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MEMORANDUM

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DATE: **May 19, 2005**

SUBJECT: **Correlation of Ra-226 in soil with gamma exposure rate at the Moab site**

BACKGROUND

Cleanup criteria for the uranium mill site near Moab, Utah require that average residual (above background) soil concentrations of Ra-226 in the top 15 cm (6 inches) of the soil profile cannot exceed 5 pCi/g. Background concentrations of Ra-226 in soil at the Moab site average about 1 pCi/g. Thus, any location potentially impacted by site activities, and having an average Ra-226 soil concentration greater than 6 pCi/g in the top 15 cm of the soil profile, will require cleanup as part of the decommissioning process.

An automated, GPS-based in situ gamma scanning system developed by MFG Inc. is being used to estimate Ra-226 concentrations in soil at the Moab site. The basic methodology is as follows:

1. Perform comprehensive gamma scan surveys of background locations and areas of potential contamination, recording collimated* gamma exposure rate readings and UTM coordinates at 1-2 second intervals using backpack or vehicle mounted systems.
2. Plot gamma scan survey results on detailed base maps of the area.
3. Establish small-scale (100 m^2) plots within survey areas. Re-survey 100 m^2 plots to determine average gamma readings, take composite and/or individual soil samples within plots (to a depth of 15 cm) and analyze them to determine average soil radionuclide concentrations.

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* Throughout this document, the term "gamma exposure rate" refers to measurements from a collimated detection system (i.e. a system shielded to help reduce "shine" and limit the area being measured to a small portion of the soil surface directly underneath the detector).

4. Develop a statistical correlation between average gamma readings and average soil radionuclide concentrations for the 100 m^2 plots.
5. Use the correlation equation to predict a *baseline* gamma exposure rate reading that corresponds to the 6 pCi/g Ra-226 clean-up criteria with a 95% level of statistical confidence.
6. Assess the gamma survey map with respect to the *baseline* gamma exposure rate to determine areas requiring cleanup, areas already in compliance, and borderline areas that might require further sampling and radiological measurements.

Items 1-3 above are being conducted by on-site field technicians. Items 4 and 5 are being performed by MFG Inc. The purpose of this technical memo is to report the results to date of items 4 and 5 above. This information will be used to conduct evaluations as described above for item 6.

CORRELATION RESULTS

Ra-226 concentrations ranged from background to over 40 pCi/g and mean gamma exposure rates ranged up to 32 µR/hr for the sampled 100 m^2 grids as shown in Table 1.

Table 1. Average Ra-226 concentrations and gamma exposure rates for correlation plots to date.

Sample Location Number	Mean Ra-226 Concentration (pCi/g)	Mean Gamma Exposure Rate (uR/hr)	Sample Location Number	Mean Ra-226 Concentration (pCi/g)	Mean Gamma Exposure Rate (uR/hr)
X-LK-149	22.5	21.0	V-LJ-35	1.9	4.7
X-LK-150	30.0	25.6	V-LJ-37	1.4	5.0
X-LK-151	30.3	31.4	V-LJ-41	1.1	5.3
X-LK-169	23.0	19.3	V-LJ-54	2.3	4.7
X-LI-180	11.1	10.6	V-LJ-55	2.8	5.1
X-LI-181	7.2	11.0	V-LJ-57	1.8	5.2
X-LK-172	38.4	32.0	V-LJ-59	1.9	5.2
X-LK-173	19.5	19.5	V-LJ-81	1.4	5.3
X-LK-189	40.9	29.6	V-LJ-83	0.9	4.7
X-LK-194	14.9	12.5	V-MJ-333	0.9	4.8
V-LJ-77	2.2	6.0	V-MJ-335	2.4	4.3
V-LK-85	1.3	5.0	V-MJ-353	0.9	4.3
V-LJ-100	2.7	6.1	V-MJ-355	2.7	4.2
V-LJ-13	3.8	4.6	V-MJ-369	1.7	4.5
V-LJ-15	3.5	4.5	V-MJ-371	2.3	4.8
V-LJ-17	1.1	4.8	V-MJ-373	2.1	4.6
V-LJ-19	2.5	4.9	V-MJ-375	0.8	4.2
V-LJ-21	0.7	4.4	V-MJ-377	0.8	4.5
V-LJ-33	2.9	4.7			

The correlation curve and regression statistics for the data pairs provided in Table 1 are shown in Fig. 1.

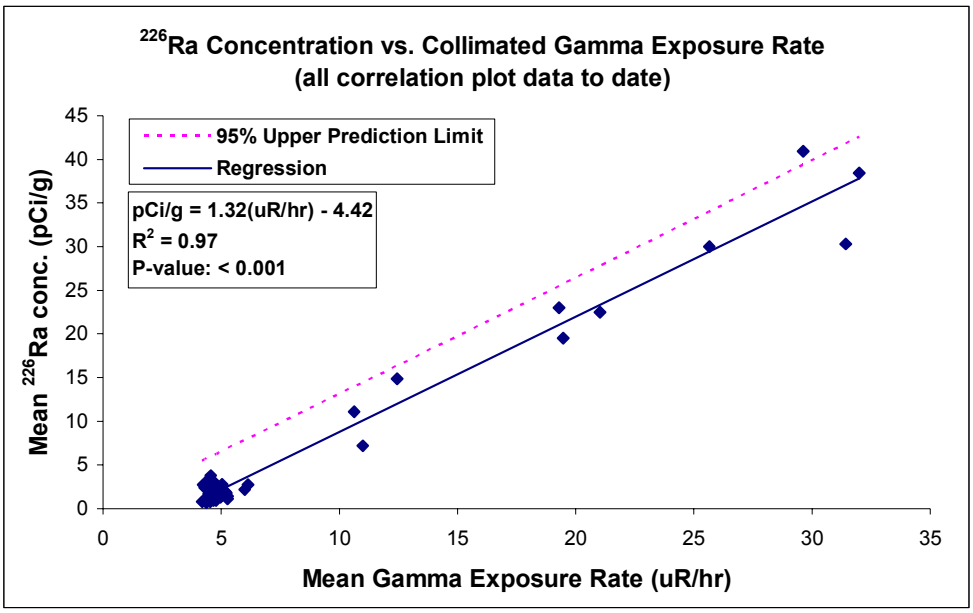

Fig. 1. Mean Ra-226 concentration in surface soils vs. gamma exposure rates.

DISCUSSION / CONCLUSION

The regression equation and correlation statistics shown in Figure 1 demonstrate that the relationship between exposure rate and Ra-226 soil concentration is highly significant (p-value < 0.001). The p-value indicates that there is less than a 0.1 % probability that the apparent relationship is due to chance. The r^2 value indicates that 97% of the variance in Ra-226 soil concentration can be explained by the regression on gamma exposure rate readings.

Also shown in Figure 1 is a one-tailed, 95% upper prediction limit (UPL) for Ra-226 soil concentration versus collimated exposure rate reading. The UPL applies statistical uncertainty to the regression line. UPL's and p-values were calculated using the StatMost™ statistical software package (StatMost, 1994-1995). The 95% UPL provides an estimate, with 95% certainty, of the maximum Ra-226 soil concentration that will exist at a given collimated gamma exposure rate reading. Table 2 shows StatMost generated 95% UPL data in tabular format.

Table 2. 95% UPL values for Ra-226 soil concentration corresponding to various gamma exposure rate readings.

Collimated Exposure Rate (uR/hr)	95% Upper Prediction Limit (pCi/g)	Collimated Exposure Rate (uR/hr)	95% Upper Prediction Limit (pCi/g)
4.2	5.5	6.0	7.9
4.3	5.6	6.1	8.0
4.4	5.8	10.6	13.9
4.5	5.9	11.0	14.4
4.6	6.0	12.5	16.4
4.7	6.1	19.3	25.5
4.8	6.3	19.5	25.8
4.9	6.4	21.0	27.8
5.0	6.5	25.6	33.9
5.1	6.7	29.6	39.3
5.2	6.8	31.4	41.8
5.3	6.9	32.0	42.6

The results shown in Table 2 illustrate that a 6 pCi/g concentration criteria can be predicted with a high degree of statistical certainty using a *benchmark* collimated gamma exposure rate reading of 4.6 uR/hr. Statistically, this *benchmark* reading will have Ra-226 soil concentrations greater than 6 pCi/g only 5% of the time. In other words, we can be 95% certain that areas with collimated readings below 4.6 uR/hr will not require clean-up in order to meet the 6 pCi/g criteria.

REFERENCE

StatMost for Windows: Statistical Analysis and Scientific Graphics. Version 2.50. Copyright 1994-1995. DataMost Corporation, Salt Lake City, Utah 84165.