Calculations to Establish an Estimate of the Mass of ^{235}U Associated with the Floors, Walls, and Ceilings, of Auxiliary Buildings at the Hematite Site

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TABLE OF CONTENTS

Section	Title	Page
1	**Introduction**	**6**
1.1	Facility Description	6
1.1.1	Description of the Hematite Site	6
1.1.2	Hematite Site History	6
1.1.3	Current Conditions	6
1.2	Purpose	8
1.3	Scope	8
1.4	Definition of Acronyms, Abbreviations and Terms Used	8
2	**Methodology**	**10**
2.1	General Site Surveys	10
2.2	Calibration Analysis	12
2.3	Calculation Inputs and Assumptions	12
2.3.1	Assumptions	12
2.3.2	Building Room Dimensions	12
2.3.3	General Site Surveys and Grid Surveys	12
3	**Analysis and Results**	**13**
3.1	General Site Survey Calibration Analysis	13
3.2	Building Surface Analysis	13
3.2.1	Summary	16
3.2.2	Floors	17
3.2.1	Walls and Ceilings	18
4	**Conclusions**	**18**
5	**References**	**19**
Attachment 1		**20**

LIST OF TABLES

Table	Title	Page
Table 1-1	Auxiliary Buildings	7
Table 1-2	Glossary of Acronyms, Abbreviations and Terms	9
Table 2-1	Proportionality Constants	12
Table 3-1	Summary of Proportionality Constants for Site Surveys	13
Table 3-2	Region Identification in Building 101 Tile Barn – First Floor	14
Table 3-3	Hotspot Identification in Building 101 Tile Barn – First Floor	14
Table 3-4	Summary of floor mass estimates for Building 101 Tile Barn – First Floor	15
Table 3-5	Combined summary of ^{235}U mass estimates by building group	16
Table 3-6	Summary of floor mass estimates by building group	17
Table 3-7	Summary of floor mass estimates by building floor	17
Table 3-8	Summary of wall and ceiling mass estimates by building group	18
Table 3-9	Summary of walls and ceilings mass estimates by building floor	18

LIST OF FIGURES

Figure **Title** **Page**

Figure 2-1 Representative general site survey showing measured gross count rates in NaI detector....11
Figure 3-1 Illustration of dimensional takeoffs using the Acrobat Measure tool....15

1 Introduction

A comprehensive radiological survey program was recently planned and undertaken to provide radiological data to assist in quantifying the residual mass of ^{235}U associated with piping, equipment, and miscellaneous materials remaining within the former process buildings at the Hematite site. The characterization activities were also expanded to encompass building surfaces including the floors, walls, ceilings, and roof of the various former process buildings. These comprehensive characterization activities were initiated in response to the results of preliminary radiological surveys of piping performed during late 2008, which indicated the presence of residual ^{235}U not previously identified.

A previous calculation [1] established limiting contamination levels for primary buildings used for process activities at the Hematite facility. This calculation uses the results of recent additional radiological surveys to establish an estimate of the ^{235}U mass associated with the floors, walls, and ceilings of certain auxiliary buildings at the Hematite facility which were not included in the prior analysis.

1.1 Facility Description

This section provides an overview of the Hematite facility and includes a description of its current condition (i.e., its condition at the time of development of this document), as relevant to the calculations described herein.

1.1.1 Description of the Hematite Site

The Westinghouse Hematite site, located near Festus, MO, is a former nuclear fuel cycle facility that is currently undergoing decommissioning. The Hematite site consists of approximately 228 acres, although operations at the site were confined to the "central tract" area which spans approximately 19 acres. The central tract area currently includes non-operational facility buildings, administrative buildings, a burial area, two evaporation ponds, a site pond, storm drains, sewage lines with a corresponding drain field, and several locations comprising contaminated limestone fill.

1.1.2 Hematite Site History

The Hematite facility was used for the manufacture of low-enriched (≤ 5.0 wt.% ^{235}U), intermediate-enriched (>5 wt.% and up to 20 wt.% ^{235}U) and high-enriched (> 20 wt.% ^{235}U) materials during the period 1956 through 1974. In 1974 production of intermediate and highly enriched material was discontinued and all associated materials and equipment were removed from the facility. From 1974 to cessation of manufacturing operations in 2001, the Hematite facility produced nuclear fuel assemblies for commercial nuclear power plants. In 2001, fuel manufacturing operations were terminated and the facility license was amended to reflect a decommissioning scope.

1.1.3 Current Conditions

The Hematite Decommissioning Project (HDP) includes the demolition of six adjacent process buildings with some common walls. These were formerly used for fuel manufacturing operations. In addition, certain auxiliary buildings listed in Table 1-1 are slated for demolition. These auxiliary buildings are examined in this calculation.

Table 1-1 Auxiliary Buildings

Building	Description
115	Fire Pump House
245	Well House
SWTP	Sanitary Waste Treatment Plant
101	Tile Barn
120	Red Barn
235	West Vault
252	South Vault

Source: Original

The current condition of each of the auxiliary buildings listed in Table 1-1 is summarized below.

Site Barns

The Hematite site barns encompass the Tile and Wood barns, which are known as buildings 101 and 120, respectively. These barns were used for retired equipment storage during plant operations and are currently empty, with the exception of a small number of waste items with very low or negligible contamination level. No further use of the barns is planned prior to their demolition.

Site Vaults

The Hematite site vault/storage buildings encompass the West and South vaults, which are known as buildings 235 and 252, respectively. These buildings were used for storage of Special Nuclear Material (SNM) during plant operations. The South vault (building 252) is currently empty except for metallic spacing rings in place on the floor and one metal bin. The West vault (building 235) currently contains a total of fourteen (14) Low Enriched Uranium (LEU) pellets held within a lidded container, in addition to bagged trash (mainly used protective clothing) used during recent characterization activities.

The Hematite site vault/storage buildings may be used in support of future site operations concerning storage of SNM recovered from decommissioning activities. Prior to demolition of the West and South vault all SNM will be removed.

Other non-production buildings

The other non-production auxiliary buildings listed in Table 1-1 include building 115, building 245, and the Sanitary Waste water Treatment Plant (SWTP) shed.

Building 115 was known as the Fire Pump House and had a generator and a fire pump previously. The building was built in 1992 and housed a diesel-powered generator and fire water pump, and has no history of radioactive material use. It is currently empty but may be used in the future (prior to demolition) as a material handling/evaluation area and/or radiological survey area. Prior to demolition of building 115 all introduced radioactive materials/SNM will be removed.

Building 245 was known as the Well House and was previously used for potable water well and chlorination. This building is no longer in use and was abandoned in accordance with state regulations. Currently, building 245 is empty except of a small number of miscellaneous items with very low or negligible contamination level. No further use of building 245 is planned prior to its demolition.

The SWTP shed historically received discharge from multiple site structures during operation of the facility. The SWTP received water from sinks, toilets, showers and drinking fountains. The SWTP was also used to receive laundry water (after the water was filtered and held for sampling) and waste water from the former process water demineralizer system and laboratory sinks. The SWTP shed consists of a series of settling and aeration tanks and an adjacent building that contains data logging and electronic instrumentation, floor drains and an open work area. The portions of this system that have been impacted by licensed activities are limited to the process components in contact with waste water, and that have the potential to collect solids that settle from the suspension. Prior to demolition of the SWTP shed, the equipment described above will be removed.

1.2 Purpose

The primary purpose of this document is to establish an estimate of the ^{235}U mass associated with surface contamination of the floors, walls, and ceilings of the auxiliary buildings at the Hematite facility listed in Table 1-1. This analysis supplements the results presented in [1] which established mass estimates for the Hematite facility former process buildings. Mass estimates are obtained by relating observed radiation survey count rate measurements to areal density of ^{235}U surface contamination based on a calibration analysis.

1.3 Scope

This document establishes an estimate of the ^{235}U mass associated with surface contamination of the floors, walls, and ceilings of the non-process auxiliary buildings listed in Table 1-1. The results reported in this document are specific to this scope.

The methodology developed here is adequate only for the determination of areal densities of surface contamination. For floors and walls, it is assumed that no significant ^{235}U absorption or leakage into the surface substrate has occurred. The methodology is not sensitive to the enrichment of uranium present since quantitative estimates are based on unique radioactive properties of ^{235}U.

1.4 Definition of Acronyms, Abbreviations and Terms Used

Table 1-2 provides a glossary of acronyms, definitions and terms used in this document.

Table 1-2 Glossary of Acronyms, Abbreviations and Terms

Acronym/Abbreviation/Term	Definition
'	foot (12")
"	inch (2.54 cm)
cm	Centimeter
cpm	counts per minute
D&D	Decontamination and Decommissioning
g	Gram
keV	kilo electron Volt
kg	Kilogram
µ	micro (1.0 x 10^{-6})
m	Meter
M	Mega (1.0 x 10^{6})
MeV	Mega electron Volt
mg	Milligram
NaI	Sodium Iodide
RSR	Radiation Survey Report
U	Uranium
vol. %	percentage by volume
wt. %	percentage by weight

Source: Original

2 Methodology

An estimate of ^{235}U contamination is obtained based on the observed count rate in a sodium iodide (NaI) detector used in close-proximity scans of building surfaces. A calibration between areal density of ^{235}U contamination and observed count rate previously developed in [1] is used to determine mass estimates.

2.1 General Site Surveys

Building surfaces were scanned at a range of 2 to 4 inches with a NaI detector with a lower energy discriminator set at 100 keV. The resulting gross counts per minute are wholly attributed to radioactive decay from ^{235}U and its ^{231}Th daughter with which it is in secular equilibrium. The analysis in Section 3.1.2.2 of [1] shows that above 100 keV, 94% of gammas emitted from uranium enriched to 5 wt% ^{235}U originate from ^{235}U (92.9%) or ^{231}Th (1.3%). The percentage increases with enrichment. Hence, the assumption that all observed gammas in the survey detector are associated with ^{235}U is conservative.

Since all counts observed in the NaI detector are deemed to be associated with ^{235}U contamination, the basis for the analysis is that the areal density of ^{235}U present nearby the detector is proportional to the observed count rate in the detector:

$$\rho = \alpha c \qquad \text{Eqn. 1}$$

where

ρ = Areal density of ^{235}U [g/cm^2]

c = Observed NaI gross count rate [/min]

α = Constant of proportionality

A separate calibration analysis described in Section 2.2 of [1] has been conducted to determine the constant of proportionality. The results of a typical NaI survey conducted for the auxiliary buildings are shown in Figure 2-1.

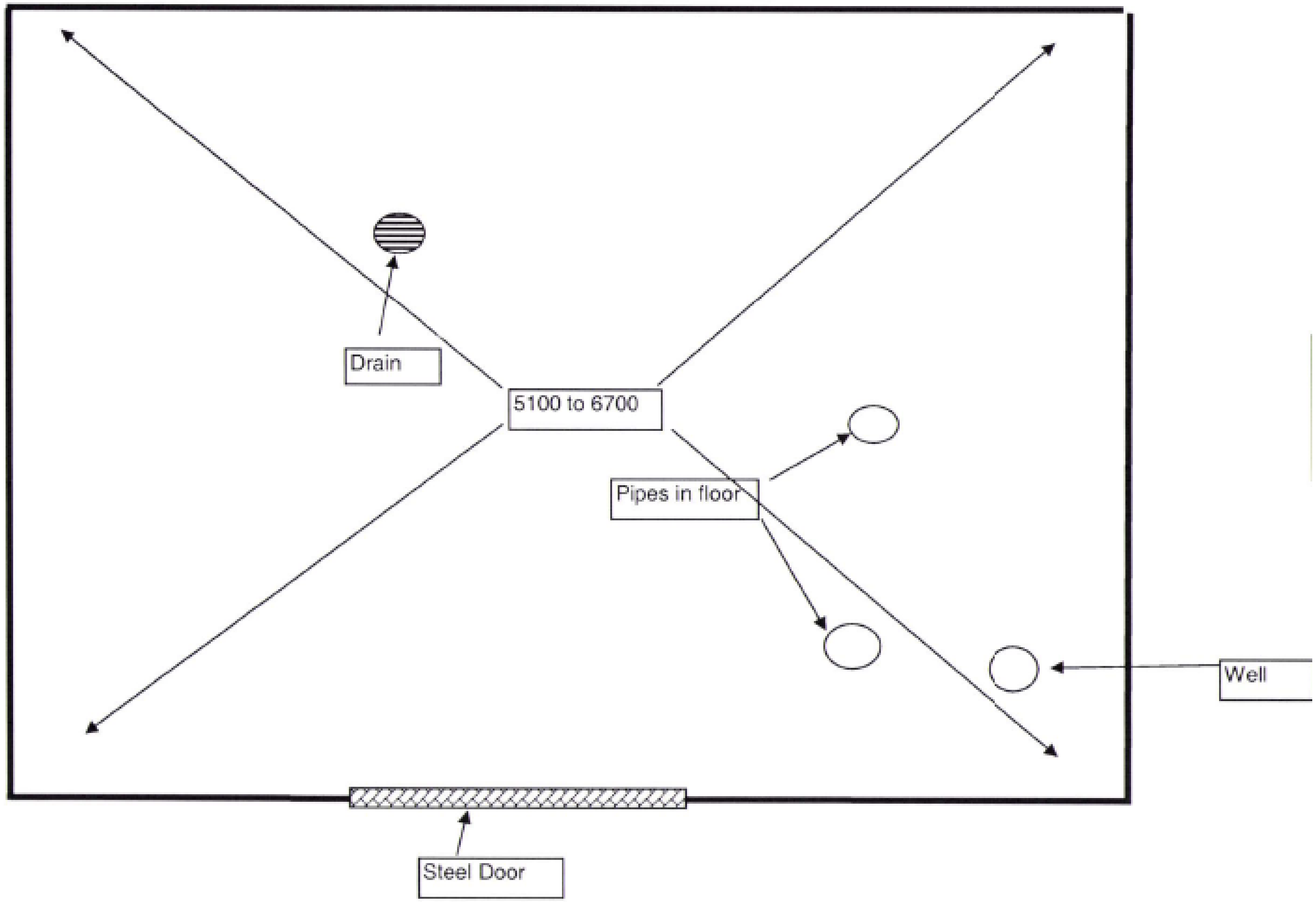


Figure 2-1 Representative general site survey showing measured gross count rates in NaI detector

2.2 Calibration Analysis

The high and low estimates of the calibration constant α in Eq. 1 have been determined in a previous analysis [1] for floor and wall configurations. These values are listed in Table 2-1.

Table 2-1 Proportionality Constants

Surface Type	α Value [(g/cm^2)/(/min)]	
	Low	High
Floors	1.7E-09	2.5E-09
Walls	5.0E-10	6.0E-10

Source: [1] Table 3-15

2.3 Calculation Inputs and Assumptions

2.3.1 Assumptions

Since the purpose of the analysis is to provide an estimate of surface contamination, the following assumptions are made:

1. Contamination on floors and walls lies directly on building surfaces with minimal absorption into the surface.
2. Radiation attenuation due to the fixative applied to building surfaces is negligible.
3. Background radiation included in general site survey results is neglected. All observed counts in the NaI detectors are associated with ^{235}U contamination.
4. For floors and walls, the effect of the surface substrate on radiation transport is neglected.
5. For the roofs, since no equipment, piping, or other related process activities were conducted on the roofs of the auxiliary buildings considered here, the roofs are assumed to be free of contamination.

2.3.2 Building Room Dimensions

Room dimensions are taken from measured data provided in files included in Attachment 2.

2.3.3 General Site Surveys and Grid Surveys

Files reporting the results of the general site surveys of the auxiliary buildings are summarized in Attachment 1 and included in Attachment 2.

3 Analysis and Results

3.1 General Site Survey Calibration Analysis

The calibration analysis developed in [1] results in the low and high estimates for the proportionality constant α for floors and walls shown in Table 3-1.

Table 3-1 Summary of Proportionality Constants for Site Surveys

Surface Type	α Value [(g/cm^2)/(/min)]	
	Low	High
Floors	1.7E-09	2.5E-09
Walls	5.0E-10	6.0E-10

Source: [1] Table 3-15

3.2 Building Surface Analysis

With the proportionality constants α determined (as a range) in the calibration analysis as shown in Table 3-1, the general site surveys are now used to determine mass estimates for the auxiliary building surfaces. The site surveys generally report count rates as a range for indicated *region* and *hotspot* areas in each room. The analysis procedure involves estimating the areas of each region and hotspot and recording the indicated low and high count rates for each. The areal density of contamination is then estimated by multiplying these values by the low and high estimates of α, resulting in a total of four mass estimates for each area.

The bounding mass estimate is that resulting from the high α value, high count rate value (referred to as the "high-high" value). A best estimate value may be obtained by assuming that surface contamination is uniformly distributed over each surface between the low and high count rate values, and that the best estimate of α is the average of its range. In this case, the best estimate is simply the average of the four reported mass estimates.

The calculations required to determine region and hotspot areas are quite detailed and are fully described in the accompanying Excel workbook "walls_v1203.xlsm" Sheets "FloorsAux" and "WallsAux" included in Attachment 2. The procedure is illustrated here for a typical building floor.

Figure 3-1 shows the NaI detector survey result for the first floor of Building 101 Tile Barn overlain with dimensions (red graphics) discussed below.

The survey result shows the count rates in four regions within the general room area as 6.5K counts per minute (cpm) in the northwest and 5.5K to 9.5K in the three other quadrants. There are three hotspots in the northwest region, one with indicated count rate 10K cpm, one with 12K cpm, and a third with 28K cpm.

In order to estimate areas, linear dimensions of the regions and hotspots are required. These dimensions are obtained by scaling takeoffs from the actual survey report. The takeoffs are linear "paper-space" dimensions obtained using the Distance tool (on the Measuring toolbar) in Adobe Acrobat 8. The required scale factors are determined by using the Distance tool to measure known building dimensions on the same survey report.

Since the aspect ratio of the graphic in the survey report may not be unity, separate scale factors are established for building north-south (N-S, vertical page) and east-west (E-W, horizontal page) dimensions. In this case, the E-W scale factor is based on the measured value of 8.07 in (shown in red in Figure 3-1) and the supplied room dimension of 126' 5", resulting in a scale factor of 15.67 ft/in. The N-S scale factor is determined in the same manner, using the paper measured value of 3.30 in and the indicated room dimension of 34' 5", resulting in a N-S scale factor of 5.17 ft/in. Note that scale factors must be computed individually for each survey report.

In this case the general room area is described using four regions as detailed in Table 3-2. Region dimensions are determined by applying the appropriate scale factors to paper-space measurements of the regions taken from the survey report. The area of each region is computed from these scaled dimensions, allowing for the exclusion of any contained regions or hotspot areas as indicated in the "Area Adjust" column. In this case, the contained hotspot areas in the northwest region are subtracted from the computed region area as they are accounted for separately as discussed below.

Table 3-2 Region Identification in Building 101 Tile Barn – First Floor

Regions								
	E-W		**N-S**		**Area**		**CPM**	
No.	**Dwg [in]**	**Dim [ft]**	**Dwg [in]**	**Dim [ft]**	**Adjust [cm2]**	**Net [cm2]**	**Low [1000/min]**	**High [1000/min]**
1	4.00	62.66	1.20	12.52	-3.48E+03	7.25E+05	6.5	6.5
2		63.76	2.37	24.72	0.00E+00	1.46E+06	5.5	9.5
3		62.66		21.90	0.00E+00	1.27E+06	5.5	9.5
4		63.76		9.70	0.00E+00	5.75E+05	5.5	9.5

Source: Original

Hotspot areas in the northwest corner of the room are estimated based on paper-space dimensions of each hotspot, unless hotspot dimensions are explicitly provided on the survey report. For circular shaped hotspots, a bounding rectangular box is conservatively used to contain the hotspot, and the more limiting scale factor is applied to estimate hotspot area. The analysis for Building 101 Tile Barn – First Floor is shown in Table 3-3.

Table 3-3 Hotspot Identification in Building 101 Tile Barn – First Floor

Hotspots								
	E-W		**N-S**		**Area**		**CPM**	
No.	**Dwg [in]**	**Dim [ft]**	**Dwg [in]**	**Dim [ft]**	**Adjust [cm2]**	**Net [cm2]**	**Low [1000/min]**	**High [1000/min]**
1	0.09	1.41	0.09	0.94	0.00E+00	1.23E+03	10.0	10.0
2	0.11	1.72	0.11	1.15	0.00E+00	1.84E+03	12.0	12.0
3		0.67		0.67	0.00E+00	4.13E+02	28.0	28.0

Source: Original

With the region and hotspot areas determined, the mass estimates are obtained by summing the product of the count rates and the subregion areas for each and multiplying the result by the high and low values of α. The resulting four mass estimate values are shown in Table 3-4 for this example.

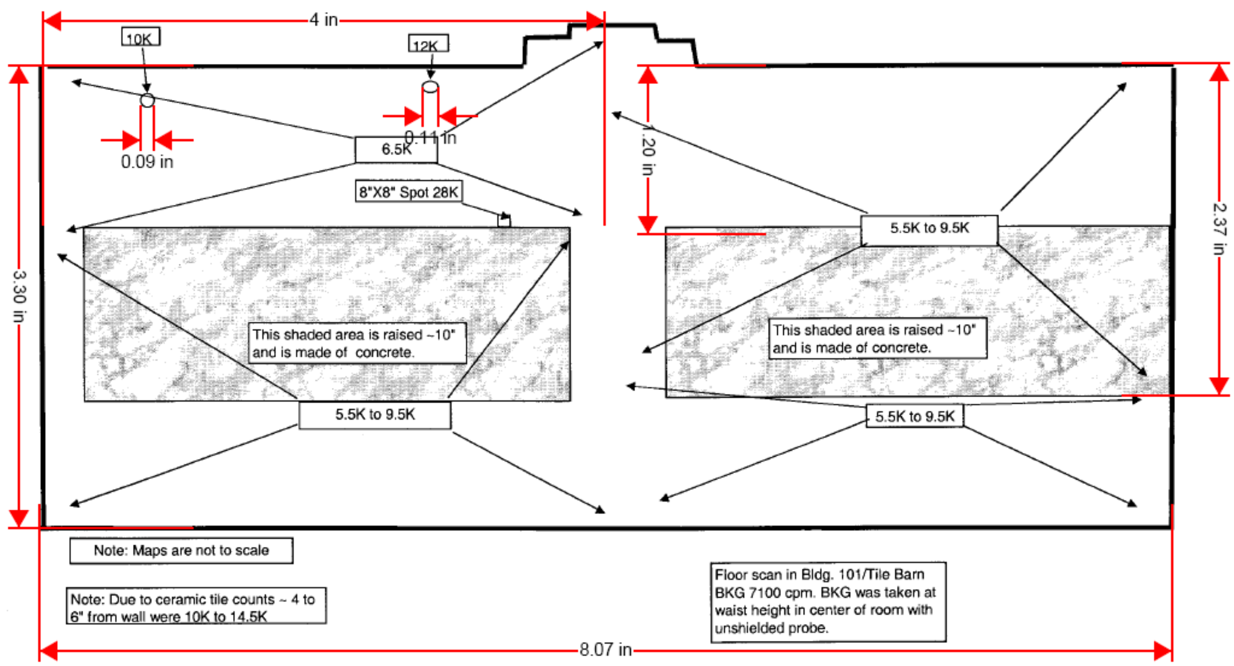
Table 3-4 Summary of floor mass estimates for Building 101 Tile Barn – First Floor

Room Number	Identification	α Value Low		α Value High		High-High Areal Density [mg/ft^2]
		Count Rate Low	Count Rate High	Count Rate Low	Count Rate High	
4	Bldg 101 Tile Barn - Floor 1	39.1	61.6	57.5	90.6	20.8

Source: Original

This procedure is performed for each floor of the auxiliary buildings. Wall mass estimates are determined in an identical fashion using the survey results taken for the building walls.

Ceiling mass estimates for each room are based on the design input ceiling area (assumed equal to the floor area) and the general area count rate results for the walls in the room. No hotspots are considered in ceiling mass estimates.



Source: Bldg 101 Tile Barn - Floor 1st level.pdf in Attachment 2

Figure 3-1 Illustration of dimensional takeoffs using the Acrobat Measure tool

3.2.1 Summary

The combined mass estimates for floors, walls, and ceilings are shown for each of three groups of auxiliary buildings in Table 3-5. The results are summarized in terms of building groups for later convenience. Detailed results are provided below.

Table 3-5 Combined summary of ^{235}U mass estimates by building group

Area Summary [g ^{235}U]					
Building Group	α Value				Best Estimate
	Low		High		
	Count Rate				
	Low	High	Low	High	
Bldg 115, 245, SWTP	9	13	12	19	13
Bldg 101, 120	163	228	229	322	235
Bldg 235, 252	83	193	119	277	168
Total	255	434	360	618	417

Source: Original

3.2.2 Floors

^{235}U mass estimates for the floors are shown by area in Table 3-6 and by building floor in Table 3-7. The peak hotspot areal density observed in the floor surveys results in a computed localized high-high areal density estimate of 3842 mg/ft^2. The estimated mass of contamination associated with this hotspot is 15.4 g ^{235}U. Room averaged areal density estimates are provided in Table 3-7.

Table 3-6 Summary of floor mass estimates by building group

Floors Summary [g ^{235}U]					
Building Group	α Value				Best Estimate
	Low	1.7E-09	High	2.5E-09	
	Count Rate				
	Low	High	Low	High	
Bldg 115, 245, SWTP	6	10	9	14	10
Bldg 101, 120	126	179	186	264	189
Bldg 235, 252	70	171	103	251	149
Total	203	360	298	529	347

Source: Original

Table 3-7 Summary of floor mass estimates by building floor

Identification	α Value				Average High-High Areal Density [mg/ft^2]	Best Estimate [g ^{235}U]
	Low	1.7E-09	High	2.5E-09		
	Count Rate					
	Low	High	Low	High		
Bldg 115	4.4	7.3	6.5	10.8	16.2	7.2
Bldg 245	0.4	0.5	0.5	0.7	15.6	0.5
SWTP	1.4	2.0	2.0	3.0	9.8	2.1
Bldg 101 Tile Barn - Floor 1	39.1	61.6	57.5	90.6	20.8	62.2
Bldg 101 Tile Barn - Floor 2	41.2	55.0	60.6	80.8	18.6	59.4
Bldg 120 Red Barn - Floor 1	25.1	33.5	37.0	49.3	18.6	36.2
Bldg 120 Red Barn - Floor 2	20.9	29.3	30.8	43.1	16.3	31.0
Bldg 235 West Vault	14.1	24.6	20.8	36.2	62.8	23.9
Bldg 252 South Vault	56.1	145.9	82.6	214.6	118.8	124.8
Total	203	360	298	529		347
Max					119	

Source: Original

3.2.3 Walls and Ceilings

^{235}U mass estimates for the walls and ceilings are shown by area in Table 3-8 and by building floor in Table 3-9. The peak computed wall hotspot areal density is 111 mg/ft^2 with an associated mass of 0.1 g ^{235}U. Room averaged areal density estimates are provided in Table 3-9.

Table 3-8 Summary of wall and ceiling mass estimates by building group

Walls and Ceilings Summary [g ^{235}U]					
Building Group	**α Value**				**Best Estimate**
	Low 1.7E-09		**High 2.5E-09**		
	Count Rate				
	Low	**High**	**Low**	**High**	
Bldg 115, 245, SWTP	3	4	3	4	3
Bldg 101, 120	36	48	43	58	47
Bldg 235, 252	13	22	16	27	19
Total	52	74	62	89	69

Source: Original

Table 3-9 Summary of walls and ceilings mass estimates by building floor

Identification	**α Value**				**Average High-High Areal Density [mg/ft^2]**	**Best Estimate [g ^{235}U]**
	Low 1.7E-09		**High 2.5E-09**			
	Count Rate					
	Low	**High**	**Low**	**High**		
Bldg 115	1.9	2.3	2.3	2.8	1.3	2.3
Bldg 245	0.2	0.2	0.2	0.3	1.1	0.2
SWTP	0.6	1.0	0.7	1.2	1.1	0.9
Bldg 101 Tile Barn - Floor 1	9.6	14.4	11.5	17.3	2.5	13.2
Bldg 101 Tile Barn - Floor 2	17.5	22.2	21.0	26.6	2.1	21.8
Bldg 120 Red Barn - Floor 1	4.1	5.5	5.0	6.6	1.3	5.3
Bldg 120 Red Barn - Floor 2	5.0	6.3	6.0	7.5	1.1	6.2
Bldg 235 West Vault	2.3	3.5	2.8	4.2	1.3	3.2
Bldg 252 South Vault	10.7	18.6	12.8	22.3	2.3	16.1
Total	52	74	62	89		69
Max					3	

Source: Original

4 Conclusions

The analysis presents mass estimates of the bounding and best-estimate ^{235}U contamination in certain non-process auxiliary buildings at the Hematite facility based on detailed radiation survey measurements.

5 References

[1] NSA-TR-09-23, Rev. 0, Calculations to Establish an Estimate of the Mass of ^{235}U Associated with the Floors, Walls, Ceilings, and Roof of the Hematite Facility Former Process Buildings, C. Henkel, October, 2009.

Attachment 1

List of Files on Attached Media

This attachment contains a listing and description of the files contained in the attached DVD of this document (Attachment 2). The file attributes on the DVD are as follows:

Files on Attachment 2		
Name	**Size**	**Last write date**
	34 866 102	**22-02-2010 02:53**
<Excel>	<DIR>	22-02-2010 02:53
<Surveys>	<DIR>	18-02-2010 19:05
\Excel	**2 820 774**	**22-02-2010 02:53**
walls_v1203.xlsm	2 818 990	22-02-2010 02:53
\Surveys	**32 045 328**	**18-02-2010 19:05**
Bldg 101 First Floor Tile barn.doc	32 768	12-02-2010 14:09
Bldg 101 Second Floor Tile barn.doc	29 184	12-02-2010 14:09
Bldg 101 Tile Barn - Floor 1st level.pdf	874 357	13-02-2010 19:50
Bldg 101 Tile Barn - Floor 2nd level.pdf	702 997	10-02-2010 14:38
Bldg 101 Tile Barn - Walls 1st level.pdf	796 803	15-02-2010 03:41
Bldg 101 Tile Barn - Walls 2nd level.pdf	792 494	15-02-2010 03:44
Bldg 115-floor.pdf	2 031 721	13-02-2010 19:02
Bldg 115-walls.pdf	2 805 976	15-02-2010 03:21
Bldg 115.doc	21 504	12-02-2010 12:41
Bldg 120 First Floor Red Barn.doc	28 672	15-02-2010 04:12
Bldg 120 Red Barn - Floors.pdf	2 620 424	10-02-2010 14:47
Bldg 120 Red Barn - Walls.pdf	2 673 715	15-02-2010 04:10
Bldg 120 Second Floor Red Barn.doc	24 064	12-02-2010 12:41
Bldg 235 West Vault - Floors.pdf	836 203	15-02-2010 02:30
Bldg 235 West Vault - Walls.pdf	763 173	10-02-2010 14:39
Bldg 235 West Vault Dimensions.pdf	23 095	14-02-2010 18:35
Bldg 235 West Vault Follow-Up.pdf	2 116 649	15-02-2010 03:02
Bldg 245-floor.pdf	1 988 306	13-02-2010 19:12
Bldg 245-walls.pdf	2 105 275	15-02-2010 03:25
Bldg 245.doc	24 064	12-02-2010 12:41
Bldg 252 South Vault - Floor Follow-up.pdf	2 270 956	15-02-2010 03:00
Bldg 252 South Vault - Floor.pdf	2 129 110	15-02-2010 02:57
Bldg 252 South Vault - Walls.pdf	2 128 581	15-02-2010 05:04
Bldg 252 South Vault.doc	26 624	12-02-2010 12:41
Item List .doc	24 576	12-02-2010 14:09
SWTP floor.pdf	2 016 232	13-02-2010 19:26
SWTP Wall and Floor .doc	24 064	12-02-2010 12:41
SWTP walls.pdf	2 133 741	15-02-2010 03:35