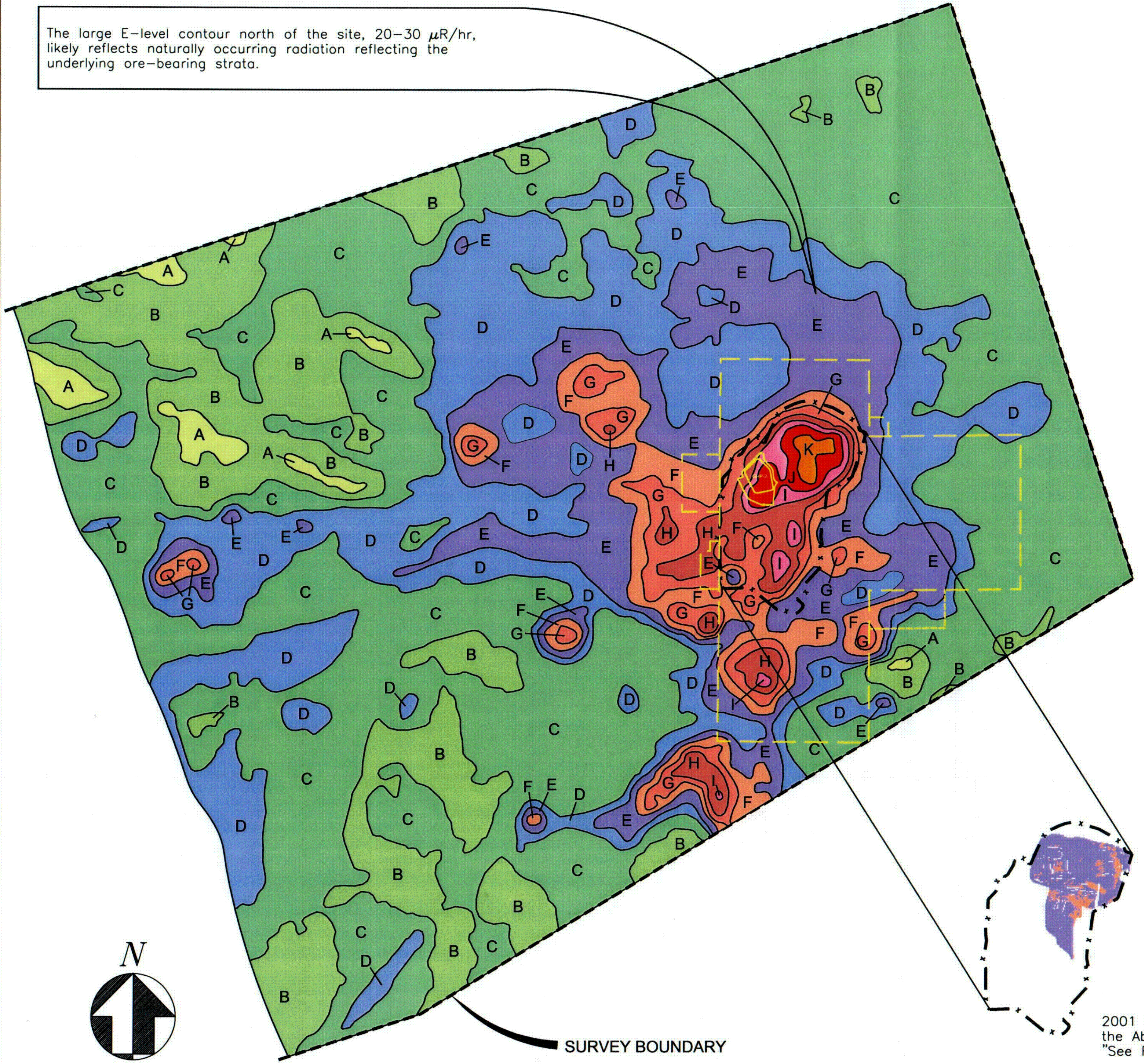


Exposure Rate in uR/hr

- 16 - 30
- 31 - 35
- 36 - 40
- 41 - 50
- 51 - 97

Figure 4
Map of Exposure Rate Measurements Used as the Basis for the Umetco 2000 Background Report
Gas Hills, Wyoming Site

C04



SCALE: 1" = 4000'

2001 Exposure Measurements for the Above Grade and Heap Leach. "See FSSR Plates 1 and 2"

LEGEND

- GAS HILLS SITE RESTRICTED AREA BOUNDARY
- PERMIT BOUNDARY 349C (EAST), 349C-IBR-8-02, AND 349C-IBR-9-04
- PERMIT BOUNDARY 349C-A2
- EG&G SURVEY BOUNDARY

	TERRESTRIAL EXPOSURE RATE AT 1m HEIGHT (μR/h)
A	5 - 8
B	8 - 11
C	11 - 15
D	15 - 20
E	20 - 30
F	30 - 45
G	45 - 65
H	65 - 100
I	100 - 150
J	150 - 250
K	250 - 450

Source:

EG&G 1982, Figure 2: Isoradiation Contours of Terrestrial Gamma Ray Exposure Rate on an Aerial Photograph of the Gas Hills Mining District. Date of Photo: June 1981. As noted in Figure 4, survey corresponding to the Gas Hills site.

Explanation:

Contours indicate gamma ray exposure rate extrapolated to 1m above the ground due to terrestrial sources only, inferred from gamma count rate observed at 76m altitude. Extrapolation valid only over large areas comparable to detectors field-of-view. Cosmic rays contribute an additional exposure rate of approximately 6.8 μR/hr to the reported values. Due to averaging over large areas by the aerial detection system, exposure rates reported over highly localized sources of radiation may be underestimated (EG&G 1982).

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EARLY RADIOLOGICAL SETTING IN THE EAST GAS HILLS MINING DISTRICT EXPOSURE RATE CONTOURS JUNE 1981

JANUARY 2006

FIGURE 5

FIG-5.DWG

C05

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"UMETCO MINERALS CORP. EAST GAS HILL GHP #2 GAMMA EXPOSURE RATE PLATE 1",

WITHIN THIS PACKAGE... OR, BY SEARCHING USING THE DOCUMENT/REPORT

D01

Appendix A

GHP-2 Subgrade and Radon Barrier Soil Sampling Results

Table A.1.

GHP-2 Subgrade Radium-226 Soil Sampling Results

Composite Sample Depth (ft)	GHP-2 Subgrade Layer	Grid Number	Preparation & Initial Count Date	Ingrowth Count Date	Initial Results ^{226}Ra pCi/g	Ingrowth Results ^{226}Ra pCi/g (after 21 days)	Radon Model Input Parameters ^{226}Ra pCi/g
0-3'	Layer 4	1	7/25/2005	8/17/2005	19.3	24.3	69
3-6'	Layer 3	1	7/25/2005	8/17/2005	71.9	85.7	62
6-9'	Layer 2	1	7/25/2005	8/17/2005	101.1	125.1	55
9-12'	Layer 1	1	7/25/2005	8/17/2005	132.6	167.2	62
12-16'		1	7/25/2005	8/17/2005	126.3	164.0	62
0-3'	Layer 4	2	5/23/2005	6/26/2005	---	75.0	69
3-6'	Layer 3	2	5/23/2005	6/26/2005	---	68.5	62
6-9'	Layer 2	2	5/23/2005	6/26/2005	---	71.6	55
9-12'	Layer 1	2	5/23/2005	6/26/2005	---	62.0	62
12-15'		2	5/23/2005	6/26/2005	---	69.0	62
15'+		2	5/23/2005	6/26/2005	---	113.0	62
0-3'	Layer 4	3	5/23/2005	6/26/2005	9.0	15.9	69
3-6'	Layer 3	3	5/23/2005	6/26/2005	24.1	26.4	62
6-9'	Layer 2	3	5/23/2005	6/26/2005	13.1	14.9	55
9-12'	Layer 1	3	5/23/2005	6/26/2005	22.2	24.5	62
12-15'		3	5/23/2005	6/26/2005	21.2	23.2	62
15'+		3	5/23/2005	6/26/2005	22.0	26.2	62
0-3'	Layer 4	4	5/23/2005	6/27/2005	14.4	17.8	69
3-6'	Layer 3	4	5/23/2005	6/27/2005	14.7	19.4	62
6-9'	Layer 2	4	5/23/2005	6/27/2005	21.1	28.0	55
9-12'	Layer 1	4	5/23/2005	6/27/2005	11.5	14.7	62
12-15'		4	5/23/2005	6/27/2005	15.2	18.8	62
15'+		4	5/23/2005	6/26/2005	22.6	28.7	62
0-3'	Layer 4	5	5/23/2005	6/14/2005	12.8	14.9	69
3-6'	Layer 3	5	5/23/2005	6/14/2005	14.5	18.6	62
6-9'	Layer 2	5	5/23/2005	6/14/2005	17.4	21.6	55
9-12'	Layer 1	5	5/23/2005	6/24/2005	17.6	24.4	62
12-15'		5	5/23/2005	6/24/2005	15.6	20.9	62
15'+		5	5/23/2005	6/24/2005	27.5	36.0	62
0-3'	Layer 4	6	7/28/2005	9/14/2005	16.1	16.6	69
3-6'	Layer 3	6	7/28/2005	9/14/2005	13.2	15.6	62
6-9'	Layer 2	6	7/28/2005	9/14/2005	11.2	13.5	55
9-12'	Layer 1	6	---	---	---	---	62
12-16'		6	---	---	---	---	62
0-3'	Layer 4	7	7/27/2005	12/19/2005	17.7	23.2	69
3-6'	Layer 3	7	7/27/2005	12/13/2005	9.9	16.4	62
6-9'	Layer 2	7	7/27/2005	12/19/2005	13.6	18.0	55
9-12'	Layer 1	7	7/27/2005	9/14/2005	12.4	18.1	62
12-16'		7	7/27/2005	9/14/2005	12.7	18.7	62

Table A.1.
GHP-2 Subgrade Radium-226 Soil Sampling Results

Composite Sample Depth (ft)	GHP-2 Subgrade Layer	Grid Number	Preparation & Initial Count Date	Ingrowth Count Date	Initial Results ^{226}Ra pCi/g	Ingrowth Results ^{226}Ra pCi/g (after 21 days)	Radon Model Input Parameters ^{226}Ra pCi/g
0-3'	Layer 4	8	7/26/2005	8/23/2005	11.6	15.3	69
3-6'	Layer 3	8	7/26/2005	8/23/2005	12.3	16.5	62
6-9'	Layer 2	8	7/26/2005	8/23/2005	11.2	15.2	55
9-12'	Layer 1	8	7/26/2005	8/23/2005	11.2	11.0	62
12-16'		8	7/26/2005	8/23/2005	28.2	34.7	62
0-3'	Layer 4	9	7/25/2005	8/15/2005	10.5	13.1	69
3-6'	Layer 3	9	7/25/2005	8/15/2005	14.3	19.2	62
6-9'	Layer 2	9	7/25/2005	8/15/2005	7.1	8.2	55
9-12'	Layer 1	9	7/25/2005	8/15/2005	15.1	19.5	62
12-16'		9	7/25/2005	8/15/2005	7.8	10.8	62
0-3'	Layer 4	10	7/20/2005	12/19/2005	79.1	106.5	69
3-6'	Layer 3	10	7/20/2005	12/19/2005	53.1	75.4	62
6-9'	Layer 2	10	7/21/2005	12/19/2005	43.7	60.7	55
9-12'	Layer 1	10	7/21/2005	12/19/2005	46.5	67.5	62
12-16'		10	7/20/2005	12/19/2005	7.4	9.4	62
0-3'	Layer 4	11	8/10/2005	9/7/2005	12.4	26.8	69
3-6'	Layer 3	11	8/3/2005	8/25/2005	7.0	10.5	62
6-9'	Layer 2	11	8/3/2005	12/14/2005	18.1	71.9	55
9-12'	Layer 1	11	7/26/2005	8/25/2005	44.7	46.0	62
12-16'		11	7/26/2005	12/14/2005	51.0	54.7	62
0-3'	Layer 4	12	7/26/2005	8/24/2005	15.2	15.2	69
3-6'	Layer 3	12	7/26/2005	8/23/2005	15.4	19.6	62
6-9'	Layer 2	12	7/26/2005	8/23/2005	29.6	38.1	55
9-12'	Layer 1	12	7/26/2005	8/23/2005	13.1	16.4	62
12-16'		12	7/26/2005	8/23/2005	16.0	21.0	62
0-3'	Layer 4	13	8/3/2005	12/15/2005	8.1	12.7	69
3-6'	Layer 3	13	7/26/2005	12/14/2005	17.6	18.7	62
6-9'	Layer 2	13	7/26/2005	12/15/2005	33.5	34.6	55
9-12'	Layer 1	13	7/26/2005	12/15/2005	14.3	15.3	62
12-16'		13	7/26/2005	12/15/2005	29.0	30.6	62
0-3'	Layer 4	14	7/28/2005	12/20/2005	34.8	37.9	69
3-6'	Layer 3	14	7/25/2005	12/20/2005	43.1	50.9	62
6-9'	Layer 2	14	7/25/2005	12/20/2005	99.2	117.8	55
9-12'	Layer 1	14	7/25/2005	12/20/2005	29.9	33.6	62
12-16'		14	7/25/2005	12/20/2005	5.9	7.7	62
0-3'	Layer 4	15	7/20/2005	12/20/2005	17.6	24.1	69
3-6'	Layer 3	15	7/20/2005	12/20/2005	10.0	12.5	62
6-9'	Layer 2	15	7/20/2005	12/20/2005	13.0	18.1	55
9-12'	Layer 1	15	7/20/2005	12/20/2005	18.8	30.0	62
12-16'		15	7/20/2005	12/20/2005	51.8	69.9	62

Table A.1.
GHP-2 Subgrade Radium-226 Soil Sampling Results

Composite Sample Depth (ft)	GHP-2 Subgrade Layer	Grid Number	Preparation & Initial Count Date	Ingrowth Count Date	Initial Results ^{226}Ra pCi/g	Ingrowth Results ^{226}Ra pCi/g (after 21 days)	Radon Model Input Parameters ^{226}Ra pCi/g
0-3'	Layer 4	16	7/20/2005	8/15/2005	17.8	26.7	69
3-6'	Layer 3	16	7/20/2005	8/15/2005	11.4	16.8	62
6-9'	Layer 2	16	7/20/2005	8/15/2005	21.7	32.5	55
9-12'	Layer 1	16	7/20/2005	8/15/2005	14.7	22.9	62
12-16'		16	7/20/2005	8/15/2005	32.1	46.5	62
0-3'	Layer 4	17	7/26/2005	8/24/2005	11.6	16.7	69
3-6'	Layer 3	17	7/26/2005	8/24/2005	11.7	15.8	62
6-9'	Layer 2	17	7/26/2005	8/25/2005	11.6	14.2	55
9-12'	Layer 1	17	7/26/2005	8/25/2005	7.6	10.4	62
12-16'		17	7/26/2005	8/25/2005	11.8	14.7	62
0-3'	Layer 4	18	7/27/2005	8/24/2005	17.9	20.1	69
3-6'	Layer 3	18	7/27/2005	8/24/2005	31.6	40.3	62
6-9'	Layer 2	18	7/27/2005	8/24/2005	7.3	10.2	55
9-12'	Layer 1	18	7/27/2005	8/24/2005	6.5	8.9	62
12-16'		18	7/27/2005	8/24/2005	6.8	9.0	62
0-3'	Layer 4	19	8/3/2005	12/20/2005	11.8	13.2	69
3-6'	Layer 3	19	7/27/2005	12/20/2005	6.6	7.5	62
6-9'	Layer 2	19	7/27/2005	12/20/2005	11.3	11.3	55
9-12'	Layer 1	19	7/27/2005	12/21/2005	11.2	25.1	62
12-16'		19	7/27/2005	12/21/2005	24.5	32.0	62
0-3'	Layer 4	20	7/28/2005	12/21/2005	18.4	22.0	69
3-6'	Layer 3	20	7/28/2005	12/21/2005	12.4	16.4	62
6-9'	Layer 2	20	7/28/2005	12/21/2005	11.0	12.8	55
9-12'	Layer 1	20	7/28/2005	12/21/2005	7.5	7.7	62
12-16'		20	7/28/2005	12/21/2005	10.1	11.8	62
0-3'	Layer 4	21	7/28/2005	12/21/2005	8.1	8.6	69
3-6'	Layer 3	21	7/28/2005	12/21/2005	10.7	11.8	62
6-9'	Layer 2	21	7/28/2005	12/21/2005	7.8	8.8	55
9-12'	Layer 1	21	7/28/2005	12/21/2005	12.5	13.7	62
12-16'		21	7/28/2005	12/21/2005	20.9	24.0	62
0-3'	Layer 4	22	7/27/2005	12/22/2005	8.0	8.7	69
3-6'	Layer 3	22	7/28/2005	12/22/2005	21.4	25.1	62
6-9'	Layer 2	22	7/27/2005	12/22/2005	14.0	15.4	55
9-12'	Layer 1	22	7/27/2005	12/22/2005	25.5	28.7	62
12-16'		22	7/28/2005	12/22/2005	22.9	28.0	62
0-3'	Layer 4	23	7/26/2005	8/25/2005	11.3	15.8	69
3-6'	Layer 3	23	7/26/2005	8/25/2005	16.5	21.1	62
6-9'	Layer 2	23	7/26/2005	8/25/2005	11.9	16.1	55
9-12'	Layer 1	23	7/26/2005	8/25/2005	11.0	12.6	62
12-16'		23	7/26/2005	8/25/2005	7.0	8.7	62

Table A.1.
GHP-2 Subgrade Radium-226 Soil Sampling Results

Composite Sample Depth (ft)	GHP-2 Subgrade Layer	Grid Number	Preparation & Initial Count Date	Ingrowth Count Date	Initial Results ^{226}Ra pCi/g	Ingrowth Results ^{226}Ra pCi/g (after 21 days)	Radon Model Input Parameters ^{226}Ra pCi/g
0-3'	Layer 4	24	7/25/2005	8/16/2005	47.8	17.3	69
3-6'	Layer 3	24	7/25/2005	8/16/2005	23.5	19.3	62
6-9'	Layer 2	24	7/25/2005	8/16/2005	25.4	30.9	55
9-12'	Layer 1	24	7/25/2005	8/16/2005	13.8	29.1	62
12-16'		24	7/25/2005	8/16/2005	13.0	56.2	62
0-3'	Layer 4	25	7/25/2005	8/15/2005	7.7	10.5	69
3-6'	Layer 3	25	7/25/2005	8/15/2005	4.8	5.3	62
6-9'	Layer 2	25	7/25/2005	8/15/2005	4.8	5.5	55
9-12'	Layer 1	25	7/25/2005	8/15/2005	4.7	5.5	62
12-16'		25	7/25/2005	8/15/2005	12.6	14.6	62
0-3'	Layer 4	26	7/25/2005	8/17/2005	13.5	19.4	69
3-6'	Layer 3	26	7/25/2005	8/17/2005	21.4	28.2	62
6-9'	Layer 2	26	7/25/2005	8/17/2005	33.0	40.0	55
9-12'	Layer 1	26	7/25/2005	8/17/2005	23.7	28.4	62
12-16'		26	7/25/2005	8/17/2005	8.8	12.5	62
0-3'	Layer 4	27	7/25/2005	8/17/2005	6.5	9.1	69
3-6'	Layer 3	27	7/25/2005	8/16/2005	19.8	27.3	62
6-9'	Layer 2	27	7/25/2005	8/16/2005	19.4	23.8	55
9-12'	Layer 1	27	7/25/2005	8/16/2005	23.5	29.8	62
12-16'		27	7/25/2005	8/16/2005	23.4	31.9	62
0-3'	Layer 4	28	7/21/2005	8/16/2005	8.0	11.7	69
3-6'	Layer 3	28	7/21/2005	8/16/2005	22.3	31.4	62
6-9'	Layer 2	28	7/21/2005	8/16/2005	25.0	34.2	55
9-12'	Layer 1	28	7/25/2005	8/16/2005	22.5	29.9	62
12-16'		28	7/25/2005	8/16/2005	7.7	9.7	62
0-3'	Layer 4	29	7/21/2005	12/22/2005	11.6	18.1	69
3-6'	Layer 3	29	7/21/2005	12/22/2005	14.7	20.7	62
6-9'	Layer 2	29	7/21/2005	12/22/2005	7.9	12.2	55
9-12'	Layer 1	29	7/21/2005	12/22/2005	4.7	7.2	62
12-16'		29	7/21/2005	12/22/2005	8.8	11.0	62
0-3'	Layer 4	30	8/2/2005	12/15/2005	1.3	19.3	69
3-6'	Layer 3	30	7/26/2005	12/22/2005	19.4	20.5	62
6-9'	Layer 2	30	7/27/2005	12/23/2005	11.3	26.5	55
9-12'	Layer 1	30	7/27/2005	12/23/2005	11.2	16.6	62
12-16'		30	7/27/2005	12/23/2005	24.5	11.9	62
0-3'	Layer 4	31	7/27/2005	12/23/2005	7.1	8.0	69
3-6'	Layer 3	31	7/28/2005	12/23/2005	14.5	17.8	62
6-9'	Layer 2	31	7/27/2005	12/23/2005	11.5	13.4	55
9-12'	Layer 1	31	7/28/2005	12/23/2005	9.2	11.1	62
12-16'		31	7/27/2005	12/27/2005	24.2	27.6	62

Table A.1.
GHP-2 Subgrade Radium-226 Soil Sampling Results

Composite Sample Depth (ft)	GHP-2 Subgrade Layer	Grid Number	Preparation & Initial Count Date	Ingrowth Count Date	Initial Results ^{226}Ra pCi/g	Ingrowth Results ^{226}Ra pCi/g (after 21 days)	Radon Model Input Parameters ^{226}Ra pCi/g
0-3'	Layer 4	32	7/28/2005	12/27/2005	10.8	11.3	69
3-6'	Layer 3	32	7/27/2005	12/27/2005	10.1	11.3	62
6-9'	Layer 2	32	7/28/2005	12/27/2005	10.4	13.0	55
9-12'	Layer 1	32	7/28/2005	12/27/2005	4.7	5.1	62
12-16'		32	7/28/2005	12/27/2005	6.5	7.1	62
0-3'	Layer 4	33	7/28/2005	12/15/2005	14.4	15.7	69
3-6'	Layer 3	33	7/28/2005	12/15/2005	2.4	3.1	62
6-9'	Layer 2	33	7/28/2005	12/15/2005	2.2	2.2	55
9-12'	Layer 1	33	7/28/2005	12/14/2005	13.7	16.8	62
12-16'		33	7/28/2005	12/15/2005	6.7	8.0	62
0-3'	Layer 4	34	7/28/2005	12/27/2005	17.7	18.7	69
3-6'	Layer 3	34	7/28/2005	12/28/2005	10.4	10.4	62
6-9'	Layer 2	34	7/28/2005	12/28/2005	8.9	10.0	55
9-12'	Layer 1	34	7/28/2005	12/28/2005	7.6	8.5	62
12-16'		34	7/28/2005	12/28/2005	7.1	7.5	62
0-3'	Layer 4	35	7/28/2005	12/28/2005	13.7	15.1	69
3-6'	Layer 3	35	7/27/2005	12/28/2005	176.2	175.3	62
6-9'	Layer 2	35	7/27/2005	12/28/2005	101.5	109.0	55
9-12'	Layer 1	35	7/27/2005	12/29/2005	19.6	22.7	62
12-16'		35	7/28/2005	12/29/2005	25.4	29.3	62
0-3'	Layer 4	36	7/26/2005	8/18/2005	10.7	13.6	69
3-6'	Layer 3	36	7/26/2005	8/18/2005	5.7	8.0	62
6-9'	Layer 2	36	7/26/2005	8/18/2005	28.0	33.3	55
9-12'	Layer 1	36	7/26/2005	8/25/2005	8.4	5.8	62
12-16'		36	7/26/2005	8/18/2005	41.8	53.4	62

Layer (Depth)	Average Initial	Average Ingrowth	Percent Ingrowth
Layer 4 (0-3')	17.1	21.1	18.9
Layer 3 (3-6')	19.1	28.0	31.8
Layer 2 (6-9')	22.2	31.5	29.4
Layer 1 (9-16'	22.7	28.5	20.5

Table A.2.

GHP-2 Radon Barrier Clay Radium-226 Soil Sampling Results

Sample Number	Sample Date	Preparation & Initial Count Date	Ingrowth Count Date	Initial Results ^{226}Ra pCi/g	Ingrowth Results ^{226}Ra pCi/g (after 21 days)	Daily Average Initial Results ^{226}Ra pCi/g	Daily Average Ingrowth Results ^{226}Ra pCi/g
GHP2-1	8/15/2005	8/16/2005	9/7/2005	2.5	3.0		
GHP2-2	8/15/2005	8/16/2005	9/12/2005	2.2	3.2		
GHP2-3	8/15/2005	8/16/2005	9/13/2005	2.0	3.0		
GHP2-4	8/15/2005	8/16/2005	9/13/2005	3.0	3.3		
GHP2-5	8/15/2005	8/16/2005	9/13/2005	2.6	3.6		
GHP2-6	8/15/2005	8/16/2005	9/13/2005	2.1	3.7	*2.4*	*3.3*
81505-1	8/15/2005	8/17/2005	9/8/2005	2.8	3.4		
81505-2	8/15/2005	8/17/2005	9/7/2005	1.6	1.6		
81505-3	8/15/2005	8/17/2005	9/8/2005	1.7	2.4	*2.0*	*2.5*
81605-1	8/16/2005	8/17/2005	9/8/2005	--	2.5		
81605-2	8/16/2005	8/17/2005	9/6/2005	--	2.9		
81605-3	8/16/2005	8/17/2005	9/8/2005	2.2	3.3		
81605-4	8/16/2005	8/17/2005	9/8/2005	2.2	3.2		
81605-5	8/16/2005	8/17/2005	9/8/2005	1.7	2.6		
81605-6	8/16/2005	8/17/2005	9/6/2005	1.5	2.7	*1.9*	*2.9*
81705-1	8/17/2005	8/18/2005	9/12/2005	2.1	2.1		
81705-2	8/17/2005	8/18/2005	9/8/2005	1.9	3.1		
81705-3	8/17/2005	8/18/2005	9/9/2005	1.9	2.7		
81705-4	8/17/2005	8/18/2005	9/8/2005	1.4	2.6	*1.8*	*2.6*
82205-1	8/22/2005	8/24/2005	9/12/2005	2.4	4.0	*2.4*	*4.0*
82305-1	8/23/2005	8/24/2005	9/13/2005	1.8	2.9	*1.8*	*2.9*
83005-1	8/30/2005	9/1/2005	9/21/2005	2.5	2.9		
83005-2	8/30/2005	9/1/2005	9/22/2005	2.4	2.9		
83005-3	8/30/2005	9/1/2005	9/21/2005	1.8	2.4	*2.2*	*2.7*
83105-1	8/31/2005	9/1/2005	9/22/2005	2.2	2.9		
83105-2	8/31/2005	9/1/2005	9/22/2005	1.9	2.6		
83105-4	8/31/2005	9/1/2005	9/22/2005	2.3	2.5		
83105-5	8/31/2005	9/1/2005	9/22/2005	2.0	2.4	*2.1*	*2.6*
90105-1	9/1/2005	9/1/2005	9/23/2005	2.0	3.3		
90105-2	9/1/2005	9/6/2005	9/15/2005	2.6	3.2		
90105-3	9/1/2005	9/1/2005	9/23/2005	1.8	3.0		
90105-4	9/1/2005	9/6/2005	9/23/2005	2.1	2.9		
90105-5	9/1/2005	9/1/2005	10/21/2005	2.3	2.7		
90105-6	9/1/2005	9/6/2005	9/23/2005	2.2	2.6		
90105-7	9/1/2005	9/6/2005	9/23/2005	2.8	2.5		
90105-8	9/1/2005	9/6/2005	9/26/2005	2.6	3.1	*2.3*	*2.9*

Table A.2.
GHP-2 Radon Barrier Clay Radium-226 Soil Sampling Results

Sample Number	Sample Date	Preparation & Initial Count Date	Ingrowth Count Date	Initial Results ^{226}Ra pCi/g	Ingrowth Results ^{226}Ra pCi/g (after 21 days)	Daily Average Initial Results ^{226}Ra pCi/g	Daily Average Ingrowth Results ^{226}Ra pCi/g
90705-1	9/7/2005	9/9/2005	10/19/2005	1.6	2.2		
90705-2	9/7/2005	9/9/2005	10/19/2005	1.6	2.2		
90705-3	9/7/2005	9/12/2005	10/18/2005	2.4	2.7		
90705-4	9/7/2005	9/12/2005	10/18/2005	2.0	2.3		
90705-5	9/7/2005	9/12/2005	10/18/2005	2.1	2.2	*1.9*	*2.3*
90805-1	9/8/2005	9/9/2005	10/19/2005	1.6	2.3		
90805-2	9/8/2005	9/12/2005	10/19/2005	1.8	1.6		
90805-3	9/8/2005	9/12/2005	10/19/2005	1.8	1.9		
90805-4	9/8/2005	9/12/2005	10/19/2005	2.1	1.6		
90805-5	9/8/2005	9/12/2005	10/19/2005	1.7	2.2		
90805-6	9/8/2005	9/12/2005	10/18/2005	1.5	1.9	*1.8*	*1.9*
91205-1	9/12/2005	9/14/2005	10/20/2005	1.6	2.0		
91205-2	9/12/2005	9/14/2005	10/19/2005	2.3	1.8		
91205-3	9/12/2005	9/14/2005	10/19/2005	2.2	2.3		
91205-4	9/12/2005	9/14/2005	10/19/2005	2.2	1.9	*2.1*	*2.0*
91305-1	9/13/2005	9/14/2005	10/20/2005	2.5	2.3		
91305-2	9/13/2005	9/15/2005	10/20/2005	1.9	1.4		
91305-3	9/13/2005	9/15/2005	10/20/2005	1.5	1.2		
91305-4	9/13/2005	9/15/2005	10/20/2005	1.4	2.1		
91305-5	9/13/2005	9/15/2005	10/21/2005	1.4	2.4	*1.7*	*1.9*
91505-1	9/15/2005	9/16/2005	10/24/2005	1.7	2.1		
91505-2	9/15/2005	9/19/2005	10/24/2005	1.4	2.3		
91505-3	9/15/2005	9/19/2005	10/24/2005	1.4	2.0		
91505-4	9/15/2005	9/19/2005	10/24/2005	2.2	2.0		
91505-5	9/15/2005	9/20/2005	10/24/2005	1.9	2.4	*1.7*	*2.2*
91605-1	9/16/2005	9/19/2005	10/24/2005	1.2	1.5		
91605-2	9/16/2005	9/19/2005	10/24/2005	1.7	1.7		
91605-3	9/16/2005	9/20/2005	10/24/2005	1.7	1.7		
91605-4	9/16/2005	9/20/2005	10/24/2005	2.5	2.7		
91605-5	9/16/2005	9/19/2005	10/26/2005	2.2	2.7	*1.9*	*2.1*
91905-1	9/19/2005	9/21/2005	10/26/2005	1.6	1.8		
91905-2	9/19/2005	9/21/2005	10/26/2005	1.8	1.6	*1.7*	*1.7*
92005-1	9/20/2005	9/21/2005	10/26/2005	1.3	1.8		
92005-2	9/20/2005	9/21/2005	10/26/2005	1.8	1.5		
92005-3	9/20/2005	9/21/2005	10/26/2005	1.5	1.9		
92005-4	9/20/2005	9/21/2005	10/26/2005	1.7	1.8	*1.6*	*1.8*
92205-1	9/22/2005	9/26/2005	10/28/2005	1.1	1.8		
92205-2	9/22/2005	9/26/2005	10/27/2005	1.5	2.2	*1.3*	*2.0*

Table A.2.
GHP-2 Radon Barrier Clay Radium-226 Soil Sampling Results

Sample Number	Sample Date	Preparation & Initial Count Date	Ingrowth Count Date	Initial Results ^{226}Ra pCi/g	Ingrowth Results ^{226}Ra pCi/g (after 21 days)	Daily Average Initial Results ^{226}Ra pCi/g	Daily Average Ingrowth Results ^{226}Ra pCi/g
92305-1	9/23/2005	9/28/2005	10/27/2005	1.6	2.2		
92305-2	9/23/2005	9/28/2005	10/27/2005	1.8	2.5		
92305-3	9/23/2005	9/28/2005	10/27/2005	2.2	2.3	*1.9*	*2.3*
92605-1	9/26/2005	9/28/2005	10/27/2005	1.8	2.3	*1.8*	*2.3*
92705-1	9/27/2005	10/6/2005	10/28/2005	1.7	2.1		
92705-2	9/27/2005	10/6/2005	10/28/2005	2.1	2.1		
92705-3	9/27/2005	10/6/2005	10/28/2005	2.2	2.1		
92705-4	9/27/2005	10/7/2005	10/28/2005	2.3	2.0		
92705-5	9/27/2005	10/6/2005	10/27/2005	1.4	1.3	*1.9*	*1.9*
92805-1	9/28/2005	10/3/2005	11/1/2005	1.6	1.7		
92805-2	9/28/2005	10/3/2005	11/1/2005	1.7	1.6		
92805-3	9/28/2005	10/3/2005	11/1/2005	2.1	2.3		
92805-4	9/28/2005	10/6/2005	11/1/2005	2.1	1.7		
92805-5	9/28/2005	10/6/2005	11/1/2005	2.1	1.8	*1.9*	*1.8*
92905-1	9/29/2005	10/6/2005	11/2/2005	2.2	1.9		
92905-2	9/29/2005	10/6/2005	11/2/2005	2.2	2.2		
92905-3	9/29/2005	10/6/2005	11/2/2005	1.8	2.0	*2.1*	*2.0*
93005-1	9/30/2005	10/12/2005	11/2/2005	2.3	2.4		
93005-2	9/30/2005	10/12/2005	11/2/2005	2.4	3.3	*2.4*	*2.9*
10405-1	10/4/2005	10/10/2005	11/3/2005	1.3	1.4		
10405-2	10/4/2005	10/11/2005	11/3/2005	2.3	2.3	*1.8*	*1.9*
10805-1	10/8/2005	10/17/2005	11/3/2005	1.7	2.6		
10805-2	10/8/2005	10/17/2005	11/3/2005	1.1	2.0		
10805-3	10/8/2005	10/17/2005	11/3/2005	1.9	2.0		
10805-4	10/8/2005	10/17/2005	11/3/2005	1.8	1.8	*1.6*	*2.1*

Average Initial Count	Average Ingrowth Count
1.9	2.3

1. Radon Barrier clay samples were collected from the clay on the same day that it was placed.
2. 71,808 cubic yards (based on load counts) of radon barrier placed wason GHP-2. Clay sampes were required for every 800 cubic yards placed thus requiring a total of 90 samples. 99 samples were tested.

Appendix B

January 2006 Radon Flux Model Runs

Appendix B
January 2006 Radon Flux Model Runs

This appendix documents the results of the RADON model reruns performed in support of this license amendment report. As discussed in Section 3.2, the radon attenuation design for the GHP-2 cover was initially evaluated in the 2003 *Final Design and Reclamation Plan* (Section 2.0) and assumed an average radium activity for the frost protection layer of 10 pCi/g Ra-226.

Because of the deviation requested in this License Amendment report—increasing the allowable average Ra-226 in frost protection soils from 10 pCi/g to 15 pCi/g—it was necessary to re-run the RADON model. Based on recent sampling, the Ra-226 input initially assumed for subgrade layers is also no longer valid—in fact, based on the data provided in Appendix A, the averages have decreased (essentially halved for Layers 1-4). Before presenting the revised radon model results, a brief discussion of the September 2003 radon model assumptions and results is provided below.

September 2003 Radon Modeling Results (see Attachment 1)

The radon attenuation design for the GHP-2 cell cover presented in the September 2003 *Final Design and Reclamation Plan* was modeled using the RADON computer code, Version 1.2, February 2, 1989. To facilitate review of this appendix, relevant excerpts of the September 2003 report are provided in Attachment 1. Two model runs were performed at that time. RUN 1 represented a conservative scenario, assuming an emanation coefficient of 0.20 and a code-calculated diffusion coefficient of 0.01277 cm^2/sec for radon barrier (Layer 5) soils. Because much conservatism is inherent in the RADON code, RUN 2 was performed to provide a more realistic long-term radon flux estimate reflecting site-specific data. As such, RUN 2 used the same input parameters as RUN 1, except for the following:

- emanation coefficient of 0.17 for the radon barrier, the average of 9 samples tested (vs. 0.20 assumed in RUN1- this difference probably had a minimal effect on model output); and
- an input diffusion coefficient of 0.0031 cm^2/sec for the radon barrier layer, the average of 6 samples tested (vs. code-calculated value of 0.01277 cm^2/sec used in RUN 1.

Using these assumptions, exit flux values of 19.40 pCi/m^2/s and 14.30 pCi/m^2/s were calculated for RUN 1 and RUN 2, respectively.

January 2006 Radon Modeling Results

As stated above, the radon model was re-run in January 2006 to account for the difference in the frost protection layer radium content (15 pCi/g vs. 10 pCi/g) and the lower Ra-226 averages in subgrade samples (Appendix A, Table A.1). RUN 2 from the September 2003 radon attenuation design was used as the basis for the 2006 model re-runs because it incorporated site-specific data and as considered to yield the most realistic estimate of GHP-2 cover radon flux. With the exception of the Ra-226 input changes, all other input parameters used in the September 2003 model RUN 2 were retained.

Two model runs were performed in support of this license amendment request.

1. The first retained all input parameters used in the September 2003 model RUN 2 except for the frost protection layer (Layer 6), for which the Ra-226 content was increased from 10 to 15 pCi/g.

2. The second was run to provide a more representative case, accounting for the increased radium in Layer 6, but the decreased radium in subgrade layers documented in Appendix A, Table A.1.

Table B.1 summarizes the differences in Ra-226 model input (vs. the Sep-03 model runs) and the corresponding results.

Table B.1 September 2003 vs. January 2006 RADON Model Ra-226 Input and Results

	Sep-03 RUN 2*	**Jan-06 Run 1**	**Jan-06 Run 2**
Layer No.	**Ra-226 (pCi/g)**	**Ra-226 (pCi/g)**	**Ra-226 (pCi/g)**
Layer 1 – Waste	62	62	29
Layer 2 – Waste	55	55	31
Layer 3 – Waste	62	62	28
Layer 4 – Waste	69	69	21
Layer 5 - Radon Barrier	2	2	2
Layer 6 - Frost Protection	10	15	15
Model Results: Calculated Exit Flux	14.30 pCi/m^2-s	18.7 pCi/m^2-s	14.60 pCi/m^2-s

* *Most site-specific (realistic) run performed for the September 2003 radon attenuation design.*

The Uranium Mill Tailings Cover Calculator, a clone of the RAECOM code (Radiation Attenuation Effectiveness and Cover Optimization with Moisture Effects) was used to calculate radon fluxes. This code is readily available and widely used and can be found at www.wise-uranium .org (last updated July 2, 2004). Umetco attempted to use NRC's 1989 code, but it is no longer compatible with our computer hardware setup. To verify that results would be compatible with those yielded by the NRC code used to perform the September 2003 runs, the Sep-03 RUN 2 was re-run using the cover calculator cited above (Table B.2). As shown in Table B.2, the results were very similar, with the radon fluxes just slightly higher than those yielded using the NRC code.

The RADON models run to support this license amendment resulted in an exit flux of 18.7 pCi/m^2-s and 14.6 pCi/m^2-s for January 2006 model Runs 1 and 2, respectively (Tables B.3 and B.4). Both results are below the 20 pCi/m^2-s exit flux limit established in 10 CFR 40, Appendix A, Criterion 6.

Table B.2 GHP-2 Radon Attenuation Model Verification Run

Date: 1/19/06
Code: Uranium Mill Tailings Cover Calculator (www.wise-uranium.org), clone of the RAECOM code
Rationale/Purpose: To verify that use of the cover calculator code would yield no difference in output compared to that initially yielded using NRC's RADON computer code, Version 1.2, February 2, 1989. All parameter values were the same as those used in the September 2003 model RUN 2 (see Attachment 1, Table 2-1).

———— Input Parameters ————

Number of Layers: 6
Radon Flux into Layer 1: 0 pCi/m2s
Surface Radon Concentration: 0 pCi/L
Bare Source Flux (Jo) from Layer 1: 62.15 pCi/m2s
Specific Bare Source Flux from Layer 1: 1.002 pCi/m2s per pCi_Ra-226/g

Layer No.	Thickness [m]	Ra-226 [pCi/g]	Emanat Fract	Porosity	Moisture [dry wt. %]	Diff Coeff [m2/s]
1	2.257	62	0.262	0.34	6	2.32E-06
2	0.914	55	0.262	0.34	6	2.32E-06
3	0.914	62	0.262	0.34	6	2.32E-06
4	0.914	69	0.262	0.34	6	2.32E-06
5	0.305	2	0.17	0.4	12	3.10E-07
6	1.372	10	0.262	0.34	6	2.32E-06

—— Results of Radon Diffusion Calculation ——

Layer No.	Thickness [m]	Exit Flux [pCi/m2s]	8/27/03 Results	RPD	Exit Conc. [pCi/L]	MIC
1	2.257	3.00	-0.16	--	8.10E+04	0.767
2	0.914	0.15	-1.12	--	7.93E+04	0.767
3	0.914	4.52	3.959	13.2%	7.68E+04	0.767
4	0.914	19.63	19.21	2.2%	6.36E+04	0.767
5	0.305	11.48	11.21	2.4%	1.67E+04	0.64
6	1.372	14.69	14.39	2.1%	0.00E+00	0.767

Total cover radon retention: 76.37%

Table B.3 January 2006 GHP-2 Radon Attenuation Model Run 1: Frost Protection Ra-226 Changed from 10 pCi/g to 15 pCi/g

Date: 1/19/06
Code: Uranium Mill Tailings Cover Calculator (www.wise-uranium.org), clone of the RAECOM code
Rationale/Purpose: To re-calculate radon fluxes using an average Ra-226 content of 15 pCi/g for the frost protection layer. All other input parameter values were the same as those used in the September 2003 model RUN 2 (see Attachment 1, Table 2-1).

------------ Input Parameters ------------

Number of Layers: 6
Radon Flux into Layer 1: 0 pCi/m2s
Surface Radon Concentration: 0 pCi/L
Bare Source Flux (Jo) from Layer 1: 62.15 pCi/m2s
Specific Bare Source Flux from Layer 1: 1.002 pCi/m2s per pCi_Ra-226/g

Layer No.	Thickness [m]	Ra-226 [pCi/g]	Emanat Fract	Porosity	Moisture [dry wt. %]	Diff Coeff [m2/s]
1	2.257	62	0.262	0.34	6	2.32E-06
2	0.914	55	0.262	0.34	6	2.32E-06
3	0.914	62	0.262	0.34	6	2.32E-06
4	0.914	69	0.262	0.34	6	2.32E-06
5	0.305	2	0.17	0.4	12	3.10E-07
6	1.372	15	0.262	0.34	6	2.32E-06

------ **Results of Radon Diffusion Calculation** ------

Layer No.	Thickness [m]	Exit Flux [pCi/m2s]	Exit Conc. [pCi/L]	MIC
1	2.257	2.966	8.11E+04	0.767
2	0.914	0.065	7.94E+04	0.767
3	0.914	4.315	7.70E+04	0.767
4	0.914	19.14	6.42E+04	0.767
5	0.305	10.67	1.88E+04	0.64
6	1.372	18.73	0.00E+00	0.767

Total cover radon retention: 69.87%

Table B.4 January 2006 GHP-2 Radon Attenuation Model Run 2: Frost Protection and Subgrade Layer Ra-226 Revised

Date: 1/19/06
Code: Uranium Mill Tailings Cover Calculator (www.wise-uranium.org), clone of the RAECOM code
Rationale/Purpose: To re-calculate radon fluxes using the same input parameter values as those used in the September 2003 model RUN 2 (Attachment 1, Table 2-1), except for the following:

1. Layer 1 (frost protection) Ra-226 changed from 10 to 15 pCi/g
2. Ra-226 for Layers 1-4 decreased to reflect recent subgrade sampling (lower averages)

The radon barrier - Layer 2 - remained the same at 2 pCi/g.

———— Input Parameters ————

Number of Layers: 6
Radon Flux into Layer 1: 0 pCi/m2s
Surface Radon Concentration: 0 pCi/L
Bare Source Flux (Jo) from Layer 1: 62.15 pCi/m2s
Specific Bare Source Flux from Layer 1: 1.002 pCi/m2s per pCi_Ra-226/g

Layer No.	Thickness [m]	Ra-226 [pCi/g]	Emanat Fract	Porosity	Moisture [dry wt. %]	Diff Coeff [m2/s]
1	2.257	29	0.262	0.34	6	2.32E-06
2	0.914	31	0.262	0.34	6	2.32E-06
3	0.914	28	0.262	0.34	6	2.32E-06
4	0.914	21	0.262	0.34	6	2.32E-06
5	0.305	2	0.17	0.4	12	3.10E-07
6	1.372	15	0.262	0.34	6	2.32E-06

——— **Results of Radon Diffusion Calculation** ———

Layer No.	Thickness [m]	Exit Flux [pCi/m2s]	Exit Conc. [pCi/L]	MIC
1	2.257	0.565	3.91E+04	0.767
2	0.914	3.393	3.69E+04	0.767
3	0.914	5.914	3.18E+04	0.767
4	0.914	6.107	2.52E+04	0.767
5	0.305	2.546	1.10E+04	0.64
6	1.372	14.62	0.00E+00	0.767

Total cover radon retention: 49.70%

Appendix B, Attachment 1
September 2003 Report Excerpts re: Radon Model

Source: Final Design and Reclamation Plan for GHP No.2/Mill Area.
September 11, 2003, Rev. 1 of May 2003 document

to within a few inches of the pond/liner subgrade to account for potential impact to the affected subgrade soils. Once the usable portion of the clay liner material has been removed, the bottom of the pond will be regraded to provide the appropriate subgrade slope for constructing the reclamation cover. Regrading the pond bottom shall be accomplished in a manner that avoids a continuous low permeability layer in the bottom of the GHP No. 2 disposal cell.

Umetco will verify by collimated field gamma survey that clay soils excavated from the GHP No. 2 liner and used for construction of the radon barrier are within a range of reasonably anticipated ^{226}Ra activities, i.e., as shown on Table 2-3, and average less than 2 pCi/g as used in the radon attenuation design. A gamma-radium correlation for the clay soil will be developed by obtaining at least six clay soil samples and associated collimated gamma measurements. In addition to continuous gamma scans, soil samples will be obtained from the constructed radon barrier at a frequency of 1 sample per 800 cubic yards which is approximately 1 sample per acre per lift of radon barrier soils. Laboratory ^{226}Ra analysis by gamma spectrometry shall be performed on each sample in accordance with Gas Hills site procedure.

1.3.3 Reclamation Cover Design

The GHP No. 2 reclamation cover consists of a 12-inch thick radon barrier layer, 54-inch thick frost protection layer, and an erosion protection layer. The reclamation cover for the GHP No. 2/Mill Area has been designed with a gentle one-percent top slope and 20 percent side slope as shown on the drawings. Depending on the final volume of soil used to solidify the remaining liquids, it may be necessary to increase the elevation of the top cover by a few feet. The hydraulic calculations provided in Section 4.0 account for the worst case cell height in the design of erosion protection materials.

2.0 RADON ATTENUATION DESIGN

This section details the radon attenuation design for the GHP No. 2/Mill Area. The reclamation cover for GHP No. 2 has been designed to limit the release of Radon (^{222}Rn) from uranium byproduct materials to a rate of 20 pCi/m^2/sec. from the surface of the cell as required by 10 CFR Part 40, Appendix A.

2.1 General

GHP No. 2 was constructed in the former mill process area at the Gas Hills site. Site characterization, studied in the summer and fall of 1995, indicate that this area contained a significant volume of contaminated soil and foundation debris that were not removed during the initial mill demolition activities at the site. Construction activities associated with constructing GHP No. 2 included removing remaining mill foundations, process facilities, and related mill utilities. However, the soil beneath the existing pond contains elevated concentrations of radionuclides, which appear to occur from both natural mineralization, and mill related impacts, i.e., elevated sulfates and high concentrations of uranium and thorium. Accordingly, Umetco has elected to reclaim the GHP No. 2/Mill Area in place with a closure cover designed and constructed in accordance with 10 CFR Part 40, Appendix A.

2.2 Cover Design

The conceptual design for closing the GHP No. 2/Mill Area was provided with the Heap Leach design approved by May 28, 1998 License Amendment 38. That conceptual design assumed a significant volume of 11e.(2) material to be placed in the cell prior to final closure. However, the sequence of reclamation activities at the site resulted in a situation in which the previously assumed volume of contaminated material may be significantly reduced.

2.3 Soil Properties/Input Parameters

The radon attenuation design for the cover was evaluated using the RADON computer code, Version 1.2, February 2, 1989. Table 2-1 is a summary of model input parameters used for the attenuation design. The following sections provide the rationale for selecting model input parameters.

2.3.1 Waste Material Input Parameters

Mass Density – The remaining pond liquids and residue will be solidified by mixing with mine spoil material, then placed and compacted within the disposal cell. The soil to be used for solidifying the remaining liquids has the same characteristics as the frost protection soils used for constructing the heap cover. These soils are clayey sand and/or silty-clayey sand and classify as SC and/or SC-SM. The maximum standard Proctor density ranges from 109 pcf to 121 pcf with optimum moisture content of 11 to 14 percent (NRC Heap Leach TER). Since the waste material placed within the disposal cell will be compacted to a minimum 95 percent standard Proctor maximum density, 95 percent of the average density (or 1.75 g/cm^3) was used for the mass dry density of waste material.

The GHP No. 2/Mill Area is underlain with the same natural soils that are beneath the adjacent Heap Leach and comprise the major portion of the upper 500 cm of waste material. Details of the adjacent subsurface geotechnical investigation are contained in Umetco's August 19, 1997 letter, referenced in LC 61. These soils consist mainly of yellowish-brown, fine-to-coarse sand and gravel, with some cobbles up to 8 inches in diameter with occasional layers/lenses of brown-to-gray silty clay and sandy clay. The sands and gravels are medium dense to very dense. The lenses of silty clay and sandy clay are very stiff. Laboratory tests for this material include moisture, density, grain size distribution, compaction and strength tests. The unit weight of the foundation soils ranges from 107 pcf to 128 pcf.

To be conservative in selecting the mass density input for the model, a value of 1.75 g/cm^3 was selected which represents 95 percent of the average density for placed and compacted material and the lower range of densities for the foundation soils.

Radium Activity – Waste material in the upper 500 cm (equivalent to infinitely thick source of radon) is comprised of a thin layer or thin concentration of soils used to solidify remaining pond liquids and the GHP No. 2 subgrade (former mill process area). Accurate determination of the ^{226}Ra activity of the placed waste materials can not be made until soil mixing has occurred and will be dependent upon the ^{226}Ra activity of the remaining liquids and mine spoil material. The residual pond liquids and residue when mixed with soil (approximately 30 to 50 gallons per

Table 2-1

SUMMARY OF RADON MODEL INPUT PARAMETERS - RUN 1

Layer No.	Thickness (cm)	Porosity	Mass Density (g/cm^3)	^{226}Ra Activity (pCi/g)	Emanation Coefficient	Moisture Content (dry wt. %)	Diffusion Coefficient (cm^2/sec)
Layer 1 - Waste	225.68	Code Calc.	1.75	62	0.262	6	Code Calc.
Layer 2 - Waste	91.44	Code Calc.	1.75	55	0.262	6	Code Calc.
Layer 3 - Waste	91.44	Code Calc.	1.75	62	0.262	6	Code Calc.
Layer 4 - Waste	91.44	Code Calc.	1.75	69	0.262	6	Code Calc.
Layer 5 - Radon Barrier	30.48	Code Calc.	1.59	2	0.20	12	Code Calc.
Layer 6 - Frost Protection	137.16	Code Calc.	1.75	10	0.262	6	Code Calc.

1) Upper 9-feet (0 cm to 274.32 cm) of waste material is divided into 3-foot segments. Waste layer 4 (274.32 cm to 500 cm) assumes the average ^{226}Ra activity from the existing subsurface data.
2) Previously approved emanation coefficient of 0.20 used for RUN 1.
3) Default (code calculated) diffusion coefficient used for all layers of waste and cover.

SUMMARY OF RADON MODEL INPUT PARAMETERS - RUN 2

Layer No.	Thickness (cm)	Porosity	Mass Density (g/cm^3)	^{226}Ra Activity (pCi/g)	Emanation Coefficient	Moisture Content (dry wt. %)	Diffusion Coefficient (cm^2/sec)
Layer 1 - Waste	225.68	Code Calc.	1.75	62	0.262	6	Code Calc.
Layer 2 - Waste	91.44	Code Calc.	1.75	55	0.262	6	Code Calc.
Layer 3 - Waste	91.44	Code Calc.	1.75	62	0.262	6	Code Calc.
Layer 4 - Waste	91.44	Code Calc.	1.75	69	0.262	6	Code Calc.
Layer 5 - Radon Barrier	30.48	Code Calc.	1.59	2	0.17	12	0.0031
Layer 6 - Frost Protection	137.16	Code Calc.	1.75	10	0.262	6	Code Calc.

1) Emanation coefficient of 0.17 used for radon barrier layer (average of 9 samples tested).
2) Diffusion coefficient of 0.0031 cm2/sec input for radon barrier layer (average value of 6 samples tested).

cubic yard of soil) is anticipated to have a relatively low radium content. Although the radium content of the placed waste material will be low (average < 50 pCi/g) the ^{226}Ra of the subgrade soils which exist beneath the existing liner will be the controlling factor in designing the reclamation cover.

The soil ^{226}Ra concentration for the former mill area soils was obtained during the 1995 characterization work conducted prior to constructing GHP No. 2 over the former mill area. Subsequent to radiological characterization of this area, GHP No. 2 was constructed, resulting in removing a portion of the soils represented by the downhole measurements. A summary of the average ^{226}Ra activity of the applicable portions, i.e., measurements which exist in the upper 500 cm, are provided in Table 2-2. Complete borehole logs showing all ^{226}Ra measurements and portions removed during construction of GHP No. 2 are provided in Appendix A. Borehole locations are shown on Figure 2-1. ^{226}Ra measurements were taken using downhole gamma logging methods at 0.5-foot intervals.

Table 2-2 Average Radium Activity

Borehole No.	Avg. ^{226}Ra of Applicable Portion (pCi/g)	Avg. ^{225}Ra of 0' - 3' (0 to 91.44 cm) (pCi/g)	Avg. ^{226}Ra of 3' - 6' (91 - 183 cm) (pCi/g)	Avg. ^{226}Ra of 6' - 9' (183 - 274 cm) (pCi/g)
MB-01	N/A			
MB-02	23.3	23.3		
MB-03	23.9	46.4	15.5	17.4
MB-04	N/A			
MB-05	20.6	24.7	21.0	18.1
MB-06	47.0	95.6	73.6	18.8
MB-07	N/A			
MB-08	N/A			
MB-09	N/A			
MB-10	30.4	30.4		
MB-11	N/A			
MB-12	N/A			
MB-13	30.4	35.3	22.4	33.7
MB-14	84.8	31.2	40.4	105.9
MB-15	12.2	12.2		
MB-16	28.0	28.0		
MB-17	49.4	61.3	41.4	22.2
MB-18	97.6	86.3	100.9	101.1
MB-19	38.8	63.2	43.6	29.7
MB-20	318.5	318.5		
MB-21	104.5	190.0	274.7	80.2
MB-22	91.7	95.9	107.7	
MB-23	56.6	49.4	54.9	65.4
MB-24	49.8	82.4	31.1	26.7
MB-25	68.6	62.9	29.1	23.3
RB-08	79.6	28.7	69.6	125.0
RB-10	N/A			
RB-12	N/A			
RB-24	22.5	34.0	16.9	11.9
	Avg. of applicable values = 61.4 pCi/g	Avg. of all segment measurements = 69 pCi/g	Avg. of all segment measurements = 62 pCi/g	Avg. of all segment measurements = 54 pCi/g

The radium concentration input is based on the average ^{226}Ra concentration in 3-foot segments for the upper 9-feet (274.32 cm) of waste material. The average of all subsurface ^{226}Ra measurements was input for the 9 feet to 16.4 feet (274.32 cm to 500 cm) layer of waste material.

Prior to cover construction, Umetco will verify the ^{226}Ra activity of the upper 500 cm below the radon barrier. Subsurface borings will be made at a density of one borehole per acre to a depth of 500 cm. Composite samples for each 3-foot segment of the borehole will be obtained with subsequent onsite laboratory analysis of ^{226}Ra.

Emanation Coefficient – As discussed above, the mine spoil material that will be utilized in solidifying residual liquids has the same physical characteristics as the frost protection soil used for constructing the Heap Leach cover. The measured emanation coefficient for this soil is 0.262. This value also coincides well with the average value for the heap filter layer, as these soils are essentially the same.

Moisture Content – The long-term moisture content of the soil used for solidification as well as the foundation soils may be impacted by the characteristics of the remaining pond liquids and former mill processing activities. Accordingly, conservative moisture content of 6 percent was included in the model.

Diffusion Coefficient – To provide a conservative model, the code calculated diffusion coefficient was used for the placed waste materials and foundation soils.

2.3.2 Radon Barrier Input Parameters

Mass Density – The mass density of the radon barrier soils was estimated from standard Proctor tests on 5 samples of clay soil used in constructing the Heap Leach radon barrier. The maximum dry density of the samples rage from 103.3 pcf to 105.7 pcf with an average of 104.28 pcf. Since the radon barrier soil will be compacted to at least 95 percent of standard Proctor maximum density, 95 percent of the average maximum density was used, i.e., 95 percent of 104.8 = 1.59 g/cm^3. This value is conservative since 95 percent of the standard Proctor density is the minimum allowable dry density accepted during placement and additional consolidation of the radon barrier will occur over time.

Radium Activity – A ^{226}Ra activity of 2 pCi/g was input for the radon barrier layer based on the average of 9 samples tested by Rodgers and Associates for the borrow source. Test results are contained in Umetco's September 25, 1996 and October 15, 1997 Heap Leach submittals and summarized in Table 2-3. The radium activity of the radon barrier soils borrowed from the existing GHP No. 2 liner will be verified as discussed in Section 1.3.2.

Table 2-3

Summary of Radon Barrier (Clay Soil) Test Results				
Sample ID	^{226}Ra (pCi/g)	Emanation Coefficient	Diffusion Coefficient (cm^2/sec)	Comment
A	1.4	0.18	0.0016	October 15, 1997 Submittal
B	2.0	0.23	0.0034	October 15, 1997 Submittal
C	1.8	0.07	0.0042	October 15, 1997 Submittal
C	1.2	0.13	0.0034	October 15, 1997 Submittal
E	2.3	0.09	0.0017	October 15, 1997 Submittal
HRE-1	3.6	0.261	Composite of 4 Samples = 0.0041	September 25, 1996 Submittal
HRE-2	2.4	0.143		September 25, 1996 Submittal
HRE-3	2.6	1.191		September 25, 1996 Submittal
HRE-4	1.9	0.207		September 25, 1996 Submittal
Average =	2.1	0.17	0.0031	
Values Selected for Modeling				
RUN 1	2.0	0.20	Code Calculation	
RUN 2	2.0	0.17	0.0031	

Emanation Coefficient – Emanation coefficient tests previously provided by Umetco's September 25, 1996 and October 15, 1997 submittals are shown on Table 2-3. An emanation coefficient of 0.20 was approved for Umetco's Heap Leach RADON models in the September 25, 1996 submittal.

Moisture Content – Capillary moisture tests were performed on 5 samples of radon barrier soil to determine the long-term moisture content of the soil. The equilibrium moisture content at 15-bars ranges from 16.1 percent to 19.7 percent with an average of 17.6 percent. NRC review (NRC Heap Leach TER) of this test data indicated that 15-bar capillary moisture tests are not always conservative for determining long-term moisture content. Subsequent modeling by NRC staff used a moisture content of 12 percent for the radon barrier soils. Accordingly, an input value of 12 percent is used for the GHP No. 2 model.

Diffusion Coefficient – To provide a conservative model, the code calculated diffusion coefficient was used for the waste material.

2.3.3 Frost Protection Input Parameters

Mass Density – The soil to be used for constructing the frost protection layer has the same characteristics as the frost protection soils used for constructing the Heap Leach cover. These soils are clayey sand and/or silty-clayey sand and classify as SC and/or SM. The maximum standard Proctor density ranges from 109 pcf to 121 pcf with optimum moisture content ranging from 11 to 14 percent (NRC Heap Leach TER). Since the frost protection soils will be compacted to 95 percent of the standard Proctor maximum density, 95 percent of the average density range (or 1.75 g/cm^3) was used for the mass dry density of the frost protection material.

Radium Activity – The radium activity input for the frost protection layer assumes the approved ^{226}Ra site-wide background value of 10 pCi/g.

Emanation Coefficient – As discussed above, the mine spoil material that will be utilized in constructing the frost protection layer has the same characteristics as the frost protection soil used for constructing the Heap Leach cover. The measured emanation coefficient for this soil is 0.262. This value also coincides well with the average value for the heap filter layer, as these soil types are essentially the same.

Moisture Content – The long-term moisture content of the soil used for solidification may be impacted by the characteristics of the pond solutions. Accordingly, conservative moisture content of 6 percent was input into the model.

Diffusion Coefficient – To provide a conservative model, the default code calculated diffusion coefficient was used for the frost protection layer.

2.4 Radon Attenuation Model Results

The radon attenuation design for the cell cover was modeled using the RADON computer code, Version 1.2, February 2, 1989. The radon attenuation model consists of two RADON models. RUN 1 provides a conservative model with the following input conditions.

- 3-foot segmented waste layers for the upper 9 feet of waste material.
- Radon barrier emanation coefficient of 0.20 as previously approved in Umetco's September 25, 1996 Heap Leach submittal.
- Conservative 12 percent long-term moisture content for radon barrier soils.

RUN 2 is provided to demonstrate the conservative attributes of the radon attenuation design by:

- input of an emanation coefficient of 0.17 for the radon barrier, which is the average of 9 samples tested, as shown on Table 2-3.
- input diffusion coefficient of 0.0031 cm^2/sec. for the radon barrier layer, which is the average of 6 samples tested as shown on Table 2-3.

The RADON models described above resulted in an exit flux of 19.40 pCi/m^2/sec. for RUN 1 and 14.30 pCi/m^2/sec. for RUN 2. The results of both of the RADON models are below the 20 pCi/m^2/sec. exit flux limit established in 10 CFR 40, Appendix A, Criterion 6. Both of the models used to evaluate the design are conservative because:

- diffusion coefficients for all waste and cover layers, except RUN 2 radon barrier, are code calculated.
- conservative 6 percent moisture content values are assumed for waste and frost protection layers.
- long-term moisture content for the radon barrier soils is assumed to be 12 percent, whereas the measured equilibrium moisture content at 15-bars for this soil ranges from 16.1 to 19.7 percent.

- radium activity for the frost protection soil assumes 10 pCi/g ^{226}Ra. Field measurements of ^{226}Ra during construction will control and verify that ^{226}Ra concentrations are less than 10 pCi/g ^{226}Ra.

Uranium Mill Tailings Cover Code Calculator (Radon Flux) Code Documentation & Bibliography

Uranium Mill Tailings Cover Calculator - HELP

(last updated 3 Sep 2001)

Contents:

Introduction

This calculator determines the radon fluxes and concentrations in multi-layer uranium mill tailings and cover systems, and it optimizes the cover thickness to satisfy a given flux constraint.
The calculator is a clone of the RAECOM code (Radiation Attenuation Effectiveness and Cover Optimization with Moisture Effects), as described in [Rogers 1984]. It performs one-dimensional, steady-state radon diffusion calculations for a multi-layer system.
In addition, the calculator optionally estimates the long-term moisture contents in each layer based on rainfall and evaporation, and adjusts the diffusion coefficients correspondingly.

For calculating radon flux from bare and/or water covered tailings, see the Uranium Mill Tailings Radon Flux Calculator
For calculating the gamma radiation attenuation from a uranium mill tailings pile cover, see the External Radiation Dose Calculator.

- Note that some of the parameters show wide ranges of variation. Meaningful results for actual sites can only be obtained, if site-specific data is used.
- Note that the moisture contents of the layers may vary in the long term, depending on climatic conditions.
- Note that the optimization only concerns radon flux, while other factors, such as mitigation of infiltration, or resistance against erosion, biointrusion, etc., also affect the cover construction.

The properties of the tailings and cover system are defined in the **Input Data** table.

The **Result** field repeats the input data and shows the calculation results.
The contents of the Result field can be highlighted and copied for further use.

This calculator is suitable for offline use.

The **Activity unit** can be selected for the whole calculator as pCi (pico-Curie = 10^{-12} Ci) or Bq (Becquerel). This selection must be made before any other entry, since it resets the complete calculator.

Input Data

The button "**Sample Data**" initializes the parameters to the values of the example given in [Rogers 1984], typical for a dry climate. It comprises the tailings (Layer 1), a clay cover (layer 2), and an overburden cover (layer 3). The thickness of the overburden layer is to be optimized to satisfy the permissible surface radon-222-flux of 20 pCi/m^{2}s (0.74 Bq/m^{2}s).

Layer Data

This table contains parameters describing the properties of each layer. Layer 1 is the tailings layer, covered by one or more cover layers.

Thickness [m]

Layer thickness

If the thickness of a layer is empty or 0, this and all following layers are discarded.

Ra-226 Activity Concentration [Bq/g] · [pCi/g]

Activity concentration of Radium-226 in the layer.

If no entry is made, a default of 0 is used.

A value can not only be entered for the tailings layer, but also for each other layer.

In case the value for the tailings layer is unknown, it can be estimated from the grade of the ore processed in the uranium mill. Assuming secular equilibrium in the ore between uranium-238 and radium-226, and that all radium goes into the tailings, an ore grade of 0.1% U (or 0.1179% U_3O_8) corresponds to a Ra-226-concentration of 12.4 Bq/g (334 pCi/g). (see also Unit Converter)

Rn-222 Emanation Fraction

fraction of the total amount of radon-222 produced by radium decay that escapes from the soil particles and gets into the pores of the soil.

It depends on the soil material and the moisture content. It varies over a range of 0.1 - 0.4 or more; typical values are in the range of 0.2 - 0.3.

Porosity

ratio of the pore volume (air- and water-filled) to the total volume of the soil

Sand	0.25 - 0.50
Silt	0.35 - 0.50
Clay	0.40 - 0.70

Moisture Contents [dry wt_%]

percentage of water weight to dry soil weight

Fraction Passing #200 Mesh (75 µm)

fraction by weight of the soil passing a No. 200 Mesh, corresponding to a particle diameter of 75 µm or less.

If no value is entered, no estimate for long-term moisture is performed for this layer.

Since 75 µm particle diameter marks the sand/silt dividing line, this figure denominates the fraction that is not sand, or the fraction of combined silt and clay contents.

> See also U.S. Department of Agriculture (USDA) diagram of soil textures [Yu 1993]

Rn-222 Effective Diffusion Coefficient [m^2/s]

defined from Fick's equation as the ratio of the diffusive flux density of radon activity across the pore area to the gradient of the radon activity concentration in the pore or interstitial space.

If no value is entered, a value is calculated from porosity and moisture contents. However, this estimate may be wrong by an order of magnitude, for example.

Caution: The effective (or interstitial) diffusion coefficient D_e is not to be confused with the bulk radon diffusion coefficient D. D is obtained by multiplying D_e by the total soil porosity. The use of the terminology for the diffusion coefficients in literature is highly inconsistent - in some cases, the symbols of D and D_e are used reversely!

The diffusion coefficient in porous media is a property of the diffusing species, the pore structure, the type of fluids present in the pores, the adsorption properties of the solid matrix, the fluid saturations, and temperature. The effective radon diffusivity values in porous media (soils and concrete included) vary over a wide range of several orders of magnitude depending on the porous material and particularly on its degree of water

moisture content is about 10^{-6} m^2/s. The upper limit is represented by the radon diffusion coefficient in open air, D_o, which is about 1.1 x 10^{-5} m^2/s. At the lower extreme, in a fully saturated soil material the radon diffusion coefficient may be as low as 10^{-10} m^2/s.

Options

Entrance Radon flux to Layer 1 [Bq/m^2s] · [pCi/m^2s]
Radon-222-flux from the subsoil into the tailings layer.
If -1 is entered, then a value is computed internally for infinitely thick subsoil.
If no value is entered, a default of 0 is used.

Surface Radon concentration at top of system [Bq/m^3] · [pCi/L]
Radon-222-concentration in air above the top cover.
If no value is entered, a default of 0 is used.

Layer No. to be optimized
No. of the layer, the thickness of which is to be optimized to meet the surface flux constraint.
The tailings layer (Layer 1) cannot be optimized.
If no value, or 0, is entered, no optimization is performed.

Surface flux constraint for optimization [Bq/m^2s] · [pCi/m^2s]
value that is to be attained for the radon-222-flux from the top layer to the atmosphere.
If no value, or 0, is entered, no optimization is performed.
The U.S. EPA standard set in 40 CFR 192 is 20 pCi/m^2s (0.74 Bq/m^2s) (see also legislation).

Surface flux convergence criterion (fraction)
error allowance for the surface flux from the constraint, expressed as fraction.
Enter 0.01 for a permissible error of 1%, for example.
If no value is entered, a default value of 0.001 is used.

Annual Precipitation [cm]

If no value, or 0, is entered, no estimate for long-term moisture is performed.

Annual Lake Evaporation [cm]

If no value, or 0, is entered, no estimate for long-term moisture is performed.

Depth to Water Table [m]
If no value, or 0, is entered, a deep water table is assumed. This parameter is only used for estimating long-term moisture.

Calculation Details

The calculator contains some minor modifications vs. RAECOM:

- the activity unit can be selected (pCi or Bq),

- The pore space radon source term for each layer, other than in RAECOM, is not entered directly, but it is calculated from the Ra-226 activity concentration and the radon emanation fraction. The layer bulk density rho_b (required for this calculation) is calculated from the porosity p using an assumed specific gravity g of 2.7 g/cm^3, as follows: $rho_b = g * (1 - p)$,
- the calculator optionally estimates the long-term moisture contents in each layer, and adjusts the diffusion coefficients correspondingly,
- the number of optimization iterations has been limited to prevent hang-up in case no convergence occurs.

Apart from that, the calculator is a strict clone of the RAECOM code [Rogers 1984].

Bibliography

[Rogers 1984] Rogers, V.C., K.K. Nielson, D.R. Kalkwarf: **Radon Attenuation Handbook for Uranium Mill Tailings Cover Design**, prepared for U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CR-3533, PNL-4878, April 1984, 87 p.

[Yu 1993] C. Yu, J.J. Cheng, et al.: Data Collection Handbook To Support Modeling Impacts Of Radioactive Material In Soil, Environmental Assessment and Information Sciences Division, Argonne National Laboratory, Argonne, Illinois, ANL/EAIS-8, April 1993, 165 p.

compiled by:
WISE Uranium Project (home) · Uranium Mill Tailings Cover Calculator · Calculators

Appendix C

ALARA Analysis Supporting GHP-2 License Amendment

C.0 AS LOW AS REASONABLY ACHEIVABLE (ALARA) ANALYSIS IN SUPPORT OF GHP-2 LICENSE AMENDMENT

This appendix evaluates the potential costs and benefits of not implementing the deviations requested in this license amendment—i.e.: What would be the effect on public dose and associated reclamation costs if Umetco proceeded with removal and replacement of frost protection cover soils to meet the 10 pCi/g average Ra-226 cover criterion?

To address this question, an ALARA analysis was performed consistent with NRC guidance (NUREG-1727, NRC 2000). A similar evaluation was undertaken for the approved FSS Addendum 1 to support a no further action alternative for cleanup of GHP-1 and the windblown area (Umetco 2004a). The following analysis uses the same approach and most of the same assumptions as those used in the 2004 ALARA analysis.

Assumptions which differ include costs (see Table C.1) and the expected Ra-226 reduction, which for this scenario is 5 pCi/g. This value equals 15 pCi/g, the deviation in allowable radium content for cover materials requested herein, minus the current 10 pCi/g criterion.

C.1 Technical Approach

This ALARA evaluation was conducted in general accordance with the procedures outlined in Appendix D (ALARA Analyses) of the NRC's NMSS Decommissioning Standard Review Plan, or NUREG-1727 (NRC 2000), as referenced in NUREG-1620, Section H2.2.3(4).[1] For consistency, this analysis uses the same exposure assumptions and Derived Concentration Guideline Levels (DCGLs) for Ra-226 as those developed for the FSS Addendum 1 (Umetco 2004a). These DCGLs, derived using RESRAD, correspond to the average concentration of residual Ra-226 radioactivity that would result in a public dose of 25 mrem/yr, the allowable dose limit established by the NRC.

In the FSS Addendum 1, two DCGLs for soil Ra-226 were derived (see Table 3.2 and associated footnotes). The first—141 pCi/g—was considered the most realistic estimate, and formed the basis for most of the ALARA analysis permutations evaluated in that document (see FSS Addendum 1 Table 3.4). The second—26.9 pCi/g—assumed a much more conservative outdoor fraction and was used for the worst-case scenario ALARA calculations. The following ALARA analysis uses both values.

C.2 Costs Associated With Removal and Replacement of GHP-2 Cover Soils

To meet the current 10 pCi/g average allowable Ra-226 content in frost protection soils, Umetco would have to remove the top two feet of material already in place (which exceeds this criterion) and replace it with two feet of $\leq$ 10 pCi/g material. Based on the detailed assumptions documented in Table C.1, the cost associated with this effort was estimated to be $905,000.

[1] The NUREG-1727 guidance document supersedes the previous draft guide DG-4006 issued in August 1998.

Table C.1 ALARA Cost Estimate: Removal and Replacement of Top Two Feet of GHP-2 Frost Protection Cover Material to Meet 10 pCi/g Ra-226 Criterion

Assumptions/Basis: Removal and Placement Costs

Parameter		Assumed Value	Units	Basis/Comment
Soil volume to be removed from GHP-2 exceeding 10 pCi/g		120,362	cu yds	Assumes two 1-ft lifts @ 60,181 cubic yards per lift (latter based on remediation specs to date)
Removal cost per cu yd	$	2.60	$/cu yd	Bid for unsuitable excavation at borrow areas (2005 Bid Schedule).
Placement cost per cu yd	$	2.75	$/cu yd	Slight cost increase reflects increase in haulage distance to find the 10 pCi/g material
Rejection rate		30%		Based on historical reject rates for cover material--i.e., a certain percentage not meeting criteria is rejected for placement but nonetheless disturbed-a minimum rejection rate of 30 percent is assumed.
Corresponding cost		36,109	cu yds	= Soil volume required * reject rate
Removal cost for reject	$	2.60	$/cu yd	2005 Bid Schedule (see above)

Total Removal Cost	$	312,941
Total Placement Cost	$	330,996
Cost Ass. w/ Rejected Material	$	93,882

Assumptions/Basis: Revegetation and Topsoil Placement Costs

Parameter		Assumed Value	Units	Basis/Comment
Additional area that would have to be disturbed		30	acres	In Sep-04, Umetco requested a boundary revision for 85.5 acres. To date, we have disturbed approx. 36 acres or 42 percent. To find clean frost, Umetco anticipates disturbing an additional 30 to 40 acres of previously undisturbed ground to yield the required volume. This would leave only 10 percent of the boundary area revision available as a borrow source. This analysis conservatively assumes the lower bound of this range.
Cost per acre for disking, seeding, mulch, and bed prep.	$	564	$/acre	Cost based on Wyoming Dept. of Environmental Quality (DEQ) experience.
Topsoil volume required		48,400	cu yds	Assumes 30 acres @ 1-ft thickness
Topsoil removal cost	$	2.00	$/cu yd	2005 Bid Schedule (see above)
Topsoil placement cost	$	1.10	$/cu yd	" "

Re-Seeding Cost	$	16,920	= Area to be disturbed * reclamation cost
Topsoil Removal Cost	$	96,800	= Topsoil volume * removal cost/cu yd
Topsoil Placement Cost	$	53,240	= Topsoil volume * placement cost/cu yd

TOTAL COST: $ 904,779

C.3 ALARA Calculations: Equations and Assumptions

In accordance with NRC guidance, the benefit from the collective averted dose, B_{AD}, is calculated by first determining the present worth of the future collective averted dose and then multiplying it by a factor to convert the dose to monetary value. Using the assumptions documented in Table C.2, the present worth of the future collective averted dose, PW ($AD_{collective}$) is calculated as follows:

Equation 1: Present Worth of the Future Collective Averted Dose *NUREG-1727, Eq. D2*

$$PW(AD_{collective}) = P_D * A * BRDL * F * \frac{Conc}{DCGL} * \frac{1 - e^{-(r+\lambda)N}}{r + \lambda}$$

When N = 1000 yrs, this portion of the equation is essentially = 0.

where:

P_D	=	population density for the critical group scenario in persons/m^2
A	=	area being evaluated in square meters (m^2) – see explanation below
BRDL	=	Basic Radiation Dose Limit, 0.025 rem/yr
F	=	fraction of the residual radioactivity removed by the remediation action
Conc	=	average concentration of residual radioactivity in the area being evaluated (pCi/g). In this analysis, F is assigned a value of 1, but is accounted for by substituting "Conc" with $C_1 - C_2$, or 5 pCi/g Ra-226
DCGL	=	derived concentration guideline equivalent to the average concentration of Ra-226 that would give a dose of 25 mrem/yr to the average member of the critical group: 141 pCi/g or, for the worst-case exposure scenario, 26.9 pCi/g.
r	=	monetary discount rate, 0.03/year
λ	=	radiological decay constant for Ra-226, 0.000247/year
N	=	number of years over which the collective dose will be calculated, 1000 years

The above equation was modified slightly to be consistent with assumptions used in the FSS Addendum ALARA analysis (Umetco 2004a), wherein the (P_D *A) portion of the equation was replaced with a value of 10, the expected number of potentially exposed persons (see Table C.2).

Equation 2: Benefit from Collected Averted Dose (B_{AD}) *Source: NUREG-1727, Eq. D1*

Based on the above, the benefit from the collective averted dose is calculated as follows:

$$B_{AD} = \$2000 * PW(AD_{collective})$$

where:

B_{AD}	=	benefit from averted dose for a remediation action, in $
$2000	=	value in dollars of a person-rem averted
$PW(AD_{collective})$	=	present worth of future collective averted dose

In accordance with NRC guidance, B_{AD} should be evaluated in the following context: Any future corrective action that costs more than the calculated B_{AD} does not support a concomitant health benefit.

Table C.2 Equation Terms and Assumptions Used in the ALARA Analysis

Parameter/ Equation Term	Definition	Assumed Value	Reference and Comments
$PW(AD_{collective})$	Present worth of future collective averted dose (units = person-rem)	Calculated See Equation 1	NUREG-1727, Appendix D (ALARA Analyses), Eq. D2
B_{AD}	Benefit from averted dose for a remediation action ($ per person-rem)	$= PW(AD_{collective}) *$ $2000 See Equation 2	NUREG-1727, Appendix D, Eq. D1. $2000 is the value in dollars of a person-rem averted (NUREG/BR-0058, as cited in NRC 2000)
$Cost_R$	Monetary cost of remediation	$905,000	Estimated using the assumptions documented in Table C.1.
Cost per Person-rem	$= Cost/PW(AD_{collectie})$	Calculated See Equation 3	$20,000 per person-rem is considered "prohibitively expensive" (NRC 2000, App. D, Section 4.0)
Persons Exposed	Population density for the critical group scenario	10 persons	This assumption differs slightly from NUREG-1727 guidance, which calls for multiplying 0.0004 persons/m^2 by the area in question (in this case 141,640 m^2), which would yield 57 persons. 10 persons is consistent with the preceding ALARA/risk analyses undertaken for the Gas Hills site.
BRDL = Basic Radiation Dose Limit	Annual dose to an average member of the critical group from residual radioactivity at the DCGL (see below).	25 mrem/year or 0.025 rem/year	NRC (2003) dose criterion & default assumption in RESRAD code.
F	Fraction of the residual radioactivity removed by the remediation action	1	This factor was retained to be consistent with NUREG-1727. It is accounted for by substituting Conc with $C_1 - C_2$ (see below).
Conc: $= C_1 - C_2$	Reduction in average Ra-226 expected if Umetco is held to the 10 pCi/g Ra-226 frost cover limit.	5 pCi/g	C1 = 15 pCi/g, the requested Ra-226 limit; C1 = 10 pCi/g, the current standard
DCGL Derived Concentration Guideline Level	Average concentration of residual radioactivity (Ra-226) that would give a dose of 25 mrem/yr to the average member of the critical group	Best estimate – 141 pCi/g Worst-case scenario: 26.9 pCi/g	See FSS Addendum 1 report Table 3.2, where DCGL derivation is documented extensively.
r	Monetary discount rate	0.03/year	NUREG-1727, Table D.2, value applied to soils
λ	Radiological decay constant for Ra-226	0.000247/year	NUREG-1727, Appendix D, Section 1.4
N	Number of years over which the collective dose will be calculated.	1000 years	NRC default value (NUREG-1727, Appendix D, Table D.2).

Shaded rows correspond to calculated values.

Equation 3: Averted Cost per Person-rem

The averted cost per person-rem is calculated by dividing the cost by the collective averted dose, as follows: Cost per person-rem = Cost / $PW(AD_{collective})$.

C.4 ALARA Analysis Results

ALARA calculation results are documented in Tables C.3 and C.4 for the most realistic and worst-case exposure scenarios, respectively. These results are summarized in Table C.5 below.

Table C.5 Summary of GHP-2 License Amendment ALARA Results

Scenario	Model Permutation	Scenario Description	$PW(AD_{collective})$, in person-rem	B_{AD}	Cost per person-rem
1	Best Estimate	Ra-226 DCGL=141 pCi/g: most realistic exposure scenario	0.29	$586	$3,088,000 (rounded)
2	Upper Bound Exposure Scenario	Ra-226 DCGL=26.9 pCi/g: upper bound exposure	1.54	$3,073	$589,000 (rounded)

Interpretation of Results:

$PW(AD_{collective})$ is the present worth of the future collective averted dose. B_{AD} represents the benefit from averted dose for a remediation action—or $PW(AD_{collective})$ * $2000/person-rem. Any future corrective action that costs more than the calculated B_{AD} value does not support a concomitant benefit. In this case, $905,000—the estimated costs of removal and replacement of GHP-2 cover soils—far exceeds both $586 and $3,073, the B_{AD} values calculated herein for best estimate and upper bound scenarios.

As shown above, costs per person-rem for the upper bound and most realistic exposure scenarios are $589,000 and $3,088,000, respectively. These costs are substantially higher than the $20,000 cost per person-rem considered "prohibitively expensive" by the NRC (NUREG-1727, NRC 2000).

C.5 Summary

Radiation protection regulations mandate that doses be ALARA, taking into account the economics of improvement in relation to benefits to public health and safety as well as other factors. License termination, or site decommissioning, requires that the licensee demonstrate that the applicable dose criteria have been met and that doses are ALARA. The results of the preceding ALARA analysis demonstrate that removal and replacement of GHP-2 cover soils to meet a 10 pCi/g (vs. 15 pCi/g) Ra-226 criterion is not justified.

Table C.3. GHP-2 ALARA Calulation Excel Spreadsheet Documentation: Assumes 141 pCi/g DCGL

Original PWAD Equation:

$$PW(AD_{collective}) = PD * A * BRDL * F * \frac{C1 - C2}{DCGL} * \frac{1 - e^{-(r+\lambda)N}}{r + \lambda}$$

Modified Equation (see text):

$$PW(AD_{collective}) = 10 \text{ persons} * 0.025 \text{ rem/yr} * \frac{C1 - C2 \text{ pCig}}{DCGL} * \frac{1}{0.030247 \text{ yr}^{-1}}$$

Residual Radioactivity Levels that are ALARA

$$\frac{Conc}{DCGL} = \frac{\text{Cost (\$)}}{\$2000/\text{person-rem}*0.025 \text{ rem/yr}*10 \text{ persons}} * \frac{r + \lambda}{1 - e^{-(r-\lambda)N}}$$

Parameter	Assumed Value	Units	Type	Definition
$PW(AD_{collective})$	0.29	person-rem	Calculated	Total collective averted dose
B_{AD}	$ 586	$	Calculated	Benefit from averted dose for a remediation action, = $PW(AD_{collective})$ * $2000
Cost per person-rem	$ 3,087,735		Calculated	= Cost / PW(ADcollective)
ALARA Level, Conc/DCGL	54.75	unitless ratio	Calculated	Ratio
Conc	7,719	pCi/g	=Conc/DCGL * 141 pCi/g DCGL	The residual radioactivity that is ALARA is the concentration, Conc, at which the benefit from removal equals the cost of removal.
$Cost_R$	$ 905,000	dollars	Variable	Assumes removal of the top two feet and replace with 10 pCi/g materials - see cost calcs.
BRDL	0.025	rem/yr	Fixed	
r	0.03	yr^{-1}	Fixed	monetary discount rate
λ	0.000247	yr^{-1}	Fixed	radiological decay constant for Ra-226
N	1000	yrs	Fixed	Number of years over which the collective dose will be calculated.
DCGL	141	pCi/g	Variable	Altenate analysis uses more conservative value of 26.9 pCi/g.
C1	15	pCi/g	Fixed	Reflects current scenario and deviation requested in this license amendment.
C2	10	pCi/g	Fixed	Assumes removal and replacement of frost protection cover materials to meet 10 pCi/g criterion.
$r + \lambda$	0.030247			
$(r + \lambda) N$	30.247			
$e^{-(r+\lambda)N}$	7.30977E-14			
P (persons exposed)	10	persons	Fixed	Value used in place of NRC term P_D *A, to be consistent with the ALARA evaluation provided in the FSS Addendum 1 (see Table 3.2). Use of P_D*A for GHP-2 would correspond to an exposed population of 57 persons, an unlikely scenario for GHP-2.

Table C.4. GHP-2 ALARA Calulation Excel Spreadsheet Documentation: Assumes 26.9 pCi/g DCGL

Original PWAD Equation:

$$PW(AD_{collective}) = PD * A * BRDL * F * \frac{C1 - C2}{DCGL} * \frac{1 - e^{-(r+\lambda)N}}{r+\lambda}$$

Modified Equation (see text):

$$PW(AD_{collective}) = 10 \text{ persons} * 0.025 \text{ rem/yr} * \frac{C1 - C2 \text{ pCig}}{DCGL} * \frac{1}{0.030247 \text{ yr}^{-1}}$$

Residual Radioactivity Levels that are ALARA

$$\frac{Conc}{DCGL} = \frac{Cost (\$)}{\$2000/\text{person-rem}*0.025 \text{ rem/yr}*10 \text{ persons}} * \frac{r+\lambda}{1 - e^{-(r-\lambda)N}}$$

Parameter	Assumed Value	Units	Type	Definition
$PW(AD_{collective})$	1.54	person-rem	Calculated	Total collective averted dose
B_{AD}	$ 3,073	$	Calculated	Benefit from averted dose for a remediation action, = $PW(AD_{collective})$ * $2000
Cost per person-rem	$ 589,078		Calculated	= Cost / PW(ADcollective)
ALARA Level, Conc/DCGL	54.75	unitless ratio	Calculated	Ratio
Conc	1,473	pCi/g	=Conc/DCGL * 26.9 pCi/g DCGL	The residual radioactivity that is ALARA is the concentration, Conc, at which the benefit from removal equals the cost of removal.
$Cost_R$	$ 905,000	dollars	Variable	Assumes removal of the top two feet and replace with 10 pCi/g materials - see cost calcs.
BRDL	0.025	rem/yr	Fixed	
r	0.03	yr^{-1}	Fixed	monetary discount rate
λ	0.000247	yr^{-1}	Fixed	radiological decay constant for Ra-226
N	1000	yrs	Fixed	Number of years over which the collective dose will be calculated.
DCGL	26.9	pCi/g	Variable	This DCGL corresponds to a worst-case exposure scenario.
C1	15	pCi/g	Fixed	Reflects current scenario and deviation requested in this license amendment.
C2	10	pCi/g	Fixed	Assumes removal and replacement of frost protection cover materials to meet 10 pCi/g criterion.
$r + \lambda$	0.030247			
$(r + \lambda) N$	30.247			
$e^{-(r+\lambda)N}$	7.30977E-14			
P (persons exposed)	10	persons	Fixed	Value used in place of NRC term P_D *A, to be consistent with the ALARA evaluation provided in the FSS Addendum 1 (see Table 3.2). Use of P_D*A for GHP-2 would correspond to an exposed population of 57 persons, an unlikely scenario for GHP-2.

Attachment 1

Final Design and Reclamation Plan for GHP No. 2/Mill Area
Revision 1, September 2003

Replacement Pages

Umetco Minerals Corporation

GAS HILLS RECLAMATION PROJECT

Docket No. 40-0299
License No. SUA-648

FINAL DESIGN and RECLAMATION PLAN

for

GHP No. 2/Mill Area

May 2003
Revision 1, September 2003
Revision 2, February 2006

Prepared by
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1.0 INTRODUCTION

This submittal provides the final reclamation design detail for the Gas Hills Pond (GHP) No. 2 area of Umetco Minerals Corporation's (Umetco), Gas Hills, Wyoming site.

Umetco requested a modification to License Condition 61 of U.S. Nuclear Regulatory Commission (NRC) License No. SUA-648 in February 2006. The purpose of the amendment was:

1) to allow the placement of frost protection cover soils with an average radium-226 (Ra-226) content of up to 15 picocuries per gram; and

2) to adjust the allowable exposure rate limit for the reclamation cover to 40 mircoroentgen per hour to reflect the increase in Ra-226 content of the cover soils and better reflect exposure rates characteristic of the background areas coinciding with borrow material sources.

This modification amended the requirements set forth in Section 2.4 of this plan (as noted in the section) and in Tables 3.1 – *Summary of Background Levels and Cleanup Criteria to be Applied in the Final Status Survey* and 4.1 – *Summary of Generalized Final Status Survey Approach* of the *Final Status Survey Plan, Gas Hills, Wyoming Site,* dated September 2000. The data and rationales supporting the amendment are documented in the *License Amendment for Final Design and Reclamation Plan, GHP No. 2/Mill Area, Gas Hills, Wyoming Site,* dated February 2006. The license amendment demonstrates that the deviations requested above will not adversely impact health, safety, or the environment. Furthermore, public access will be limited because GHP No. 2 is located within the site transfer boundary. Based on the latter findings and the additional analyses documented in the license amendment, Umetco believes that an optimal radon barrier and frost protection cover will be constructed on GHP No. 2.

1.1 Background

In a September 25, 1996 submittal, Umetco requested approval of a revised reclamation plan for the Heap Leach area including the GHP No. 2 pond area. Minimal site data was provided for reclaiming GHP No. 2 since disposal of liquid waste (evaporation of liquids from groundwater extraction) was not complete and duration of the Groundwater Corrective Action Plan (CAP) unknown. In response to NRC staff concerns regarding the limited data, Umetco acknowledged (February 11, 1998 letter) that the provided design was preliminary. Umetco committed to providing a final design for closure of GHP No. 2 when the necessary data were available.

1.2 GHP No. 2 Setting

GHP No. 2 is a 17-acre evaporation pond constructed in the former mill process and or stockpile area of the Gas Hills facility. Subsurface site characterization data obtained prior to constructing GHP No. 2 indicate that soils in the area (beneath the existing pond) contain, at depth, elevated concentrations of radionuclides which appear to occur from natural mineralization and mill related impacts. Considering the volume of potentially impacted soils and the difficulty in

distinguishing 11e.(2) affected soils from naturally elevated soils in this area, the pond will be reclaimed in place.

1.3 Design Overview

The reclamation design for the GHP No. 2 pond area was developed to provide long-term closure and stabilization of the area in accordance with the requirements of NRC regulations stated in 10 CFR Part 40, Appendix A. The key components of this design include the following:

- Solidifying remaining liquids and evaporative residue
- Removing, disposing and utilizing the existing pond lining system
- Reclamation cover design

1.3.1 Solidifying Remaining Liquids and Residue

Umetco's groundwater CAP was terminated on March 29, 2002 by NRC approval (Amendment 48) of Alternate Concentrations Limits (ACLs) for the Gas Hills site. Coinciding with ACL approval, reclamation activities at the site have progressed to a point in which soil cleanup activities have been completed with the Final Status Survey Plan (FSSP) report to be submitted in September 2003 and completion of the A-9 radon barrier in 2003. Consequently, discharge of liquid 11e.(2) byproduct liquids into the GHP No. 2 pond have terminated with the exception of solutions removed from the A-9 decant tower and contaminated storm flows, i.e., runoff from uncovered portion of A-9 disposal cell.

- radium activity for the frost protection soil assumes 10 pCi/g ^{226}Ra. Field measurements of ^{226}Ra during construction will control and verify that ^{226}Ra concentrations are less than 10 pCi/g ^{226}Ra. The February 2006 NRC license amendment request allowed the use of material with ^{226}Ra concentrations of up to 15 pCi/g for the frost protection on GHP No. 2.

3.0 GEOTECHNICAL DESIGN

This section provides the geotechnical considerations for closing the GHP No. 2 area of the Gas Hills site. Geotechnical design elements for this reclamation plan include slope stability, settlement, liquefaction, and frost penetration.

3.1 Cover Design

The GHP No. 2 reclamation cover consists of a 12-inch thick radon barrier layer, 54-inch thick frost penetration layer, and an erosion protection layer. The cover for the GHP No. 2 area has been designed with a gentle 1 percent top slope and 20 percent out slope as shown on the drawings.

3.2 Slope Stability Analysis

The long-term stability of the reclaimed GHP No. 2 embankment was evaluated using SLOPE/W, Version 5, GEO-SLOPE International Ltd. SLOPE/W is a slope stability software product that uses limit equilibrium theory to compute the factor of safety of earth and rock slopes.

3.2.1 Material Properties

The foundation and cover soil properties used in the Heap Leach analysis are the same as those that exist and are proposed for the GHP No. 2 reclamation cover. Accordingly, the material properties approved for the Heap Leach were used for the stability analysis. The following is a summary of material types and properties used for this analysis. Test results used are contained in the approved design for the Heap Leach facility and summarized in Table 3-1.

Frost Protection Soil – These soils are clayey sand and/or silty-clayey sand that classify as SC or SC-SM. The maximum standard Proctor density ranges from 109 to 121 pcf with and optimum moisture content of 11 percent to 14 percent. Consolidated undrained triaxial shear testing of these soils resulted in an average internal angle of friction (total stress) of 22 degrees and cohesion of 200 psf.

Radon Barrier Material – The clay material proposed for the radon barrier is obtained from a borrow source located 6 miles northeast of the East Gas Hills facility. Radon barrier soil generally consists of fat clays (CH) and some lean clays (CL) with generally greater than 95 percent passing the No. 200 sieve. The maximum standard Proctor density ranges from 100 to 105 psf with an optimum moisture content ranging from 19 to 22 percent. Consolidated undrained triaxial shear testing of this soil resulted in an average internal angle of friction (total stress) of 15 degrees and cohesion of 16 psf. Field hydraulic conductivity tests of this material, when compacted in place results in a coefficient of permeability of 3E-9 to 7E-9 cm/sec.