**APPENDIX P-4**

**FSS SAMPLE & MEASUREMENT LOCATIONS & COORDINATES**

**Survey Area:** BSA 04 **Description:** Building Survey Area (Misc. Structures)

**Survey Unit:** 11 **Description:** Concrete pavement overlaying LSA 08-16

**Survey Type:** FSS **Classification:** Class 1

| Measurement or Sample ID | Surface or CSM | Type | Start Elevation | End Elevation | Northing (feet) (Y Axis) * | Easting (feet) (X Axis) * | Remarks / Notes |
|---|---|---|---|---|---|---|---|
| B04-11-01-S-F-S-00 | F | S | 433.0 | 433.0 | 864758.0 | 826976.0 | Concrete |
| B04-11-02-S-F-S-00 | F | S | 433.0 | 433.0 | 864767.0 | 826971.0 | Concrete |
| B04-11-03-S-F-S-00 | F | S | 433.0 | 433.0 | 864767.0 | 826982.0 | Concrete |
| B04-11-04-S-F-S-00 | F | S | 433.0 | 433.0 | 864776.0 | 826976.0 | Concrete |
| B04-11-05-S-F-S-00 | F | S | 433.0 | 433.0 | 864776.0 | 827008.0 | Concrete |
| B04-11-06-S-F-S-00 | F | S | 433.0 | 433.0 | 861785.0 | 826961.0 | Concrete |
| B04-11-07-S-F-S-00 | F | S | 433.0 | 433.0 | 764785.0 | 826982.0 | Concrete |
| B04-11-08-S-F-S-00 | F | S | 433.0 | 433.0 | 764785.0 | 827002.0 | Concrete |
| B04-11-09-S-F-S-00 | F | S | 433.0 | 433.0 | 764794.0 | 826987.0 | Concrete |
| B04-11-10-S-F-S-00 | F | S | 437.0 | 437.0 | 864960.0 | 827102.0 | Concrete |
| B04-11-11-S-F-S-00 | F | S | 437.0 | 437.0 | 864969.0 | 827107.0 | Concrete |
| B04-11-12-S-F-S-00 | F | S | 437.0 | 437.0 | 864978.0 | 827113.0 | Concrete |
| B04-11-13-S-F-S-00 | F | B | 435.0 | 435.0 | 864977.0 | 827104.7 | Biased Concrete |
| B04-11-14-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-15-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-16-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-17-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-18-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-19-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-20-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-21-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-22-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-23-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |
| B04-11-24-S-F-S-00 | F | B | N/A | N/A | N/A | N/A | Judgemental - Transformer |

*X and Y coordinates are provided using Missouri - East State Plane Coordinates [North American Datum (NAD) 1983] (Open Land Area)
Surface: Floor = F; Wall = W; Ceiling = C; Roof = R
CSM: Three-Layer (Surface-Root-Deep) or Uniform
Type: Systematic = S, Biased = B; QC =Q; Investigation = I

| Ludlum 2360 | Ludlum 43-89 | Active Probe Area | α HDP Efficiency | α Cal. Efficiency | ß HDP Efficiency | ß Cal. Efficiency |
|---|---|---|---|---|---|---|
| 278647 | 311685 | 125 $cm^2$ | **26.5%** | N/A | **13.6%** | N/A |

**TOTAL WEIGHTED INSTRUMENT EFFICIENCY CALCULATION**

| Radionuclide | Radiation | Maximum Energy (MeV) | Instrument Efficiency ($\varepsilon_i$) | Surface Efficiency ($\varepsilon_s$) | Yield 100% | Activity Fraction | Weighted Efficiency |
|---|---|---|---|---|---|---|---|
| **Am-241** | Alpha | 5.6 | 0.2650 | 0.25 | 1.00 | 2.682E-03 | 1.78E-04 |
| **Np-237** | Alpha | 5.0 | 0.2650 | 0.25 | 1.00 | 5.573E-05 | 3.69E-06 |
| **Pu-239** | Alpha | 5.2 | 0.2650 | 0.25 | 1.00 | 2.027E-06 | 1.34E-07 |
| **Tc-99** | Beta | 0.294 | 0.1360 | 0.25 | 1.00 | 2.829E-03 | 9.62E-05 |
| **Th-232** | Alpha | 4.1 | 0.2650 | 0.25 | 1.00 | 3.214E-03 | 2.13E-04 |
| **Ra-228** | Beta | 0.046 | 0.1360 | 0.00 | 1.00 | 3.214E-03 | 0.00E+00 |
| **Ac-228** | Beta | 2.13 | 0.1360 | 0.50 | 1.00 | 3.214E-03 | 2.19E-04 |
| **Th-228** | Alpha | 5.5 | 0.2650 | 0.25 | 1.00 | 3.214E-03 | 2.13E-04 |
| **Ra-224** | Alpha | 5.8 | 0.2650 | 0.25 | 1.00 | 3.214E-03 | 2.13E-04 |
| **U-234** | Alpha | 4.9 | 0.2650 | 0.25 | 1.00 | 8.270E-01 | 5.48E-02 |
| **U-235** | Alpha | 4.7 | 0.2650 | 0.25 | 1.00 | 3.720E-02 | 2.46E-03 |
| **Th-231** | Beta | 0.390 | 0.1360 | 0.25 | 1.00 | 3.720E-02 | 1.26E-03 |
| **U-238** | Alpha | 4.3 | 0.2650 | 0.25 | 1.00 | 1.270E-01 | 8.41E-03 |
| **Th-234** | Beta | 0.270 | 0.1360 | 0.25 | 1.00 | 1.270E-01 | 4.32E-03 |
| **Pa-234m** | Beta | 2.20 | 0.1360 | 0.50 | 1.00 | 1.270E-01 | 8.64E-03 |

**Total Weighted Instrument Efficiency = Σ Weighted Instrument Efficiency for all Nuclides of Concern** **Σ=** **8.10%**

**Weighted Instrument Efficiency = $\varepsilon_i$ * $\varepsilon_s$ * Yield * Activity Fraction**

**$\varepsilon_i$ = 2 Pi Instrument Efficiency for Nuclide of Concern**

**$\varepsilon_s$ = Surface Efficiency for Nuclide of Concern**

Meter
**43-89**

| | | | | Step 8.3.2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| MEASUREMENT ID | MEASUREMENT LOCATION | DATE MEAS | MEASUREMENT | GROSS cpm (α+β) | BKG cpm (a+b) | Net cpm (α + β) | Combined Net dpm/100 $cm^2$ (α+β) | Corrected Net dpm/100$cm^2$ | Fraction of DCGL Step 8.4.3 |
| B04-11-01-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 206 | 178 | 28.333 | 280 | 280 | 1% |
| B04-11-02-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 209 | 178 | 31.333 | 310 | 310 | 2% |
| B04-11-03-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 182 | 178 | 4.3333 | 43 | 43 | 0% |
| B04-11-04-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 205 | 178 | 27.333 | 270 | 270 | 1% |
| B04-11-05-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 200 | 178 | 22.333 | 221 | 221 | 1% |
| B04-11-06-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 226 | 178 | 48.333 | 478 | 478 | 3% |
| B04-11-07-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 241 | 178 | 63.333 | 626 | 626 | 3% |
| B04-11-08-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 176 | 178 | -1.667 | -16 | 0 | 0% |
| B04-11-09-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 215 | 178 | 37.333 | 369 | 369 | 2% |
| B04-11-10-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 247 | 178 | 69.333 | 686 | 686 | 4% |
| B04-11-11-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 233 | 178 | 55.333 | 547 | 547 | 3% |
| B04-11-12-S-F-S-00 | Concrete | 02/26/2016 | alpha + beta TSC | 244 | 178 | 66.333 | 656 | 656 | 3% |
| B04-11-13-S-F-S-00 | Biased Concrete | 02/26/2016 | alpha + beta TSC | 247 | 178 | 69.333 | 686 | 686 | 4% |
| B04-11-14-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 144 | 178 | -33.67 | -333 | 0 | 0% |
| B04-11-15-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 136 | 178 | -41.67 | -412 | 0 | 0% |
| B04-11-16-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 159 | 178 | -18.67 | -185 | 0 | 0% |
| B04-11-17-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 132 | 178 | -45.67 | -452 | 0 | 0% |
| B04-11-18-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 150 | 178 | -27.67 | -274 | 0 | 0% |
| B04-11-19-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 136 | 178 | -41.67 | -412 | 0 | 0% |
| B04-11-20-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 166 | 178 | -11.67 | -115 | 0 | 0% |
| B04-11-21-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 129 | 178 | -48.67 | -481 | 0 | 0% |
| B04-11-22-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 176 | 178 | -1.667 | -16 | 0 | 0% |
| B04-11-23-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 210 | 178 | 32.333 | 320 | 320 | 2% |
| B04-11-24-S-F-S-00 | Judgemental - Transformer | 02/26/2016 | alpha + beta TSC | 127 | 178 | -50.67 | -501 | 0 | 0% |

*NOTE: Differences from documented survey results are due to rounding in Excel

| | | | |
|---|---|---|---|
| Min | 0 | **2%** | Average Fraction Step 8.4.5.g |
| Max | 686 | | |
| Mean | 229 | **DCGLso** | |
| Median | 132 | **0.5** | mrem SU Dose Contribution Step 8.4.6 |
| Stdev | 261.3 | **mrem** | |

**HDP-PR-FSS-721 *Final Status Survey Data Evaluation***
**Prelimnary Data Review and Determination of Sum-of-Fractions (SOF)**

Instrument used for FSS Static Measurements:

| | | | | | |
|---|---|---|---|---|---|
| Ludlum 2360/43-89 | S/N 278647 | 02/26/2016 | | Survey # 7113 C 160229 | |
| Detector Area (A) = | 125 $cm^2$ | ave. ambient bkg = ($\alpha$ + $\beta$) | 177.7 cpm | weighted eff ($\varepsilon_w$)= | 0.08090 |

TSC (dpm/100$cm^2$) = (gcpm-bkg) / ($\varepsilon_w$ * ($A_{det}$/100 $cm^2$))

DCGL (structures) = 18,925 dpm/100 $cm^2$

## Removable Data Evaluation

| MEASUREMENT ID | MEASUREMENT LOCATION | DATE MEAS | Alpha Gross cpm | Alpha Net cpm | Alpha Net dpm/100cm$^2$ | Corrected Alpha Net dpm/100cm$^2$ | Beta Gross cpm | Beta Net cpm | Beta Net dpm/100cm$^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 2 | Concrete | 02/26/2016 | 2.0 | 0.7 | 1.9 | 1.9 | 42.0 | 2.3 | 10.6 |
| 3 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 4 | Concrete | 02/26/2016 | 2.0 | 0.7 | 1.9 | 1.9 | 44.0 | 4.3 | 19.7 |
| 5 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 40.0 | 0.3 | 1.4 |
| 6 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 7 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 8 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 9 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 45.0 | 5.3 | 24.3 |
| 10 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 11 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 12 | Concrete | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 13 | Biased Concrete | 02/26/2016 | 2.0 | 0.7 | 1.9 | 1.9 | 39.7 | 0.0 | 0.0 |
| 14 | Judgemental - Transformer | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 50.0 | 10.3 | 47.2 |
| 15 | Judgemental - Transformer | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 51.0 | 11.3 | 51.8 |
| 16 | Judgemental - Transformer | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 17 | Judgemental - Transformer | 02/26/2016 | 2.0 | 0.7 | 1.9 | 1.9 | 39.7 | 0.0 | 0.0 |
| 18 | Judgemental - Transformer | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 19 | Judgemental - Transformer | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |
| 20 | Judgemental - Transformer | 02/26/2016 | 3.0 | 1.7 | 4.7 | 4.7 | 39.7 | 0.0 | 0.0 |
| 21 | Judgemental - Transformer | 02/26/2016 | 4.0 | 2.7 | 7.5 | 7.5 | 39.7 | 0.0 | 0.0 |
| 22 | Judgemental - Transformer | 02/26/2016 | 5.0 | 3.7 | 10.3 | 10.3 | 51.0 | 11.3 | 51.8 |
| 23 | Judgemental - Transformer | 02/26/2016 | 3.0 | 1.7 | 4.7 | 4.7 | 39.7 | 0.0 | 0.0 |
| 24 | Judgemental - Transformer | 02/26/2016 | 1.3 | 0.0 | 0.0 | 0.0 | 39.7 | 0.0 | 0.0 |

## Removable Data Evaluation

Instrument used for Removable Measurements:

Lud 3030 A 02/26/2016 Survey # 7113 C 160229

alpha bkg = 1.3 cpm alpha efficiency = 36.00% alpha MDA = 13.9
beta bkg = 39.7 cpm beta efficiency = 21.80% beta MDA = 102.7

| Corrected Beta Net dpm/100cm$^2$ | Combined Net dpm/100 cm$^2$ ($\alpha+\beta$) | Exceed 10% of Min. Sys. TSC Result? | Exceed MDA? | Exceed 10% of DCGL? |
|---|---|---|---|---|
| 0.0 | 0 | N | N | N |
| 10.6 | 12 | Y | N | N |
| 0.0 | 0 | N | N | N |
| 19.7 | 22 | Y | N | N |
| 1.4 | 1 | Y | N | N |
| 0.0 | 0 | N | N | N |
| 0.0 | 0 | N | N | N |
| 0.0 | 0 | N | N | N |
| 24.3 | 24 | Y | N | N |
| 0.0 | 0 | N | N | N |
| 0.0 | 0 | N | N | N |
| 0.0 | 0 | N | N | N |
| 0.0 | 2 | Y | N | N |
| 47.2 | 47 | Y | N | N |
| 51.8 | 52 | Y | N | N |
| 0.0 | 0 | N | N | N |
| 0.0 | 2 | Y | N | N |
| 0.0 | 0 | N | N | N |
| 0.0 | 0 | N | N | N |
| 0.0 | 5 | Y | N | N |
| 0.0 | 8 | Y | N | N |
| 51.8 | 62 | Y | N | N |
| 0.0 | 5 | Y | N | N |
| 0.0 | 0 | N | N | N |
| Min | 0 | | | |
| Max | 62 | | | |
| Mean | 10 | | | |
| Median | 1 | | | |
| StDev | 18.3 | | | |

DCGL = 18,925 dpm/100cm$^2$

Removable Activity (dpm/100cm$^2$) = (gcpm-bkg) / $\varepsilon$

Area "swiped" = 100 cm$^2$

## Performance of Statistical Tests

| Sign Test | | | | | | |
|---|---|---|---|---|---|---|
| SAMPLE ID | SAMPLE ID | Gross TSC Step 8.5.4.a | Gross TSC / Adj. Gross DCGL ($W_s$) Step 8.5.4.b | Difference (1-$W_s$) Step 8.5.4.d | Corrected Difference Step 8.5.4.e | |
| B04-11-01-S-F-S-00 | Concrete | 280 | 0.015 | 0.985 | 0.985 | α = 0.05 |
| B04-11-02-S-F-S-00 | Concrete | 310 | 0.016 | 0.984 | 0.984 | |
| B04-11-03-S-F-S-00 | Concrete | 43 | 0.002 | 0.998 | 0.998 | |
| B04-11-04-S-F-S-00 | Concrete | 270 | 0.014 | 0.986 | 0.986 | |
| B04-11-05-S-F-S-00 | Concrete | 221 | 0.012 | 0.988 | 0.988 | |
| B04-11-06-S-F-S-00 | Concrete | 478 | 0.025 | 0.975 | 0.975 | |
| B04-11-07-S-F-S-00 | Concrete | 626 | 0.033 | 0.967 | 0.967 | |
| B04-11-08-S-F-S-00 | Concrete | 0 | 0.000 | 1.000 | 1.000 | |
| B04-11-09-S-F-S-00 | Concrete | 369 | 0.020 | 0.980 | 0.980 | |
| B04-11-10-S-F-S-00 | Concrete | 686 | 0.036 | 0.964 | 0.964 | |
| B04-11-11-S-F-S-00 | Concrete | 547 | 0.029 | 0.971 | 0.971 | |
| B04-11-12-S-F-S-00 | Concrete | 656 | 0.035 | 0.965 | 0.965 | |
| | | | | Number of Positive Differences (S+) | 12 | |
| | | | | Sign Test Critical Value (MARSSIM Table I-3) | 9 | |

If every measurement in the systematic sample population is <= the DCGL, a statistical test is not required.

**TEST:** PASS

| MARSSIM Table I-3 Critical Values for the Sign Test Statistic S+ | | MARSSIM Table I-3 Critical Values for the Sign Test Statistic S+ | |
|---|---|---|---|
| N | Alpha = 0.05 | N | 0.05 |
| 4 | 4 | 28 | 18 |
| 5 | 4 | 29 | 19 |
| 6 | 5 | 30 | 19 |
| 7 | 6 | 31 | 20 |
| 8 | 6 | 32 | 21 |
| 9 | 7 | 33 | 21 |
| 10 | 8 | 34 | 22 |
| 11 | 8 | 35 | 22 |
| 12 | 9 | 36 | 23 |
| 13 | 9 | 37 | 23 |
| 14 | 10 | 38 | 24 |
| 15 | 11 | 39 | 25 |
| 16 | 11 | 40 | 25 |
| 17 | 12 | 41 | 26 |
| 18 | 12 | 42 | 26 |
| 19 | 13 | 43 | 27 |
| 20 | 14 | 44 | 27 |
| 21 | 14 | 45 | 28 |
| 22 | 15 | 46 | 29 |
| 23 | 15 | 47 | 29 |
| 24 | 16 | 48 | 30 |
| 25 | 17 | 49 | 30 |
| 26 | 17 | 50 | 31 |
| 27 | 18 | | |