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Title: Dose Assessment of LANL-Derived Residual Radionuclides in Soils Within Tract A-10 for Land Transfer Decisions

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Dose Assessment of LANL-Derived Residual Radionuclides in Soils Within Tract A-10 for Land Transfer Decisions

September 2012-Final

1.0 Background for A-10 Dose Assessment[1]

1.1 Site Location

The DP Road-3 East Tract is located between the western boundary of Technical Area-21 (TA-21) and the eastern boundaries of the commercial districts of the Los Alamos townsite (see Figure 1). World War II and Cold War facilities at TA-21 used for nuclear weapons work are planned to be decontaminated and demolished; contaminated areas will be remediated in the near term as stipulated in the Consent Order (NMED 2005).

This approximately 13.8-acre tract is located southwest of Los Alamos County (LAC) Airport (transferred from DOE to LAC in October 2008) and other variously owned County land and private properties. It is bounded on the north by commercial properties, on the south by LAC and commercial properties on DP Mesa, on the west by active and vacant commercial land, and on the east by DOE/NNSA land. The legal property boundary description of this tract is provided by the U.S. Army Corps of Engineers' *Land Survey Plat, Los Alamos National Laboratory, Tract A-10, Being a Part of Tract AA and Parcel 2, Eastern Area No. 2, County of Los Alamos, State of New Mexico,* recorded by the Los Alamos County Clerk on March 18, 2003.

A-10 is unoccupied, vacant land. No structures or facilities associated with LANL's federal, state, or local permits (such as air monitoring stations, radiation monitoring stations, or wastewater discharge outfalls) are located within A-10, although there are several stormwater outfall pipes from businesses located south of A-10.

The DP Road-3 East parcel was never actively used by the Laboratory, no Laboratory operations were conducted within the tract boundaries, and no Laboratory structures were situated within the tract.

1.2 Sampling and Analysis Plan

The sampling and analysis plan (SAP) for Tract A-10 (LANL 2012a) was developed using a MARSSIM (MARSSIM 2000) approach, as required in DOE O 458.1 and LANL policy and procedures (LANL 2012a, b). The objective of the SAP was to confirm, within the stated statistical confidence limits, that the mean levels of potential radioactive residual contamination in soils in the tract A-10 are documented, in appropriate units, and are below the 15 mrem yr^{-1} Screening Action Levels (SALs), as derived in LANL (2005). The sampling and analysis plan (SAP) for Tract A-10 follows the LANL (2012a) procedure EDA-QP-238, "Dose assessment data quality objectives for land transfers into the public domain."

1.2.1Preliminary Results from Surveys for Residual Contamination

As detailed in the Sampling and Analysis Plan (SAP) for Tract A-10 (Appendix A), previous measurements of soil concentration data from the tract were used to determine the potential for soil contamination in the tract and the standard deviation was used in the Sign Test to determine the number of samples required in the final survey of tract A-10, as outlined in MARSSIM.

[1] Text modified slightly from Swanton, B.A., Isaacson, J., Nisengard, J., Schumann, P.B., Pope, J., Smith, V., Birdsall, K.T., Bertino, P.M., 2006. Environmental baseline survey results for Tract A-10, DP Road-3 east (DP canyon). Los Alamos National Laboratory report LA-UR-06-5607.

Table 1 provides this preliminary data from Tract A-10 for radionuclides of potential interest. Based on the preliminary analysis, Tract A-10 was classified as a Class 3 area because, as shown in Table 1, the soil concentrations are near background levels and significantly below the SALs for each specific radionuclide. Based on these results, 11 samples were required and the locations randomly selected. The sampled locations are shown in Figure 2 and the coordinates provided in Table 2. As concluded from historical information and previous sediment sampling, the list of radionculides in the analysis include Am-241, Cs-137, H-3, Pu-239, Pu-238, Sr-90, U-234, U235, and U-238 (Table 1).

1.3 Statistical Analysis

The principle study question is: Does the residual radioactive contamination exceed ALs for the residential exposure scenario?

The decision alternatives are:

- If results from the soil radioactive contamination measurements are at or above the AL (collectively), the site is not a candidate for land transfer.
- If results from the soil radioactive contamination measurements are below the AL (collectively), the site is a candidate for land transfer.

The decision rule is based on the null hypothesis that the mean residual contamination levels in soil and/or sediment in Tract A-10 combined over all radionuclides is above the AL and likely to result in an all pathway radiation dose to the critical receptor above 15 mrem yr^{-1}. The alternative hypothesis is that the mean residual contamination levels in soil and/or sediment in Tract A-10 combined over all radionuclides is below the AL and not likely to result in an all pathway radiation dose to the critical receptor above 15 mrem yr^{-1}.

The assumed future land use and exposure pathway assumes residential use. The radionuclides analyzed for and the respective residential AL is provided in Table 1. The 15 mrem yr^{-1} ALs used in this analysis were calculated using RESRAD (RESRAD 2001) and documented in LANL (2005).

1.3.1 Statistical Evaluation of the Survey Results

All the applicable data that has passed the Measurement Quality Objective (MQO) evaluation will be used to determine the upper-bound confidence level (UCL) estimate of the mean for soil concentrations (generally, the 95% value) for each radionuclide. The EPA software ProUCL (EPA 2010) was used to determine this value. The statistical decision as to whether the residual soil contamination levels (i.e., the 95% UCLs) are below the authorized limits will be evaluated using the following criteria.

Decision Criteria:

1) If all samples are ≤ residential AL, then no further action is required and the site passes the criteria for residential occupation. No further actions are needed.
2) If all samples or the UCL are > the AL, then the site is not a candidate for release and site remediation is needed followed by resampling before it can be released.

3) If the UCL is below the AL but some individual measurements are above the AL, then statistical analysis is needed. Generally, non-parametric statistical approaches are used to evaluate the null hypothesis. If contamination is present in background, the Wilcoxon Rank Sum test is suggested, and if contamination is not present in background or very low relative to the AL, use the Sign Test. For Tract A-10, the Sign Test will be used with a $p < 0.05$ decision threshold for significance. See MARSSIM chapter 8 for details and examples.
4) Because of multiple radionuclides, we also tested that the ratio of the upper-confidence level (UCL) of the average concentration divided by the AL and the sum of the ratios did not exceed 1, as show in eqn. 1. Because there was no indication or reasonable physical mechanism to create hot spots, we assumed that the contamination was homogeneously distributed across the tract.

$$\sum_{i=1}^{n} \frac{C_{UCL,i}}{C_{AL}} \leq 1 \qquad \text{(eqn.1)}$$

Here $\overline{C}_{UCL}$ is the 95% upper bound estimate of the concentration mean, C_{AL} is the resident AL (15 mrem yr^{-1}).

1.3.2 ALARA Evaluation

LANL policy P410 "Los Alamos National Laboratory Environmental ALARA Program" (LANL 2011) requires an ALARA evaluation based on procedure SOP-5254 "Performing ALARA Analysis for Public Exposures" (LANL 2009). If the calculated individual dose exceeds 3 mrem/yr, then a quantitative ALARA evaluation is performed.

1.4 Instrumentation and Measurement Quality Objectives

The main objectives are to determine appropriate analysis technique for each radionuclide and ensure Measurement Quality Objectives (MQOs) are satisfied. One should be confident that the measurement results are valid and appropriate for the decisions being made.

1.4.1 Measurement Quality Objectives:

- Detection Capability: Minimum Detection Concentration (MDC) should be below the MARSSIM defined Lower Bound of the Gray Region (LBGR).
- The degree of measurement uncertainty (combined precision and bias) should be reported and the level reasonable relative to the needed accuracy of the decision and accounted for in the statistical analysis.
- Range of the instrument and measurement technique should be appropriate for the concentrations expected.
- The instrument and measurement technique should be specific for the radionuclide(s) being measured. Specificity is the ability of the measurement method to measure the radionuclide of concern in the presence of interferences.

- For field instruments, the instrument should be rugged enough to consistently provide reliable measurements. However, in this case, all samples will be analyzed in the laboratory.

2.0 Results of Soil Measurements.

Table 3 provides the measurements of soil concentrations for the randomly selected locations. Averages, standard deviations, 95 percent UCLs, and ALs for each of the radionuclides are also provided in this table. Results show that Pu-239 was detected above background but all concentrations were below the ALs and meet the real property release criteria. Combining all radionuclides by using Eqn. 1, the sum of the ratios of the 95% UCL without background subtraction divided by the ALs was 0.227, which is substantially below 1. The calculated dose, without background subtraction was 3.4 mrem/yr (15 mrem/yr * 0.227) and was driven almost exclusively by the Pu-239 measurements.

2.2 ALARA Analysis

Because the combined dose calculated using the 95% UCL without background subtraction resulted in a dose above screening level of 3 mrem/yr, the LANL environmental ALARA program, through policy P410 and procedure SOP-5254 (LANL 2009, 2011), required that an additional analysis be done. Specifically, LANL is required to subtract out background from the measurements, recalculate the dose, and compare again to the 3 mrem/yr ALARA threshold. Background levels for the radionuclides were taken from Ryti et al. (1998) and these concentrations are provided in Table 3. Table 3 shows that the calculated dose after background subtraction was 2.16 mrem/yr. Because this dose does not exceed the threshold of 3 mrem/year for performing a quantitative ALARA analysis, no further ALARA analysis is required in accordance with PD410, Los Alamos National Laboratory Environmental ALARA Program, and the calculated dose of 2.16 mrem/year is therefore considered ALARA.

2.3 Quality Assurance

Soils were collected according to procedures and the laboratory analysis techniques were appropriate for the specific radionuclides, as required in the SAP for A-10 (Appendix A). The analysis at the independent laboratory was within their predefined boundaries and met all quality assurance requirements. Only qualified data was used in this analysis and minimum detectable concentrations were below the LBGR. Thus, all measurement quality objectives were met for this data set.

2.4 Conclusion

Given that 1) all the measurements were below the ALs for each individual radionuclide, 2) the sum of the ratios was below 1, and 3) the resulting combined calculated dose was less than the 15 mrem/yr for a hypothetical resident, we conclude that the A-10 tract is a candidate for land transfer to the public for residential use.

4.0 REFERENCES

EPA (Environmental Protection Agency), 2010. ProUCL Version 4.1 User Guide (draft). EPA/600/R-07/041.

LANL (Los Alamos National Laboratory), 2005, "Derivation and Use of Radionuclide Screening Action Levels, Revision 1." (LA-UR-05-1849, ER2005-0127)

LANL (Los Alamos National Laboratory), 2009. Performing ALARA Analysis for public Exposures. ENV-ES procedure SOP-5254. Document can be found at web site address: http://www.lanl.gov/community-environment/environmental-stewardship/_assets/docs/qa/dose-assessment/SOP-5254.pdf verified 20 Sept. 2012.

LANL (Los Alamos National Laboratory), 2011. ALARA Policy P410 Los Alamos National Laboratory Environmental ALARA Program. Document can be found at web site address https://policy.lanl.gov/pods/policies.nsf/LookupDocNum/PD410/$file/PD410.pdf verified 20 Sept. 2012.

LANL (Los Alamos National Laboratory), 2012a. Dose assessment data quality objectives for land transfers into the public domain. LANL procedure EDA-QP-238.

LANL (Los Alamos National Laboratory) 2012b. Environmental Radiation protection. LANL Policy P412.

MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual), 2000. NUREG-1575, EPA 402-R-97 Rev.1, DOE/EH-0624, Rev.1

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RESRAD, 2001. User's manual for RESRAD Version 6.0. Argonne National Report ANL/EAD-4.

Ryti, R.T., Longmire, P.A., Broxton, D.E., Reneau, S.L., McDonald, E.V. 1998. Inorganic and radionuclide data for soils, canyon sediments, and Bandeleir tuff at Los Alamos National Laboratory. Los Alamos National Laboratory report LA-UR-4847.

Swanton, B.A., Isaacson, J., Nisengard, J., Schumann, P.B., Pope, J., Smith, V., Birdsall, K.T., Bertino, P.M., 2006. Environmental baseline survey results for Tract A-10, DP Road-3 east (DP canyon). Los Alamos National Laboratory report LA-UR-06-5607.

Figure 1. Map showing Tract A-10. Map taken from Swanton et al. (2006).

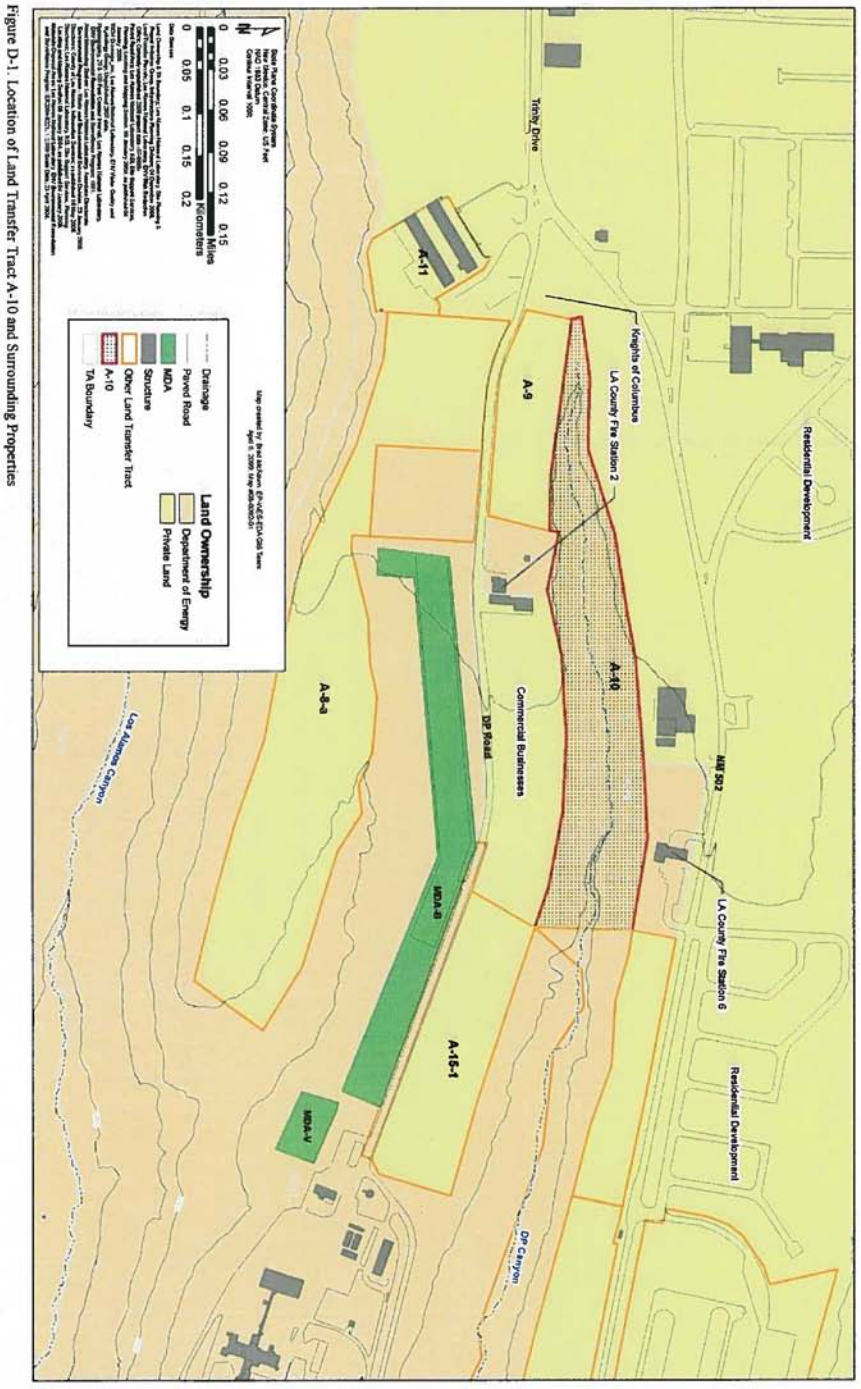

Figure D-1. Location of Land Transfer Tract A-10 and Surrounding Properties

Figure 2. Google Earth image of Tract A-10 with approximate sampling area for A-10 in yellow. Blue dots represent randomly selected sampling locations.

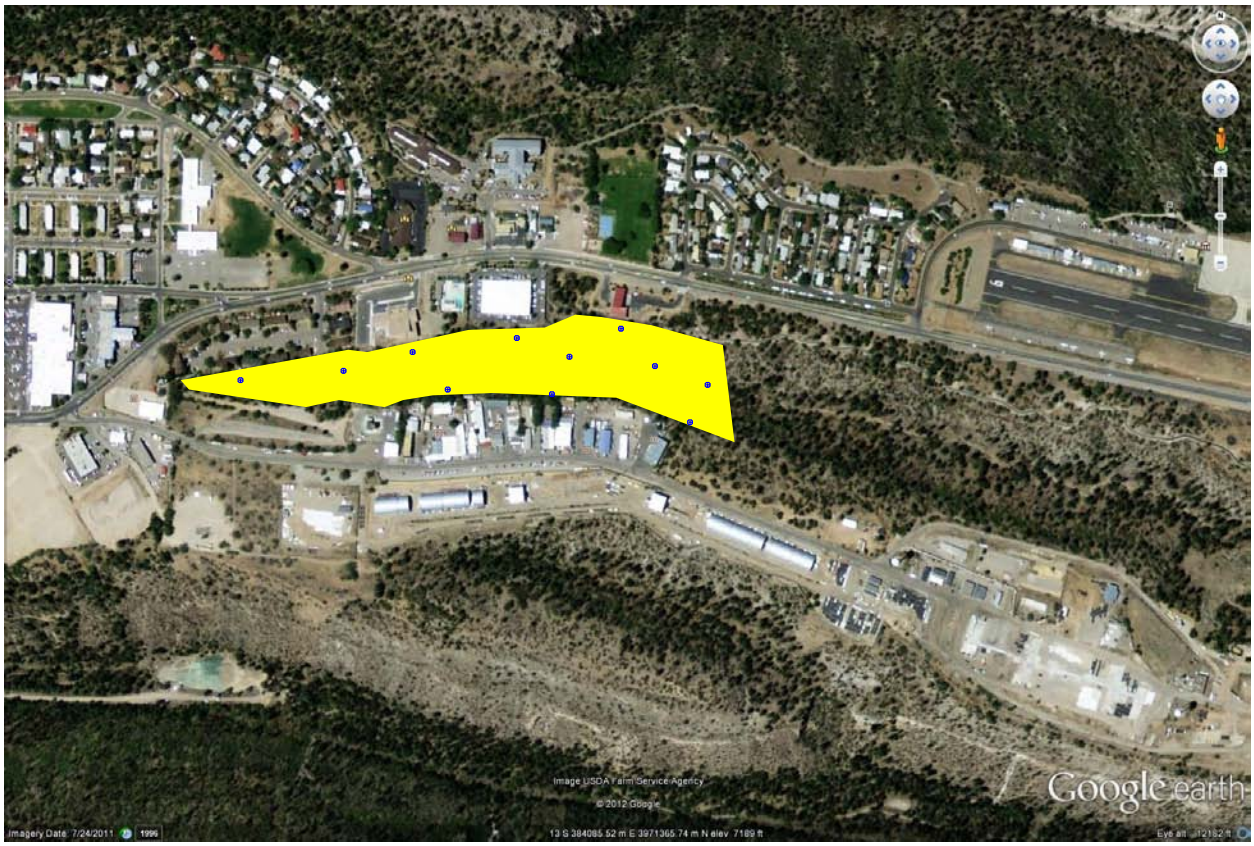

Table 1. Preliminary Results from Tract A-10 for radionuclides along with comparative values.

Am-241 (pCi/g)	**Cs-137 (pCi/g)**	**Tritium (pCi/g)**	**Pu-238 (pCi/g)**	**Pu-239/240 (pCi/g)**	**Sr-90 (pCi/g)**	**U-234 (pCi/g)**	**U-235 (pCi/g)**	**U-238 (pCi/g)**
0.34 ± 0.105	0.62 ± 0.09	0.13 ±0.035	0.02 ± 0.015	0.089 ± 0.11	0.27 ± 0.195	1.84 ± 0.13	0.105 ± 0.017	2.04±0.14
0.053 ± 0.016	0.31 ± 0.08	0.042 ± 0.005	0.013 ± 0.009	0.068 ± 0.012	0.27 ± 0.155	1.69 ± 0.25	0.099 ± 0.018	1.53±0.23
0.012 ± 0.003	0.206 ± 0.041	0.11 ± 0.05	0.005 ± 0.004	0.048 ± 0.011	0.2 ± 0.19	1.1 ± 0.2	0.077 ± 0.016	1.15±0.2
0.005 ± 0.002	0.11 ± 0.019	0.054 ± 0.017	0.003 ± 0.005	0.044 ± 0.01	0.19 ± 0.185	0.918 ± 0.07	0.054 ± 0.013	0.958±0.072
0.15 ± 0.2	0.12 ± 0.06	0.5 ± 0.025	0.002 ± 0.002	0.19 ± 0.004	0.19 ± 0.15	0.845 ± 0.065	0.051 ± 0.014	0.833±0.065
0.09 ± 0.075	0.009 ± 0.015	0.022 ±0.010	0.001 ± 0.004	0.028 ± 0.012	0.15 ± 0.155	0.67 ± 0.075	0.05 ± 0.013	0.65±0.07
0.014 ± 0.01		0.02 ± 0.008	0.001 ± 0.001	0.013 ± 0.007	0.12 ± 0.155	0.58 ± 0.055	0.048 ± 0.012	0.55±±0.055
0.011 ± 0.008		0.007 ±0.035	0.0003 ± 0.004	0.012 ± 0.009	0.11 ± 0.15	0.57 ± 0.055	0.047 ± 0.011	0.53±0.05
0.01± 0.008		0.007 ± 0.009	0 ± 0.004	0.009 ± 0.005	0.1 ± 0.14	0.55 ± 0.05	0.047 ± 0.011	0.511±0.050
0.006 ± 0.008		0.003 ± 0.01	-0.001 ±0.006	0.007 ± 0.006	0.05 ± 0.065	0.55 ± 0.055	0.072 ± 0.028	0.491±0.048
0.03 ± 0.008		0.002 ± 0.006	0.001 ± 0.004	0.006 ± 0.004	0.025 ± 0.06	0.493 ± 0.049	0.06 ± 0.05	0.487±0.048
0.001 ± 0.006		0.001 ± 0.007	-0.004 ± 0.004	0.001 ± 0.006	0.00 ± 0.058	0.475 ± 0.047	0.058 ± 0.07	0.41±0.042
0.00 ± 0.235			-0.004 ± 0.007	0.0003 ± 0.004	-0.020 ± 0.058		0.04 ± 0.035	
-0.001 ± 0.008			-0.011 ± 0.007	0.00 ± 0.007	-0.88 ± 0.31		0.039 ± 0.05	
-0.017 ± 0.041							0.036 ± 0.037	
-0.068 ± 0.053							0.03 ± 0.011	
							0.05 ± 0.165	
							-0.147 ± 0.043	
Summary Statistics and Comparative Values (pCi/g)								
Mean = 0.038	Mean = 0.229	Mean = 0.037	Mean = 0.002	Mean = 0.025	Mean = 0.055	Mean = 0.857	Mean = 0.044	Mean = 0.845
Std = 0.094	Std = 0.217	Std = 0.04	Std = 0.007	Std = 0.028	Std = 0.284	Std = 0.466	Std = 0.052	Std = 0.503
UTL = 0.14 (95%)	UTL = 0.62 (max)	UTL = 0.005 (95%)	UTL = 0.005 (95%)	UTL = 0.057 (95%)	UTL = 0.387 (95%)	UTL = 1.123 (95%)	UTL = 0.098 (95%)	UTL = 1.137 (95%)
Background 0.006	Background 0.42	Background ~0.13(@15% soil moisture)	Background 0.005	Background 0.015	Background 0.36	Background 1.4	Background 0.087	Background 1.22
Resident SAL 30	Resident SAL 5.6	Resident SAL 750	Resident SAL 37	Resident SAL 33	Resident SAL 5.7	Resident SAL 170	Resident SAL 17	Resident SAL 87

Table 2: Sample ID numbers and final coordinates from random sampling based on MARSSIM-Derived sampling plan. Shaded rows are duplicates.

SampleID	FieldID	GpsID	Y	X	Z	Parcel	Notes
RE21-12-21847	14	5014	1775667.083	1628996.327	7154	A-10	
RE21-12-21848	19	5019	1775647.006	1628515.612	7186	A-10	
RE21-12-21849	22	5022	1775645.728	1629525.426	7186	A-10	
RE21-12-21850	16	5016	1775692.312	1629986.047	7144	A-10	
RE21-12-21851	18	5018	1775562.931	1630485.259	7139	A-10	
RE21-12-21852	13	13	1775691.857	1630465.198		A-10	
CARE-12-21913	13	13	1775691.857	1630465.198		A-10	FDUP
RE21-12-21853	17	17-SURV	1775761.148	1629380.029	7124	A-10	
RE21-12-21854	20	20-SURV1	1775874.268	1629779.205	7115	A-10	
RE21-12-21855	12	12-SURV	1775864.395	1630076.184	7088	A-10	
RE21-12-21856	15	15-SURV	1775892.392	1630255.548	7116	A-10	
RE21-12-21857	21	21-SURV	1775829.247	1630477.347	7096	A-10	

Table 3: Results from random sampling based on MARSSIM-Derived sampling plan. Measurements are in pCi/g. Shaded rows are duplicates.

Radionuclide	Am-241[2]	Cs-137	H-3	Pu-238	Pu-239/240	Sr-90	U-234	U-235[2]	U-238
	0.01	0.469	1.669	0	0.104	0.132	0.921	0.051	0.997
	-0.04	0.347	-1.534	0.035	10.604	0.124	1.067	0.057	1.215
	0.03	0.213	-0.481	-0.001	0.35	0.066	0.691	0.033	0.636
	0.00	0.148	-1.495	0.001	0.049	0.069	0.617	0.034	0.608
	0.03	0.183	-0.033	-0.003	0.291	-0.036	0.813	0.032	0.818
	0.06	0.125	-1.7	0.002	0.066	0.001	0.739	0.024	0.743
	-0.04	0.137	-3.063	-0.003	0.013	0.042	0.841	0.035	0.748
	0.03	0.237	-2.685	0	0.061	0.049	0.707	0.035	0.783
	-0.01	0.318	-0.256	-0.001	0.09	-0.009	1.007	0.049	0.988
	-0.02	0.207	-1.778	0	0.07	0.068	0.852	0.041	0.934
	--0.01	0.202	-1.291	-0.002	0.141	-0.092	0.69	0.011	0.851
	-0.03	0.11	-1.205	0	0.053	0.029	0.708	0.029	0.706
				Summary Statistics and Dose Estimate					
Avg	0.001	0.225	-1.154	0.002	0.991	0.037	0.804	0.036	0.836
95% UCL	0.017	0.279	0.430	0.015	4.802	0.070	0.876	0.042	0.926
Std	0.031	0.106	1.259	0.010	3.029	0.064	0.139	0.012	0.173
AL (pCi/g)	30	5.6	750	37	33	5.7	170	17	87
Ratio of UCL	0.001	0.050	0.001	0.000	0.146	0.012	0.005	0.002	0.011
Sum of ratios	0.227								
Background	0.013	1.65	0.1	0.023	0.054	1.31	2.59	0.2	2.29
Bkg sub ratios	0.000	-0.245	0.000	0.000	0.144	-0.218	-0.010	-0.009	-0.016
Sum of ratios minus backgrounds[3]		0.144							
Estimated Dose (mrem/yr)		2.16							

[2] Was analyzed by gamma spectral analysis and radiochemical analysis. Gamma spectral measurements were used for Am-241 and radiochemical analysis results were used for U-235.

[3] Only positive ratios were added.

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Appendix A

Sampling and Analysis Plan (SAP) for Assessment of LANL-Derived Residual Radionuclides in soils within Tract A-10 for Land Transfer Decisions

May 2012

1.0 Background for A-10[4]

1.1 Site Location

The DP Road-3 East Tract is located between the western boundary of Technical Area-21 (TA-21) and the eastern boundaries of the commercial districts of the Los Alamos townsite (see Figure D-1). World War II and Cold War facilities at TA-21 used for nuclear weapons work are planned to be decontaminated and demolished; contaminated areas will be remediated in the near term as stipulated in the Consent Order (NMED 2005).

The tract consists of undeveloped canyon bottom accessed from DP Road. Vegetation includes ponderosa and piñon-juniper woodlands with open shrub, grasslands, and wildflower areas; A-10 is considered potentially sensitive wildlife habitat.

This approximately 13.8-acre tract is located southwest of Los Alamos County (LAC) Airport (transferred from DOE to LAC in October 2008) and other variously owned County land and private properties. It is bounded on the north by commercial properties, on the south by LAC and commercial properties on DP Mesa, on the west by active and vacant commercial land, and on the east by DOE/NNSA land. The legal property boundary description of this tract is provided by the U.S. Army Corps of Engineers' *Land Survey Plat, Los Alamos National Laboratory, Tract A-10, Being a Part of Tract AA and Parcel 2, Eastern Area No. 2, County of Los Alamos, State of New Mexico,* recorded by the Los Alamos County Clerk on March 18, 2003.

1.2 General History

Historical maps from the pre-LANL era (1924), aerial photographs (1935), and historical accounts of life in the area show little development prior to LANL occupancy (pre World War II). Detroit businessman Ashley Pond started the "Los Alamos Ranch School" in 1917. The school began with a few ranch buildings from the Harold H. Brook homestead.

Laboratory operations began on nearby DP Mesa in the late 1940s. They included warehousing, utility shop operations, and a materials testing laboratory, all located on the mesa-top within Tract A-11, which is south and west of A-10. Waste disposal operations were conducted at what is now designated Material Disposal Area B (MDA B) on the mesa-top south and east of this tract. Plutonium processing operations were also conducted further east on the mesa-top at TA-21. In the past, LANL fueling facilities were located on the mesa-top due south and immediately adjacent to the A-10 tract in Tract A-9. In the 1960s, following the end of LANL's use of tract A-8-a to the south, its western part was used for a residential trailer park and playground area; however, Tract A-10 has remained vacant.

The Potential Release Sites (PRSs) located on and near the A-10 tract are associated with the historical Laboratory operations on the adjacent lands. At the time of this report, LANL had conducted a series of investigations and cleanups of the PRSs (i.e., the contamination resulting from Laboratory activities) on and near the subject property.

[4] Portions of Sections 1.1, to 1.4.1 in the Background Section were directly imported into this document from the Environmental Baseline Survey (Swanton et al. 2006) with slight formatting modifications.

1.3 Current Use

A-10 is unoccupied, vacant land. No structures or facilities associated with LANL's federal, state, or local permits (such as air monitoring stations, radiation monitoring stations, or wastewater discharge outfalls) are located within A-10, although there are several stormwater outfall pipes from businesses located south of A-10.

The DP Road-3 East parcel was never actively used by the Laboratory, no Laboratory operations were conducted within the tract boundaries, and no Laboratory structures were situated within the tract.

1.4 Summary of Historical Evaluation of LANL Impact

There are no records of radioactive materials being used or stored or radioactive wastes being disposed of at this site; however, air fall from historical operations at TA-21, southeast of this tract, and stack emissions from TA-1 may have resulted in surface deposition of some radionuclides, although SWMU 21-021-99, which delineates this air-fall zone, ends at the A-10 boundary.

Tract A-10 does not meet the CERCLA 120(h) "uncontaminated" definition, even though DOE/NNSA and LANL believe all remedial actions necessary to address the known contamination on this tract, and allow its unrestricted transfer, have been completed according to the requirements of PL 105-119. Because Tract A-10 is not "uncontaminated," CERCLA Section 120(h)(4) is not applicable.

1.4.1 Adjacent Properties with Known or Suspected Releases

SWMU 21-029 and Consolidated Unit 21-021-99 are located immediately south of the A-10 tract. The remainder of the DP Canyon PRS, AOC C-00-021 is located directly east (downgradient) of the A-10 tract. See Appendix C in Swanton et al. (2008) for the history of use, site investigation and remediation activities, and current regulatory status of the PRSs in this tract.

AOC 00-027, the former DP Road storage area, was located at the intersection of Trinity Drive and DP Road at the current location of the Knights of Columbus hall. AOC 00-027 has been removed from LANL's Hazardous Waste Permit. This site was used as a fuel tank farm beginning in 1946 and was converted to a product container storage area in mid-1948. The storage capacity of the site was approximately 600 to 700 55-gal. containers. The storage area was decommissioned in the late 1950s. Numerous investigations and corrective measures were implemented at AOC 00-027 between 1992 and 2004, as summarized in the June 2005 *Addendum to the Completion Report for the Voluntary Corrective Action Using a Soil Vapor Extraction System at AOC 00-027*. The soil vapor extraction system was operated for 20 months to remove subsurface organic vapors. Sample results confirmed the corrective measures are protective of human health and the environment for the intended use of the property.

SWMU 21-029, the DP Tank Farm, located on the mesa-top in Tract A-9, is directly south of and adjacent to the A-10 tract. The DP Tank Farm was operational from 1946 to 1985 and is a 3.5-acre site located between the eastern boundary of the Knights of Columbus property and the western boundary of Los Alamos County Fire and Training Station No. 2. The tank farm was the primary fueling station supporting Los Alamos Scientific Laboratory (LASL, now LANL) operations until the late 1970s. It consisted of 15 storage tanks and 2 fill stations that contained various petroleum hydrocarbon products. Tank capacities ranged between approximately 2,100 and 51,000 gal. with a total capacity of 281,364 gal. Thirteen of the tanks were installed below ground and two were installed aboveground. The site was decommissioned in 1988. Numerous investigations and corrective actions implemented at the site are summarized in the September 2001 Phase II RCRA Facility Investigation (RFI) Report for SWMU 21-029. The RFI concluded that human health risks for contaminants released from the DP Tank Farm are within acceptable risk ranges for present-day and foreseeable future land uses and that there are no adverse ecological effects observed within terrestrial and aquatic systems in the western-most portion of DP Canyon.

1.5 Preliminary Results from Surveys for Residual Contamination

Table 1 provides data from Tract A-10 for radionuclides of potential interest. The summary statistics are also provided in the table and show that the soil concentrations are near background levels and significantly below the SALs for each specific radionuclide.

1.6 Conclusion regarding the classification of Tract A-10 relative to potential for residual radioactive contamination

Though there are properties adjacent to Tract A-10 that are either contaminated or have emitted radionuclides historically, and some LANL impact is possible, there is little evidence that the tract has been significantly impacted with regards to radionuclides (see Table 1). Thus, low-levels of residual contamination potentially exist on A-10 from activities conducted by LANL in nearby areas from the late 1940s through the 1980s and from run-off from surrounding commercial and residential properties; however, soil concentrations of radionuclides in soil are consistent with background levels. Thus, DOE/NNSA believe no additional remedial activities are needed on the A-10 tract, and based on this assessment, the A-10 tract qualifies as a Class 3 area under MARSSIM, (i.e., potentially impacted with concentrations of residual radioactive material in soils near background levels)(MARSSIM 2000).

2.0 Data Quality Objectives for Sampling and Analysis Plan

The sampling and analysis plan (SAP) for Tract A-10 follows the LANL (2012b) procedure EDA-QP-238, “Dose assessment data quality objectives for land transfers into the public domain.”

2.1 Objective of the SAP

The objective of this sampling and analysis plan is to confirm, within the stated statistical confidence limits, that the mean levels of potential radioactive residual contamination in soils in

the tract A-8-B are documented, in appropriate units, and are below the 15 mrem yr^{-1} Screening Action Levels (SALs), as derived in Mirenda et al. (2006) and provided in Table 1. **These SALs are used by LANL as preapproved Authorization Limits (ALs), as required in DOE Order 458.1 (section 2.k.(6)(f)2 in the contractors Requirements Document), and are identified as ALs in the rest of this SAP with regards to statistical decisions.**

2.2 Decision identification

The principle study question is: Does the residual radioactive contamination exceed ALs for the residential exposure scenario? The decision alternatives are:

- If results from the soil radioactive contamination measurements are at or above the AL (collectively), the site is not a candidate for land transfer.
- If results from the soil radioactive contamination measurements are below the AL (collectively), the site is a candidate for land transfer.

2.3 Inputs into the Decision

The assumed future land use and exposure pathway assumes residential use. The radionuclides analyzed for and the respective residential SAL is provided in Table 1 and the derivation of the SALs are provided in Mirenda (2006). The 15 mrem yr^{-1} SALs used in this analysis were calculated using RESRAD (RESRAD 2001) and documented in Mirenda (2006).

Data to be used in the analysis include preliminary surface soil concentration measurements. The data used were derived from RACER data base (RACER 2012). Search criteria included that the measurements were taken from soil or sediment in the A-10 tract, valid data only, and for radionuclides Cs-137, Am-241, Pu-239, H-3, U-234, U-235, U-238, tritium and Sr-90. Radionuclide concentrations from preliminary data are provided in Table 1.

The unity rule will be applied because there are multiple radionuclides in the analysis. The formula used in for the unity rule is:

$$\frac{C_1}{AL_1} + \frac{C_2}{AL_2} + \frac{C_3}{AL_3} \ldots\ldots \frac{C_n}{AL_n} \leq \mathbf{1} \qquad \text{(eqn. 1)}$$

where $C_{1\text{-}n}$ and $AL_{1\text{-}n}$ are the upper-bound estimates of the mean concentrations for radionuclides (e.g., upper 95% values) and Authorized Levels 1 through n, respectively.

2.4 Study Boundaries

The study is limited to Tract A-10, as identified in Figure 1 and described in the A-10 Tract Environmental Baseline Survey (Swanton et al. 2006). The tract available for sampling is shown in Figure 2. As concluded from historical information and previous sediment sampling, the list of radionculides in the analysis include Am-241, Cs-137, H-3, Pu-239, Pu-238, Sr-90, U-234, U235, and U-238. Individual doses are evaluated out to 1000 years.

2.5 Decision Rule

The decision rule is based on the null hypothesis that the mean residual contamination levels in soil and/or sediment in Tract A-10 combined over all radionuclides is above the AL and likely to result in an all pathway radiation dose to the critical receptor above 15 mrem yr^{-1}. The alternative hypothesis is that the mean residual contamination levels in soil and/or sediment in Tract A-10 combined over all radionuclides is below the AL and not likely to result in an all pathway radiation dose to the critical receptor above 15 mrem yr^{-1}.

2.6 Limits on Decision Errors

The acceptable statistical errors for this analysis are that Type I error (i.e., conclude contamination levels at site are < AL when in fact it is > AL) has a probability of $p < 0.05$; and the Type II error is (i.e., conclude soil contamination level is > AL when in fact it is < AL) has a probability of $p < 0.1$. Normality of the distribution for the preliminary data is not assumed.

2.7 Optimization of Design Process

The survey design is optimized by analyzing historical data. Specifically, there is no evidence of radiological operations in Tract A-10 with minimal impact from surrounding LANL operations, and the preliminary sediment data support this conclusion. Thus, the entire tract will be treated as a Class 3 area optimizing the number of required sample locations.

2.8 Statistically-Based Evaluation for Number of Samples Required using MARSSIM

Google Earth was used to download a map of the Tract A-10 area, which was then incorporated into Visual Sampling Plan (VSP) software (Matzke et al. 2010). The approximate boundary of the A-10 tract within was then delineated as a sampling area (Figure 2). The MARSSIM application within VSP was then used to determine the statistically-based sampling plan. The preliminary sampling data in Table 1 was used to determine the standard deviations needed for calculating the needed number of samples for each of the identified radionuclides. The sampling locations were randomly determined.

2.9 Instrumentation and Measurement Quality Objectives

The main objectives are to determine appropriate analysis technique for each radionuclide and ensure Measurement Quality Objectives are satisfied. One should be confident that the measurement results are valid and appropriate for the decisions being made.

2.9.1 Measurement Quality Objectives:

- Detection Capability: Minimum Detection Concentration (MDC) should be below the MARSSIM defined Lower Bound of the Gray Region (LBGR).

- The degree of measurement uncertainty (combined precision and bias) should be reported and the level reasonable relative to the needed accuracy of the decision and accounted for in the statistical analysis.

- Range of the instrument and measurement technique should be appropriate for the concentrations expected.

- The instrument and measurement technique should be specific for the radionuclide(s) being measured. Specificity is the ability of the measurement method to measure the radionuclide of concern in the presence of interferences.

- For field instruments, the instrument should be rugged enough to consistently provide reliable measurements. However, in this case, all samples will be analyzed in the laboratory.

2.9.2 Procedures used to meet these measurement quality objectives:

1) Collection of valid soil sample appropriate for the dose assessment,
    a. Sampling of soil will be done using LANL (2012a) procedure SOP-5132 "Collection of soil and vegetation samples for the environmental surveillance program." These are surface soil samples appropriate for the deposition pathway and the exposure scenario (i.e., top 5 cm). Subsurface soil samples are not required as depositions would be to surfaces with little migration to deeper soil expected.
    b. Additional quality assurance for the collection of the samples is provided through LANL (2008) procedure QAPP-0001 "Quality and assurance project plan for the soils, foodstuffs, and non foodstuff biota monitoring project."
2) Soil sample analysis using appropriate EPA approved analytical procedures for each radionuclide. The following will be used by the independent laboratory:
    a. Environmental Measurements Laboratory (EML). **The procedures manual of the Environmental Measurements Laboratory**. Report HASL-300; 1997. Radionuclide specific procedures for the radionuclides of Am-241, Pu-239 and U-238 are provided in EML (EML 1997).
    b. Environmental Protection Agency (EPA). **Method 901.1 - Gamma Emitting Radionuclides in Drinking Water***: Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980 (EPA 1980). Available from NTIS, document no. PB 80-224744.
    c. Environmental Protection Agency (EPA). **Method 905.0 - Radioactive Strontium in Drinking Water***: Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980 (EPA 1980). Available from U.S. Department of Commerce, National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, document no. PB 80-224744.
    d. Environmental Protection Agency (EPA). **Method 906.0 - Tritium in Drinking Water***: Prescribed Procedures for Measurement of Radioactivity in Drinking*

Water, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980 (EPA 1980). Available from U.S. Department of Commerce, National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, document no. PB 80-224744.

After the measurements are completed, the laboratory results in units equivalent to the ALs will be evaluated with respect to the MQOs, as stated above.

2.10 Statistical Evaluation of the Survey Results

All the applicable data that has passed the MQO evaluation will be used to determine the upper-bound estimate of the mean for soil concentrations (generally, the 95% value) for each radionuclide. The EPA software ProUCL (EPA 2010) will be used to determine this value. The statistical decision as to whether the residual soil contamination levels (i.e., the 95% UCLs) are below the authorized limits will be evaluated using the following criteria. All analyses and results will be documented.

Decision Criteria:

5) If all samples are ≤ residential AL, then no further action is required and the site passes the criteria for residential occupation. No further actions are needed.

6) If all samples or the UCL are > the AL, then the site is not a candidate for release and site remediation is needed followed by resampling before it can be released.

7) If the UCL is below the AL but some individual measurements are above the AL, then statistical analysis is needed. Generally, non-parametric statistical approaches are used to evaluate the null hypothesis. If contamination is present in background, the Wilcoxon Rank Sum test is suggested, and if contamination is not present in background or very low relative to the AL, use the Sign Test. For Tract A-10, the Sign Test will be used with a $p < 0.05$ decision threshold for significance. See MARSSIM chapter 8 for details and examples.

8) Alternatively, one could confirm that the ratio of the upper-confidence level (UCL) of the average concentration divided by the AL and the sum of hot spot activity ratios do not exceed 1, as show in Equation 3.

$$\frac{\overline{C}_{UCL}}{C_{AL}} + \sum_{i=1}^{n} \frac{C_{i,C>AL}}{C_{AL} * AF} \leq 1 \qquad \text{(eqn. 2)}$$

Here $\overline{C}_{UCL}$ is the 95% upper bound estimate of the concentration mean, C_{AL} is the resident AL (15 mrem yr^{-1}), $C_{i,c>AL}$ is the sample concentration for a single sample above the AL (i.e., has elevated measured concentrations), and *AF* is the Area Factor [ratio of effective dose calculated for area of contamination normalized to effective dose calculated for 10,000 m^2 (RESRAD default)]. If value in eqn. 2 is > 1, the site is a candidate for further characterization of the nature and extent of the contamination, remediation of the site,

follow up confirmatory sampling, and reanalysis against the decision criteria in this section. Area Factors are dependent on the exposure scenario and should be calculated individually.

9) If there are multiple radionuclides (*i*) being evaluated in a sampling unit, the sum of the ratios should be less than one, as shown in eqn. 1.

3.0 Results of the Analysis for Sampling Number and Locations

The specific details of the analysis using MARSSIM and the results are provided in Attachment 1 of this report. Results showed that approximately 11 randomly-sited samples were needed within the Tract A-10 and the approximate locations are drawn on Figure 2. Locations were randomly selected using a quasi-random number generator for x and y coordinates (Matzke et al. 2010). The specific statistical parameter values, analysis, results, and approximate coordinates for the randomly selected sampling locations are provided in the summary report (Attachment1).

4.0 REFERENCES

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Figure 1. Map showing Tract A-10. Map taken from Swanton et al. (2006).

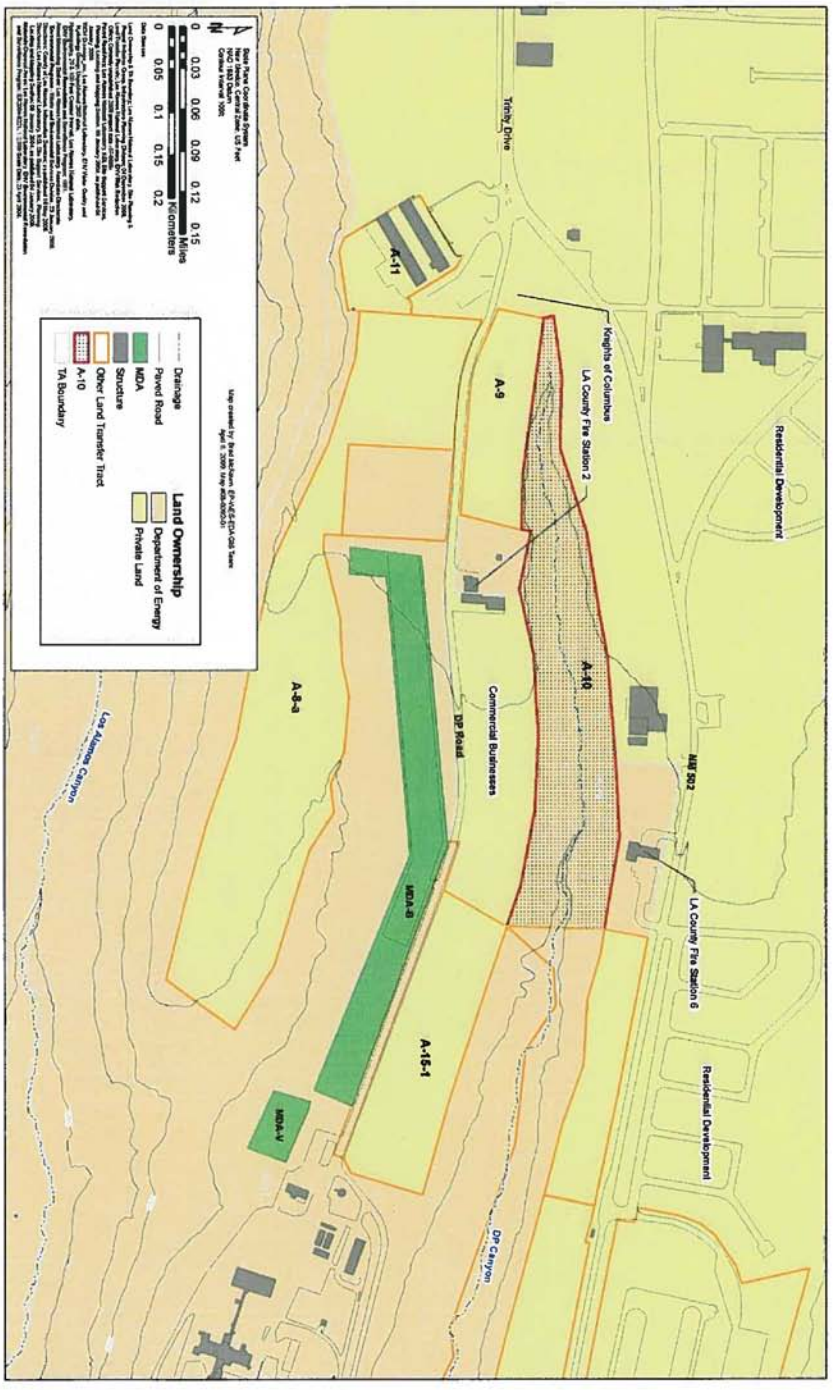

Figure D-1. Location of Land Transfer Tract A-10 and Surrounding Properties

Figure 2. Google Earth image of Tract A-10 with approximate sampling area for A-10 in yellow. Blue dots represent randomly selected sampling locations.

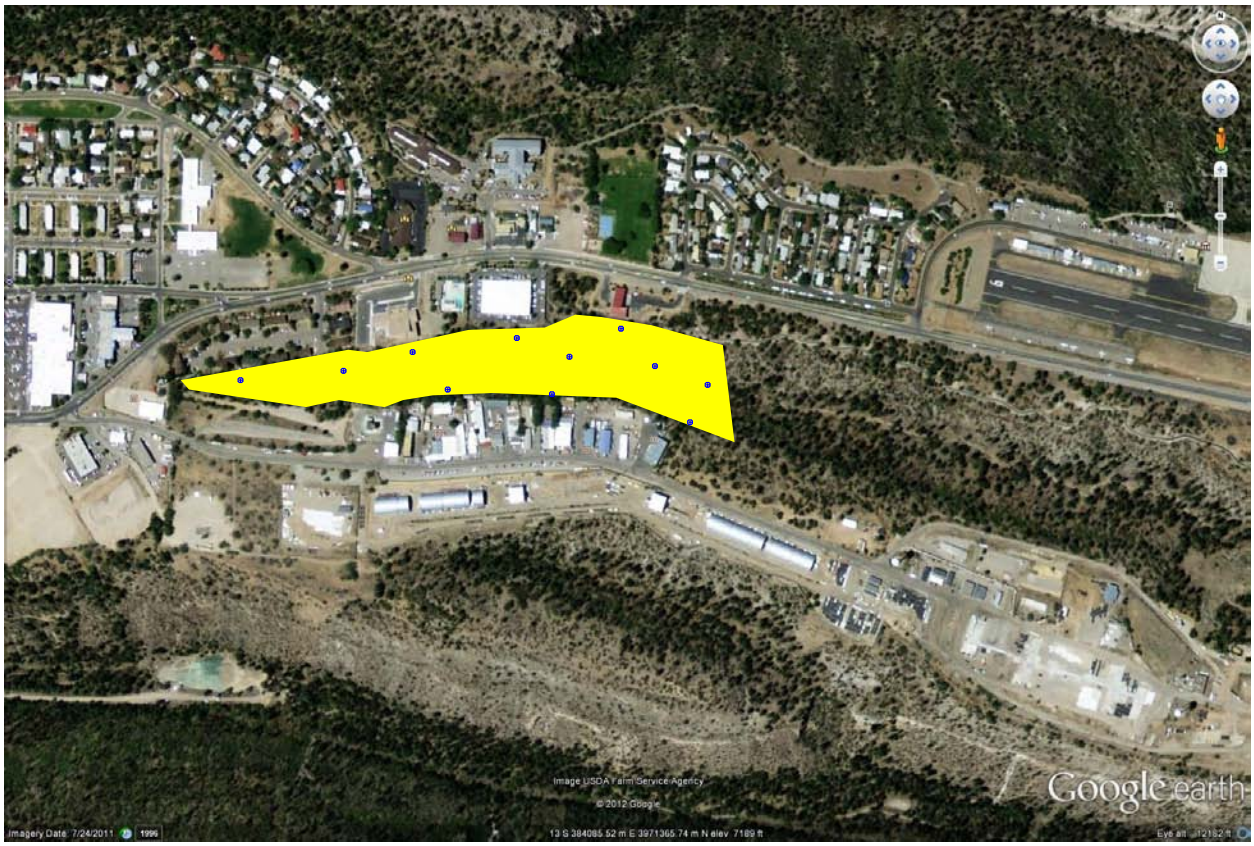

Table 1. Preliminary Results from Tract A-10 for radionuclides along with comparative values.

Am-241 (pCi/g)	**Cs-137 (pCi/g)**	**Tritium (pCi/g)**	**Pu-238 (pCi/g)**	**Pu-239/240 (pCi/g)**	**Sr-90 (pCi/g)**	**U-234 (pCi/g)**	**U-235 (pCi/g)**	**U-238 (pCi/g)**
0.34 ± 0.105	0.62 ± 0.09	0.13 ±0.035	0.02 ± 0.015	0.089 ± 0.11	0.27 ± 0.195	1.84 ± 0.13	0.105 ± 0.017	2.04±0.14
0.053 ± 0.016	0.31 ± 0.08	0.042 ± 0.005	0.013 ± 0.009	0.068 ± 0.012	0.27 ± 0.155	1.69 ± 0.25	0.099 ± 0.018	1.53±0.23
0.012 ± 0.003	0.206 ± 0.041	0.11 ± 0.05	0.005 ± 0.004	0.048 ± 0.011	0.2 ± 0.19	1.1 ± 0.2	0.077 ± 0.016	1.15±0.2
0.005 ± 0.002	0.11 ± 0.019	0.054 ± 0.017	0.003 ± 0.005	0.044 ± 0.01	0.19 ± 0.185	0.918 ± 0.07	0.054 ± 0.013	0.958±0.072
0.15 ± 0.2	0.12 ± 0.06	0.5 ± 0.025	0.002 ± 0.002	0.19 ± 0.004	0.19 ± 0.15	0.845 ± 0.065	0.051 ± 0.014	0.833±0.065
0.09 ± 0.075	0.009 ± 0.015	0.022 ±0.010	0.001 ± 0.004	0.028 ± 0.012	0.15 ± 0.155	0.67 ± 0.075	0.05 ± 0.013	0.65±0.07
0.014 ± 0.01		0.02 ± 0.008	0.001 ± 0.001	0.013 ± 0.007	0.12 ± 0.155	0.58 ± 0.055	0.048 ± 0.012	0.55±±0.055
0.011 ± 0.008		0.007 ±0.035	0.0003 ± 0.004	0.012 ± 0.009	0.11 ± 0.15	0.57 ± 0.055	0.047 ± 0.011	0.53±0.05
0.02± 0.008		0.007 ± 0.009	0 ± 0.004	0.009 ± 0.005	0.1 ± 0.14	0.55 ± 0.05	0.047 ± 0.011	0.511±0.050
0.006 ± 0.008		0.003 ± 0.01	-0.001 ±0.006	0.007 ± 0.006	0.05 ± 0.065	0.55 ± 0.055	0.072 ± 0.028	0.491±0.048
0.06 ± 0.008		0.002 ± 0.006	0.001 ± 0.004	0.006 ± 0.004	0.025 ± 0.06	0.493 ± 0.049	0.06 ± 0.05	0.487±0.048
0.001 ± 0.006		0.001 ± 0.007	-0.004 ± 0.004	0.001 ± 0.006	0.00 ± 0.058	0.475 ± 0.047	0.058 ± 0.07	0.41±0.042
0.00 ± 0.235			-0.004 ± 0.007	0.0003 ± 0.004	-0.020 ± 0.058		0.07 ± 0.035	
-0.001 ± 0.008			-0.011 ± 0.007	0.00 ± 0.007	-0.88 ± 0.31		0.039 ± 0.05	
-0.017 ± 0.041							0.036 ± 0.037	
-0.068 ± 0.053							0.03 ± 0.011	
							0.08 ± 0.165	
							-0.147 ± 0.043	
Summary Statistics and Comparative Values (pCi/g)								
Mean = 0.038	Mean = 0.229	Mean = 0.037	Mean = 0.002	Mean = 0.025	Mean = 0.055	Mean = 0.857	Mean = 0.044	Mean = 0.845
Std = 0.094	Std = 0.217	Std = 0.04	Std = 0.007	Std = 0.028	Std = 0.284	Std = 0.466	Std = 0.052	Std = 0.503
UTL = 0.14 (95%)	UTL = 0.62 (max)	UTL = 0.005 (95%)	UTL = 0.005 (95%)	UTL = 0.057 (95%)	UTL = 0.387 (95%)	UTL = 1.123 (95%)	UTL = 0.098 (95%)	UTL = 1.137 (95%)
Background 0.006	Background 0.42	Background ~0.13(@15% soil moisture)	Background 0.005	Background 0.015	Background 0.36	Background 1.4	Background 0.087	Background 1.22
Resident SAL 30	Resident SAL 5.6	Resident SAL 750	Resident SAL 37	Resident SAL 33	Resident SAL 5.7	Resident SAL 170	Resident SAL 17	Resident SAL 87

ATTACHMENT 1

Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Simple random sampling
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	11
Number of samples on map [a]	11
Number of selected sample areas [b]	1
Specified sampling area [c]	64920.51 m^2

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.

Area: Area 2					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
384013.2900	3971485.5601			Random	
384207.3209	3971446.1796			Random	
383697.9897	3971465.8698			Random	
384086.0516	3971524.9405			Random	
383989.0361	3971433.0527			Random	
383795.0052	3971492.1235			Random	
384183.0671	3971393.6722			Random	
383552.4665	3971452.7430			Random	
383940.5284	3971511.8137			Random	
384134.5593	3971472.4332			Random	
383843.5129	3971439.6161			Random	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric random sampling approach was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points randomly provides data that are separated by many distances, whereas systematic samples are all equidistant apart. Therefore, random sampling provides more information about the spatial structure of the potential contamination than systematic sampling does. As with systematic sampling, random sampling also provides information regarding the mean value, but there is the possibility that areas of the site will not be represented with the same frequency as if uniform grid sampling were performed.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$ is the cumulative standard normal distribution on (-∞,z) (see PNNL-13450 for details),
n is the number of samples,
S_{total} is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n[a]	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
Am-241	11	0.0936 pCi/g	5 pCi/g	0.05	0.1	1.64485	1.28155
Cs-137	11	0.217 pCi/g	2 pCi/g	0.05	0.1	1.64485	1.28155
Tritium	11	0.04 pCi/g	50 pCi/g	0.05	0.1	1.64485	1.28155
Pu-238	11	0.007 pCi/g	6 pCi/g	0.05	0.1	1.64485	1.28155
Pu-239	11	0.0277 pCi/g	6 pCi/g	0.05	0.1	1.64485	1.28155
Sr-90	11	0.284 pCi/g	1.7 pCi/g	0.05	0.1	1.64485	1.28155
U-234	11	0.466 pCi/g	40 pCi/g	0.05	0.1	1.64485	1.28155
U-235	11	0.0522 pCi/g	14 pCi/g	0.05	0.1	1.64485	1.28155
U-238	11	0.5 pCi/g	16 pCi/g	0.05	0.1	1.64485	1.28155

[a] The final number of samples has been increased by the MARSSIM Overage of 20%.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:
1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected randomly.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the sample locations were selected using a random process.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that $\mu >$ action level and alpha (%), probability of mistakenly concluding that $\mu <$ action level. The following table shows the results of this analysis.

Number of Samples							
AL=17		α=5		α=10		α=15	
		s=0.1044	s=0.0522	s=0.1044	s=0.0522	s=0.1044	s=0.0522
LBGR=90	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6
LBGR=80	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6
LBGR=70	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Recommended Data Analysis Activities

Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

Because the primary objective for sampling for this site is to compare the site median(mean) value with a threshold value, the data will be assessed in this context. Assuming the data are adequate, at least one statistical test will be done to perform a comparison between the data and the threshold of interest. Results of the exploratory and quantitative assessments of the data will be reported, along with conclusions that may be supported by them.

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