



facility 439136  
project 10243

# Gamma Spectroscopy Case Narrative

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## COGCC

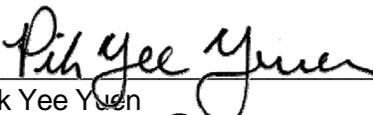
PW NORM 2017 – 10048

Work Order Number: 1705202

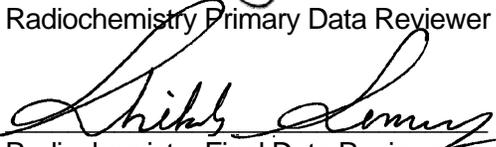
1. This report consists of analytical results and supporting documentation for one water sample received by ALS on 05/09/2017.
2. This sample was prepared according to the current revision of SOP739.
3. The sample was analyzed for the presence of gamma emitting radionuclides according to the current revision of SOP713. The analysis was completed on 05/18/2017.
4. The analysis results for this sample are reported in units of pCi/L. The sample was filtered prior to analysis.
5. In cases where there are no peaks found in the peak search routine, the software performs a net quantification. This indicates that nuclides are not detected or supported at any level above the reported MDC. Consequently, these nuclides are flagged with an “NQ” qualifier on the final reports. Please refer to the Technical Bulletin Addendum in section 5 of this report.
6. Technical considerations made in the creation of the gamma spectroscopy library used in this analysis are detailed in the document “Technical Comments Regarding Gamma Spectroscopy Libraries” found in Section 5.
7. Radium-226 quantification based on the 186.21 keV photon suffers from interference with the 185.72 keV photon emitted by  $^{235}\text{U}$ . Due to the high abundance of this photon in  $^{235}\text{U}$  emissions, even small amounts of  $^{235}\text{U}$  may bias the  $^{226}\text{Ra}$  results high. Thus, any measured activity for  $^{226}\text{Ra}$  has been flagged with an “SI” qualifier, denoting spectral interference.
8. No further problems were encountered with either the client sample or the associated quality control samples. All remaining quality control criteria were met.



The data contained in the following report have been reviewed and approved by the personnel listed below. In addition, ALS certifies that the analyses reported herein are true, complete and correct within the limits of the methods employed.

  
\_\_\_\_\_  
Pik Yee Yuen  
Radiochemistry Primary Data Reviewer

5/25/17  
Date

  
\_\_\_\_\_  
Radiochemistry Final Data Reviewer

5/25/17  
Date

Section 1

**CHAIN OF CUSTODY**

# ALS -- Fort Collins

## Sample Number(s) Cross-Reference Table

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**OrderNum:** 1705202

**Client Name:** COGCC

**Client Project Name:** PW NORM 2017

**Client Project Number:** 10048

**Client PO Number:** CT 2017-3066

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Client Sample Number	Lab Sample Number	COC Number	Matrix	Date Collected	Time Collected
439136	1705202-1		WATER	09-May-17	12:50
439136	1705202-2		WATER	09-May-17	12:50



ALS Environmental

225 Commerce Drive, Fort Collins, Colorado 80524  
TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

Chain-of-Custody

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.  
Turnaround time for samples received Saturday will be calculated beginning from the next business day.

ALS WORKORDER #  
1705202

PROJECT NAME	PW NORM 2017		TURNAROUND TIME	45 days		SAMPLER	Robert Young		PAGE	1705202	
PROJECT No.	12048		SITE ID			DISPOSAL			BY LAB	or RETURN	
COMPANY NAME	COGCC		EDD FORMAT	COGCC		PARAMETER/METHOD REQUEST FOR ANALYSIS					
SEND REPORT TO	Pete Quintana		PURCHASE ORDER	CT 2017-3066		A total metals SW6010/6020					
ADDRESS	1120 Lincoln St, Suite 801		BILL TO COMPANY			B dissolved metals SW6010					
CITY / STATE / ZIP	Denver, CO 80203		INVOICE ATTN TO			C SW9040A pH					
PHONE	719-679-1326		ADDRESS			D SM2510B specific conductance					
FAX			CITY / STATE / ZIP			E SM2320C total bicarb & carb alkalinity					
E-MAIL			PHONE			F SM2540C dissolved solids					
			FAX			G SM2540D suspended solids					
			E-MAIL			H SW9056 <del>SM2540C</del> (Br, Cl, F, SO4)					
						I SAR calc.					
						J					

LAB ID	FIELD ID	MATRIX	SAMPLE DATE	SAMPLE TIME	# OF BOTTLES	PRESERVATIVE	QC	A	B	C	D	E	F	G	H	I	J	SEE NOTES SECTION
①	439136	W	5/9/17	1250	1	Z	X	X										
↓	439136	W	5/9/17	1250	2	Z	X	X	X	X	X	X	X	X	X	X	X	

REPORT LEVEL / QC REQUIRED	Summary (Standard QC)	LEVEL II (Standard QC)	LEVEL III (Std QC + forms)	LEVEL IV (Std QC + forms + raw)
RELINQUISHED BY	Signature: Robert Young			
RECEIVED BY	Signature: Robert Young			
RELINQUISHED BY	Signature: Robert Young			
RECEIVED BY	Signature: Robert Young			
RELINQUISHED BY	Signature: Robert Young			
RECEIVED BY	Signature: Robert Young			

PRINTED NAME	DATE	TIME
Robert Young	5/9/17	1642

\*Time Zone (Circle): EST CST MST PST Matrix: O = oil S = soil NS = non-soil solid W = water L = liquid E = extract F = filter

1-HCl 2-HNO3 3-H2SO4 4-NaOH 5-NaOHZnAcetate 6-NaHSO4 7-4°C 8-Other



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**Chain-of-Custody**

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.  
 Turnaround time for samples received Saturday will be calculated beginning from the next business day.

ALS WORKORDER #  
 17052-02

TURNAROUND TIME: 45 day  
 SAMPLER: Robert Young  
 SITE ID: C00CC  
 PURCHASE ORDER: CT 2017-3066

PARAMETER/METHOD REQUEST FOR ANALYSIS

A	gross alpha/gross beta
B	210 Pb
C	210 Po
D	222 Rn
E	224 Ra + 226 Ra
F	228 Ra
G	gamma emitters
H	isotopic U
I	* isotopic Th
J	

LAB ID	FIELD ID	MATRIX	SAMPLE DATE	SAMPLE TIME	# OF BOTTLES	PRESERVATIVE	QC	A	B	C	D	E	F	G	H	I	J	SEE NOTES SECTION
	439136	W	5/9/17	1250	3	2		X	X	X	X	X	X	X	X	X	X	
	439136	W			3	7					X							

Form 2029

RELINQUISHED BY: Robert Young  
 RECEIVED BY: [Signature]  
 RELINQUISHED BY: [Signature]  
 RECEIVED BY: [Signature]  
 RELINQUISHED BY: [Signature]  
 RECEIVED BY: [Signature]

SIGNATURE: Robert Young  
 PRINTED NAME: Robert Young  
 DATE: 5/9/17  
 TIME: 1642

REPORT LEVEL / QC REQUIRED

Summary (Standard QC)  
 LEVEL II (Standard QC)  
 LEVEL III (Std QC + forms)  
 LEVEL IV (Std QC + forms + raw)

145

PRESERVATION KEY: 1-HCl 2-HNO3 3-H2SO4 4-NeOH 5-NeOH/Zn-acetate 6-NaHSO4 7-4°C 8-Other



ALS Environmental - Fort Collins  
CONDITION OF SAMPLE UPON RECEIPT FORM

Client: COGCC  
Project Manager: SS

Workorder No: 1205202  
Initials: CAT Date: 5-10-17

1. Does this project require any special handling in addition to standard ALS procedures?		YES	<input checked="" type="radio"/> NO
2. Are custody seals on shipping containers intact?	<input checked="" type="radio"/> NONE	YES	NO
3. Are Custody seals on sample containers intact?	<input checked="" type="radio"/> NONE	YES	NO
4. Is there a COC (Chain-of-Custody) present or other representative documents?		<input checked="" type="radio"/> YES	NO
5. Are the COC and bottle labels complete and legible?		<input checked="" type="radio"/> YES	NO
6. Is the COC in agreement with samples received? (IDs, dates, times, no. of samples, no. of containers, matrix, requested analyses, etc.)		<input checked="" type="radio"/> YES	NO
7. Were airbills / shipping documents present and/or removable?	<input checked="" type="radio"/> DROP OFF	YES	NO
8. Are all aqueous samples requiring preservation preserved correctly? (excluding volatiles)	N/A	YES	<input checked="" type="radio"/> NO
9. Are all aqueous non-preserved samples pH 4-9?	N/A	<input checked="" type="radio"/> YES	NO
10. Is there sufficient sample for the requested analyses?		<input checked="" type="radio"/> YES	NO
11. Were all samples placed in the proper containers for the requested analyses?		<input checked="" type="radio"/> YES	NO
12. Are all samples within holding times for the requested analyses?		<input checked="" type="radio"/> YES	NO
13. Were all sample containers received intact? (not broken or leaking, etc.)		<input checked="" type="radio"/> YES	NO
14. Are all samples requiring no headspace (VOC, GRO, RSK/MEE, Rx CN/S, radon) headspace free? Size of bubble: ___ < green pea ___ > green pea	N/A	<input checked="" type="radio"/> YES	NO
15. Do any water samples contain sediment? Amount Amount of sediment: ___ dusting ___ moderate ___ heavy	N/A	YES	<input checked="" type="radio"/> NO
16. Were the samples shipped on ice?		<input checked="" type="radio"/> YES	<input checked="" type="radio"/> NO
17. Were cooler temperatures measured at 0.1-6.0°C? IR gun used*: <input checked="" type="radio"/> #2 #4		<input checked="" type="radio"/> YES	<input checked="" type="radio"/> NO
Cooler #: <u>1 2</u>			
Temperature (°C): <u>6.0 Amb</u>			
No. of custody seals on cooler: <u>0 0</u>			
External µR/hr reading: <u>NA NA</u>			
Background µR/hr reading: <u>NA</u>			
Were external µR/hr readings ≤ two times background and within DOT acceptance criteria? YES / NO / <input checked="" type="radio"/> NA (If no, see Form 008.)			

Additional Information: PROVIDE DETAILS BELOW FOR A NO RESPONSE TO ANY QUESTION ABOVE, EXCEPT #1 AND #16.

All RAD samples in the Amb cooler.

Added 3.5ml HNO3 to EA. RAD and TOTAL METALS bottle. Final pH < 2. HNO3 lot no. 152495.

If applicable, was the client contacted? YES / NO /  NA Contact: \_\_\_\_\_ Date/Time: \_\_\_\_\_

Project Manager Signature / Date: [Signature]

## Section 2



# **SAMPLE RESULTS SUMMARY**

**Due to the nature of gamma spectroscopy data, a summary report is not provided.**

**Please refer to the individual sample results in Section 4.**

## Section 3

# QC RESULTS SUMMARY

**3**

# Gamma Spectroscopy Results

PAI 713 Rev 14

## Method Blank Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1705202

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: GS170513-2MB

Library: NATURAL+RA22

Sample Matrix: WATER

Prep SOP: PAI 739 Rev 12

Date Collected: 13-May-17

Date Prepared: 13-May-17

Date Analyzed: 16-May-17

Prep Batch: GS170513-2

QCBatchID: GS170513-2-1

Run ID: GS170513-2A

Count Time: 1000 minutes

Final Aliquot: 1000 ml

Result Units: pCi/l

File Name: 170512d08

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
14596-10-2	Am-241	3E-01 +/- 2.9E+00	4.9E+00		NA	U
14913-49-6	Bi-212	3.5E+01 +/- 3.4E+01	5.5E+01		NA	U
14733-03-0	Bi-214	7.6E+00 +/- 5.1E+00	8E+00		NA	U
10198-40-0	Co-60	-1E+00 +/- 2.6E+00	4.6E+00		NA	U
10045-97-3	Cs-137	-8E-01 +/- 2.3E+00	3.9E+00	1E+01	NA	U
13966-00-2	K-40	-1.3E+01 +/- 6.5E+01	1.08E+02		NA	U
15092-94-1	Pb-212	1E+00 +/- 6.3E+00	1.04E+01		NA	U
15067-28-4	Pb-214	2.1E+00 +/- 7.9E+00	1.31E+01		NA	U
13982-63-3	Ra-226	3.5E+01 +/- 6.7E+01	1.11E+02		NA	U,SI
14331-83-0	Ac-228	1.1E+01 +/- 1.1E+01	2.1E+01		NA	U
15100-28-4	Pa-234m	-5E+01 +/- 4E+02	6.8E+02		NA	U
15262-20-1	Ra-228	1.1E+01 +/- 1.1E+01	2.1E+01		NA	U
15065-10-8	Th-234	-3E+00 +/- 4.5E+01	7.4E+01		NA	U
15117-96-1	U-235	9E+00 +/- 8.7E+00	1.4E+01		NA	U

### Comments:

#### Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TP

!!

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

SQ - Spectral quality prevents accurate quantitation.

SI - Nuclide identification and/or quantitation is tentative.

TI - Nuclide identification is tentative.

R - Nuclide has exceeded 8 half-lives.

M - Requested MDC not met.

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

DL - Decision Level

#### Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: GSW1705202-1

# Gamma Spectroscopy Results

PAI 713 Rev 14

## Laboratory Control Sample(s)

Lab Name: ALS -- Fort Collins  
Work Order Number: 1705202  
Client Name: COGCC  
ClientProject ID: PW NORM 2017 10048

Lab ID: GS170513-2LCS	Sample Matrix: WATER	Prep Batch: GS170513-2	Final Aliquot: 1000 ml
Library: ANALYTICAL.LI	Prep SOP: PAI 739 Rev 12	QCBatchID: GS170513-2-1	Result Units: pCi/l
	Date Collected: 13-May-17	Run ID: GS170513-2A	File Name: 170564d01
	Date Prepared: 13-May-17	Count Time: 30 minutes	
	Date Analyzed: 18-May-17		

CASNO	Target Nuclide	Results +/- 2s TPU	MDC	Spike Added	% Rec	Control Limits	Lab Qualifier
14596-10-2	Am-241	1E+05 +/- 1.2E+04	2E+03	9.960E+04	101	85 - 115	P
10198-40-0	Co-60	4.15E+04 +/- 4.9E+03	2E+02	4.170E+04	99.4	85 - 115	P
10045-97-3	Cs-137	3.87E+04 +/- 4.6E+03	3E+02	3.780E+04	102	85 - 115	P,M3

### Comments:

#### Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TPU  
LT - Result is less than Requested MDC, greater than sample specific MDC.  
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.  
Y2 - Chemical Yield outside default limits.  
L - LCS Recovery below lower control limit.  
H - LCS Recovery above upper control limit.  
P - LCS Recovery within control limits.  
M - The requested MDC was not met.  
M3 - The requested MDC was not met, but thereported activity is greater than the reported MDC.

#### Abbreviations:

TPU - Total Propagated Uncertainty  
MDC - Minimum Detectable Concentration

SQ - Spectral quality prevents accurate quantitation.  
SI - Nuclide identification and/or quantitation is tentative.  
TI - Nuclide identification is tentative.  
R - Nuclide has exceeded 8 half-lives.

Data Package ID: GSW1705202-1

## Section 4

# INDIVIDUAL SAMPLE RESULTS



# Gamma Spectroscopy Results

PAI 713 Rev 14

## Sample Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1705202

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Field ID: 439136  
Lab ID: 1705202-1

Library: NATURAL+RA22

Sample Matrix: WATER  
Prep SOP: PAI 739 Rev 12  
Date Collected: 09-May-17  
Date Prepared: 13-May-17  
Date Analyzed: 16-May-17

Prep Batch: GS170513-2  
QCBatchID: GS170513-2-1  
Run ID: GS170513-2A  
Count Time: 500 minutes  
Report Basis: Filtered

Final Aliquot: 1000 ml  
Prep Basis: Filtered  
Moisture(%): NA  
Result Units: pCi/l  
File Name: 170448d09

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
14596-10-2	Am-241	2.3E+00 +/- 4.7E+00	7.8E+00		NA	U
14913-49-6	Bi-212	3.3E+01 +/- 5.4E+01	8.9E+01		NA	U
14733-03-0	Bi-214	4.1E+01 +/- 1.5E+01	2.5E+01		NA	
10198-40-0	Co-60	7E-01 +/- 4.5E+00	7.8E+00		NA	U
10045-97-3	Cs-137	-1.2E+00 +/- 4.2E+00	7.2E+00	1E+01	NA	U
13966-00-2	K-40	1.89E+02 +/- 5.9E+01	7.1E+01		NA	NQ
15092-94-1	Pb-212	8.7E+00 +/- 7.9E+00	1.25E+01		NA	U
15067-28-4	Pb-214	4.6E+01 +/- 1.2E+01	2E+01		NA	
13982-63-3	Ra-226	7E+01 +/- 9.7E+01	1.58E+02		NA	U,SI
14331-83-0	Ac-228	3.6E+01 +/- 1.7E+01	2.4E+01		NA	NQ
15100-28-4	Pa-234m	6.1E+02 +/- 7.3E+02	1.19E+03		NA	U
15262-20-1	Ra-228	3.6E+01 +/- 1.7E+01	2.4E+01		NA	
15065-10-8	Th-234	1.61E+02 +/- 3.6E+01	4.4E+01		NA	NQ
15117-96-1	U-235	9E+00 +/- 1.6E+01	2.6E+01		NA	U

**Comments:** This sample was filtered prior to analysis.

#### Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TP  
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.  
Y2 - Chemical Yield outside default limits.  
LT - Result is less than Requested MDC, greater than sample specific MDC.  
M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.  
M - The requested MDC was not met.

#### Abbreviations:

TPU - Total Propagated Uncertainty  
MDC - Sample specific Minimum Detectable Concentration  
BDL - Below Detection Limit  
DL - Decision Level

SQ - Spectral quality prevents accurate quantitation.  
SI - Nuclide identification and/or quantitation is tentative.  
TI - Nuclide identification is tentative.  
R - Nuclide has exceeded 8 half-lives.  
G - Sample density differs by more than 15% of LCS density.

**Data Package ID:** GSW1705202-1

## Section 5

# RAW DATA

5

\*\*\*\*\*  
 SEEKER            G A M M A   A N A L Y S I S   R E S U L T S   P S Version 1.8.4

ALS Laboratory Group - Fort Collins  
 GammaScan

\*\*\*\*\*  
 Geo 1 / Water

Sample ID: 1705202-1 GS170513-2

-----  
 Sampling Start:    05/16/2017 13:00:00 | Counting Start:    05/16/2017 13:46:43  
 Sampling Stop:    05/16/2017 13:00:00 | Decay Time. . . . . 7.79E-001 Hrs  
 Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 30000 Sec  
 Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 30029 Sec  
 Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170448D09.SPC  
 -----

Detector #: 9 (Detector 9)

Energy(keV)= -2.37 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 05/16/2017  
 FWHM(keV) = 0.66 + 0.018\*En + 5.48E-04\*En^2 + 0.00E+00\*En^3 11/04/2016  
 Where En = Sqrt(Energy in keV)

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 Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000  
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PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	46.40	97.27	175	68	52	496	0.95	a
2	53.13	110.69	106	74	59	586	1.11	a
3	63.19	130.76	205	61	44	436	0.69	a
4	65.48	135.31	139	76	59	654	0.97	b
5	66.58	137.50	196	52	36	327	0.45	c
6	69.54	143.41	24	45	36	327	0.42	d NET< CL
7	74.70	153.70	227	68	50	512	0.89	a
8	76.94	158.17	246	69	50	512	0.76	b
9	83.37	171.00	23	43	34	289	0.43	a NET< CL
10	87.14	178.52	79	46	35	298	0.44	a
11	92.55	189.30	361	69	48	455	0.89	a
12	102.30	208.75	29	40	32	248	0.45	a NET< CL
13	129.27	262.54	32	39	31	233	0.47	a
14	139.67	283.26	266	70	51	475	1.06	a
15	162.28	328.36	53	40	31	234	0.49	a
16	185.90	375.47	325	80	59	555	1.30	a
17	198.20	399.99	241	63	45	373	1.05	a
18	238.57	480.50	172	64	48	390	1.12	a
19	241.95	487.24	150	75	58	501	1.42	b
20	295.28	593.59	231	60	42	306	1.22	a
21	351.89	706.49	391	56	32	221	1.01	a

## =====

## PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	510.97	1023.74	699	87	57	434	2.22	a Wide Pk
23	558.38	1118.28	190	45	29	154	1.25	a
24	583.38	1168.14	33	30	23	116	0.86	a
25	596.14	1193.57	129	49	36	219	1.49	a
26	609.34	1219.90	265	48	29	169	1.22	a
27	803.14	1606.38	46	27	19	82	0.96	a
28	911.34	1822.17	58	34	25	113	1.76	a
29	961.56	1922.30	39	28	21	86	1.51	a
30	1120.44	2239.16	55	30	21	94	1.43	a
31	1460.50	2917.32	101	36	24	89	2.91	a
32	1763.19	3520.95	42	27	20	60	2.71	a

170448D09.SPC Analyzed by

\*\*\*\*\*  
SEEKER BACKGROUND SUBTRACT RESULTS Vers. 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Background File: . . . . . DET080517.BKG (051717-8 WEEKLY BKG)

Bkg.File Detector #: 8

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
1	46.40	175	68	52	5	100	82	NET<CL
2	53.13	106	74	59	66	92	74	NET<CL
3	63.19	205	61	44	-61	93	78	NET<CL
4	65.48	139	76	59	15	120	98	NET<CL
7	74.70	227	68	50	130	99	79	
8	76.94	246	69	50	155	99	79	
9	83.37	23	43	34	-29	88	73	NET<CL
10	87.14	79	46	35	39	63	51	NET<CL
11	92.55	361	69	48	-33	115	95	NET<CL
14	139.67	266	70	51	188	93	73	
15	162.28	53	40	31	31	62	50	NET<CL
16	185.90	325	80	59	122	116	94	
17	198.20	241	63	45	111	101	81	
18	238.57	172	64	48	-4	103	85	NET<CL
20	295.28	231	60	42	190	78	60	
21	351.89	391	56	32	317	87	66	
22	510.97	699	87	57	-184	159	132	NET<CL
23	558.38	190	45	29	74	71	56	
24	583.38	33	30	23	-51	67	57	NET<CL
26	609.34	265	48	29	192	81	63	
27	803.14	46	27	19	-42	57	48	NET<CL
28	911.34	58	34	25	11	53	44	NET<CL
29	961.56	39	28	21	10	53	43	NET<CL
31	1460.50	101	36	24	-30	58	48	NET<CL

ALS Laboratory Group - Fort Collins  
 GammaScan

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Geo 1 / Water

Sample ID: 1705202-1 GS170513-2

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Sampling Start: 05/16/2017 13:00:00 | Counting Start: 05/16/2017 13:46:43
Sampling Stop: 05/16/2017 13:00:00 | Decay Time. . . . . 7.79e-001 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 30000 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 30029 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 170448D09.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
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Detector #: 9 (Detector 9)

Efficiency File: (D09)(Sh01).EFF (Geo 1 Eff Cal)

Eff.=1/[3.89E-01\*En^-1.38E+00 + 1.53E+02\*En^9.21E-01] 11/04/2016

Library File: NATURAL+RA226(SUBRA22 (Natural+Ra226.LIB)

MEASURED or MDA CONCENTRATIONS

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                N
      ENERGY E   Concentration      Critical  Halflife
Nuclide  (keV) T (pCi/L )           MDA      Level      (hrs)
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U-235    143.76 N 8.51E+00 +- 1.60E+01  2.65E+01  1.29E+01  6.17E+12
          185.72      I.D.      . . . . .  . . . . . 6.17E+12
Pb-214   Average:x 4.63E+01 +- 1.06E+01  . . . . .  . . . . . 1.40E+07
          295.22  4.63E+01 +- 1.89E+01  2.98E+01  1.46E+01  1.40E+07
          351.99  4.64E+01 +- 1.28E+01  1.96E+01  9.60E+00  1.40E+07
Bi-214   Average:x 4.08E+01 +- 1.38E+01  . . . . .  . . . . . 1.40E+07
          609.32  3.67E+01 +- 1.55E+01  2.45E+01  1.20E+01  1.40E+07
          1120.28 5.64E+01 +- 3.02E+01  4.57E+01  2.15E+01  1.40E+07
Pb-210   46.50 N 1.52E+02 +- 4.87E+01  7.36E+01  3.57E+01  1.95E+05
Am-241   59.54 N 2.27E+00 +- 4.71E+00  7.83E+00  3.81E+00  3.80E+06
Th-234   92.50 N 1.61E+02 +- 3.10E+01  4.38E+01  2.13E+01  3.92E+13
Ra-226   186.21 N 6.99E+01 +- 9.69E+01  1.57E+02r 7.75E+01  1.40E+07
Th-227   236.00 N-1.88E+01 +- 1.77E+01  3.10E+01  1.51E+01  1.90E+05
Pb-212   238.63 N 8.65E+00 +- 7.85E+00  1.25E+01R 6.12E+00  1.27E+14
Tl-208   583.14 N 3.18E+00 +- 4.29E+00  7.08E+00  3.40E+00  1.27E+14
Cs-137   661.62 N-1.19E+00 +- 4.15E+00  7.24E+00  3.47E+00  2.64E+05
Bi-212   727.17 N 3.26E+01 +- 5.35E+01  8.91E+01  4.24E+01  1.27E+14
Ra-228   911.07 N 3.55E+01 +- 1.60E+01  2.37E+01  1.12E+01  5.04E+04
Pa-234m  1001.03 N 6.07E+02 +- 7.26E+02  1.19E+03  5.64E+02  3.92E+13
Co-60    1332.51 N 7.21E-01 +- 4.47E+00  7.75E+00  3.63E+00  4.62E+04
K-40     1460.75 N 1.89E+02 +- 5.47E+01  7.14E+01  3.33E+01  1.12E+13
  
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MEASURED or MDA CONCENTRATIONS

Nuclide	ENERGY (keV)	E T	Concentration (pCi/L)	MDA	Critical Level	Half-life (hrs)
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MEASURED TOTAL: 1.36E+03 +/- 1.09E+03 pCi/L

UNKNOWN, SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	66.58	137.50	196	52	36	327	0.45	Unknown
2	74.70	153.70	130	99	79	512	0.89	Unknown
3	76.94	158.17	155	99	79	512	0.76	Unknown
4	129.27	262.54	32	39	31	234	0.47	Unknown
5	139.67	283.26	188	93	73	475	1.06	Unknown
7	198.20	399.99	111	101	81	373	1.05	Unknown
8	241.95	487.24	150	75	58	501	1.42	Unknown
11	558.38	1118.28	74	71	56	154	1.25	Unknown
12	596.14	1193.57	129	49	36	219	1.49	Unknown
15	1763.19	3520.95	42	27	20	60	2.71	Unknown

c:\SEEKER\BIN\170448d09.res Analysis Results Saved.

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SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: GS170513-2MB GS170513-2

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Sampling Start: 05/16/2017 12:00:00 | Counting Start: 05/16/2017 12:17:40
Sampling Stop: 05/16/2017 12:00:00 | Decay Time. . . . . 2.94E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 60000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 60048 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170512D08.SPC
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Detector #: 8 (Detector 8)

Energy(keV)= -2.27 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 05/16/2017

FWHM(keV) = 0.66 + 0.008\*En + 7.24E-04\*En^2 + 0.00E+00\*En^3 04/18/2017

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	46.36	97.04	385	89	66	873	0.76	a
2	53.33	110.94	275	152	122	1932	1.76	a Wide Pk
3	63.20	130.64	701	101	71	1014	0.87	a
4	66.26	136.74	690	101	71	1014	0.90	b
5	69.35	142.92	60	100	81	1217	0.90	c NET< CL
6	74.80	153.80	142	77	60	799	0.72	a
7	77.15	158.48	192	66	49	599	0.41	b
8	84.31	172.77	111	96	77	1100	0.90	a
9	92.57	189.24	858	110	76	1081	0.99	a
10	119.19	242.37	39	55	44	477	0.43	a NET< CL
11	121.98	247.92	40	66	54	636	0.69	b NET< CL
12	139.76	283.41	510	81	55	667	0.70	a
13	143.40	290.67	61	57	45	501	0.43	b
14	158.95	321.70	57	54	43	449	0.45	a
15	162.60	328.98	146	108	87	1196	1.36	b
16	174.97	353.67	96	74	59	699	0.75	a
17	185.74	375.14	380	92	69	872	0.95	a
18	198.33	400.28	575	96	68	865	0.92	a
19	238.57	480.56	368	78	56	625	0.81	a
20	241.77	486.95	55	69	56	625	0.87	b NET< CL
21	253.12	509.60	104	78	62	706	0.95	a

=====  
 PEAK SEARCH RESULTS  
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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	295.13	593.43	38	46	36	324	0.51	a
23	326.30	655.61	177	138	111	1308	2.44	a Wide Pk
24	338.32	679.61	66	106	86	964	1.76	a NET< CL Wide Pk
25	352.04	706.99	153	60	45	415	0.78	a
26	416.94	836.48	61	65	52	457	1.15	a
27	500.71	1003.63	97	100	80	794	2.60	a Wide Pk
28	511.17	1024.50	1840	135	86	914	2.67	a Wide Pk
29	558.63	1119.21	490	67	41	332	1.12	a
30	569.78	1141.44	78	56	43	372	1.20	a
31	583.74	1169.29	146	54	39	305	1.22	a
32	596.30	1194.36	247	71	52	475	1.43	a
33	609.52	1220.73	131	64	49	446	1.23	a
34	617.78	1237.23	65	80	65	587	2.07	a Wide Pk
35	651.28	1304.07	84	59	46	374	1.43	a
36	803.37	1607.54	129	47	34	229	1.14	a
37	881.21	1762.85	35	34	27	163	1.00	a
38	898.82	1798.00	43	46	36	256	1.46	a
39	911.67	1823.64	91	48	36	246	1.72	a
40	962.64	1925.35	80	41	30	189	1.29	a
41	968.80	1937.63	47	39	30	189	1.35	b
42	1460.87	2919.49	212	43	26	134	1.59	a

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SEEKER BACKGROUND SUBTRACT RESULTS Vers. 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

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Background File: . . . . . DET080510.BKG (051017-8 WEEKLY BKG)

Bkg.File Detector #: 8

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN-CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN-CERTAINTY	NEW CR.LEVEL	FLAG
1	46.36	385	89	66	63	171	140	NET<CL
2	53.33	275	152	122	163	209	171	NET<CL
3	63.20	701	101	71	93	188	153	NET<CL
4	66.26	690	101	71	489	202	162	
6	74.80	142	77	60	-123	162	135	NET<CL
7	77.15	192	66	49	-23	174	143	NET<CL
8	84.31	111	96	77	-34	193	159	NET<CL
9	92.57	858	110	76	-17	228	187	NET<CL
10	119.19	39	55	44	-8	163	134	NET<CL
12	139.76	510	81	55	317	175	141	
13	143.40	61	57	45	-15	143	118	NET<CL
15	162.60	146	108	87	95	168	137	NET<CL
17	185.74	380	92	69	89	172	140	NET<CL
18	198.33	575	96	68	374	172	138	
19	238.57	368	78	56	27	164	134	NET<CL
22	295.13	38	46	36	-44	122	101	NET<CL
24	338.32	66	106	86	-9	175	144	NET<CL
25	352.04	153	60	45	35	131	107	NET<CL
28	511.17	1840	135	86	157	299	245	NET<CL
29	558.63	490	67	41	257	126	100	
30	569.78	78	56	43	-6	107	88	NET<CL
31	583.74	146	54	39	7	125	103	NET<CL
33	609.52	131	64	49	-8	163	134	NET<CL
35	651.28	84	59	46	22	105	86	NET<CL
36	803.37	129	47	34	-10	116	96	NET<CL
38	898.82	43	46	36	23	171	140	NET<CL
39	911.67	91	48	36	14	92	75	NET<CL
40	962.64	80	41	30	29	99	81	NET<CL
42	1460.87	212	43	26	-19	95	78	NET<CL

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ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: GS170513-2MB GS170513-2

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Sampling Start: 05/16/2017 12:00:00 | Counting Start: 05/16/2017 12:17:40
Sampling Stop: 05/16/2017 12:00:00 | Decay Time. . . . . 2.94e-001 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 60000 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 60048 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 170512D08.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
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Detector #: 8 (Detector 8)

Efficiency File: (D08)(Sh01).EFF (Geo 1 Eff Cal)

Eff.=1/[2.49E-01\*En^-1.50E+00 + 1.19E+02\*En^8.64E-01] 03/15/2017

Library File: NATURAL+RA226(SUBRA22 (Natural+Ra226.LIB)

MEASURED or MDA CONCENTRATIONS

Nuclide	ENERGY E (keV)	N T	Concentration (pCi/L)	MDA	Critical Level	Halflife (hrs)
Pb-210	46.50	N	2.34E+01 +- 6.34E+01	1.05E+02	5.19E+01	1.95E+05
Th-234	92.50	N	3.25E+00 +- 4.48E+01	7.43E+01	3.69E+01	3.92E+13
Ra-226	186.21	N	3.46E+01 +- 6.70E+01	1.11E+02	5.48E+01	1.40E+07
Pb-212	238.63	N	1.02E+00 +- 6.26E+00	1.04E+01	5.14E+00	1.27E+14
Pb-214	351.99	N	2.12E+00 +- 7.88E+00	1.31E+01	6.45E+00	1.40E+07
Tl-208	583.14	N	2.82E-01 +- 5.03E+00	8.38E+00	4.14E+00	1.27E+14
Ra-228	Average:x		1.11E+01 +- 1.05E+01	. . . .	. . . .	5.04E+04
	911.07	N	2.65E+00 +- 1.77E+01	2.96E+01	1.45E+01	5.04E+04
	968.90		1.57E+01 +- 1.31E+01	2.10E+01	1.01E+01	5.04E+04
K-40	1460.75	N	1.30E+01 +- 6.45E+01	1.08E+02	5.33E+01	1.12E+13
Am-241	59.54	N	2.78E-01 +- 2.91E+00	4.87E+00B	2.39E+00	3.80E+06
U-235	143.76	N	8.99E+00 +- 8.59E+00	1.40E+01	6.87E+00	6.17E+12
Th-227	236.00	N	6.02E+00 +- 1.03E+01	1.70E+01B	8.30E+00	1.90E+05
Bi-214	609.32	N	7.58E+00 +- 5.00E+00	8.05E+00	3.92E+00	1.40E+07
Cs-137	661.62	N	7.56E-01 +- 2.26E+00	3.88E+00	1.88E+00	2.64E+05
Bi-212	727.17	N	3.50E+01 +- 3.35E+01	5.47E+01	2.65E+01	1.27E+14
Pa-234m	1001.03	N	4.57E+01 +- 3.97E+02	6.81E+02	3.28E+02	3.92E+13
Co-60	1332.51	N	1.04E+00 +- 2.62E+00	4.59E+00	2.20E+00	4.62E+04

MEASURED TOTAL: 1.30E+02 +- 2.20E+02 pCi/L

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 UNKNOWN,SUM or ESCAPE PEAKS  
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
2	53.33	110.94	163	209	171	1932	1.76	Deleted
3	63.20	130.64	93	188	153	1014	0.87	Deleted
4	66.26	136.74	489	202	162	1014	0.90	Unknown
5	69.35	142.92	60	100	81	1217	0.90	Deleted
6	74.80	153.80	-123	162	135	799	0.72	Deleted
7	77.15	158.48	-23	174	143	599	0.41	Deleted
8	84.31	172.77	-34	193	159	1100	0.90	Deleted
10	119.19	242.37	-8	163	134	477	0.43	Deleted
11	121.98	247.92	40	66	54	636	0.69	Deleted
12	139.76	283.41	317	175	141	667	0.70	Unknown
13	143.40	290.67	-15	143	118	501	0.43	Deleted
14	158.95	321.70	57	54	43	449	0.45	Unknown
15	162.60	328.98	95	168	137	1196	1.36	Deleted
16	174.97	353.67	96	74	59	699	0.75	Unknown
18	198.33	400.28	374	172	138	865	0.92	Unknown
20	241.77	486.95	55	69	56	625	0.87	Deleted
21	253.12	509.60	104	78	62	706	0.95	Unknown
22	295.13	593.43	-44	122	101	324	0.51	Deleted
23	326.30	655.61	177	138	111	1308	2.44	Unknown
24	338.32	679.61	-9	175	144	964	1.76	Deleted
26	416.94	836.48	61	65	52	457	1.15	Unknown
27	500.71	1003.63	97	100	80	794	2.60	Unknown
28	511.17	1024.50	157	299	245	914	2.67	Deleted
29	558.63	1119.21	257	126	100	332	1.12	Unknown
30	569.78	1141.44	-6	107	88	372	1.20	Deleted
32	596.30	1194.36	247	71	52	475	1.43	Unknown
33	609.52	1220.73	-8	163	134	446	1.23	Deleted
34	617.78	1237.23	66	80	65	587	2.07	Unknown
35	651.28	1304.07	22	105	86	374	1.43	Deleted
36	803.37	1607.54	-10	116	96	229	1.14	Deleted
37	881.21	1762.85	35	34	27	163	1.00	Unknown
38	898.82	1798.00	23	171	140	256	1.46	Deleted
40	962.64	1925.35	29	99	81	189	1.29	Deleted

c:\SEEKER\BIN\170512d08.res Analysis Results Saved.

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SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: GS170513-2LCS GS170513-2

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Sampling Start: 05/18/2017 08:00:00 | Counting Start: 05/18/2017 08:29:48
Sampling Stop: 05/18/2017 08:00:00 | Decay Time. . . . . 4.97E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 1825 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170564D01.SPC
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Detector #: 1 (Detector 1)

Energy(keV) = -2.05 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 05/18/2017

FWHM(keV) = 0.71 + -0.000\*En + 1.20E-03\*En^2 +-8.09E-06\*En^3 08/22/2016

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	59.44	122.72	8393	210	84	1583	0.74	a
2	66.63	137.06	73	76	61	925	0.53	a
3	87.90	179.53	8116	210	89	1614	0.78	a
4	122.02	247.61	1845	131	81	1323	0.86	a
5	132.53	268.58	80	71	57	789	0.51	a
6	136.36	276.24	254	103	81	1314	0.90	b
7	154.78	313.00	23	68	55	746	0.44	a NET< CL
8	165.66	334.69	129	124	101	1729	1.23	a
9	227.04	457.20	56	70	57	788	0.48	a NET< CL
10	270.17	543.26	33	76	62	850	0.66	a NET< CL
11	310.57	623.89	47	69	56	686	0.66	a NET< CL
12	351.03	704.65	58	54	43	448	0.54	a
13	661.74	1324.71	19413	289	62	673	1.41	a HiResid
14	822.28	1645.10	44	70	57	590	1.30	a NET< CL
15	1173.37	2345.76	15096	253	48	409	1.79	a HiResid
16	1332.59	2663.50	13726	236	24	104	2.02	a HiResid

170564D01.SPC Analyzed by

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SEEKER            B A C K G R O U N D    S U B T R A C T   R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

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Background File: . . . . . DET010517.BKG (051717-1 WEEKLY BKG)

Bkg.File Detector #: 1

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
2	66.63	73	76	61	70	77	61	
3	87.90	8116	210	89	8115	210	90	
12	351.03	58	54	43	55	54	43	

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SEEKER                      F I N A L     A C T I V I T Y     R E P O R T                      Version 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: GS170513-2LCS GS170513-2

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Sampling Start:   05/18/2017 08:00:00 | Counting Start:   05/18/2017 08:29:48
Sampling Stop:   05/18/2017 08:00:00 | Decay Time. . . . . 4.97e-001 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 1825 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 170564D01.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
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Detector #: 1 (Detector 1)

Efficiency File: (D01)(Sh01).EFF (Geo 1 Eff Cal)

Eff=10^[-7.58E+01 +9.57E+01\*L +-4.10E+01\*L^2 +5.81E+00\*L^3] 08/22/2016

Eff.=10^[2.34E+00 +-2.89E+00\*L +6.89E-01\*L^2 +-7.66E-02\*L^3] Above 300.00 keV

Library File: . . . .ANALYTICAL.LIB (Analytical)

MEASURED or MDA CONCENTRATIONS

Nuclide	ENERGY E (keV)	Concentration (pCi/L)	MDA	Critical Level	Halflife (hrs)
Am-241	59.54	1.01E+05 +- 2.52E+03	2.06E+03	1.01E+03	3.79E+06
Cd-109	88.02	2.25E+05 +- 5.82E+03	5.03E+03	2.48E+03	1.11E+04
Co-57	122.07	1.40E+03 +- 9.94E+01	1.25E+02	6.16E+01	6.50E+03
Ce-139	165.85	1.00E+02 +- 9.70E+01	1.59E+02	7.85E+01	3.30E+03
Cs-137	661.62	3.87E+04 +- 5.76E+02	2.53E+02	1.24E+02	2.64E+05
Co-60	Average:x	4.15E+04 +- 4.97E+02	. . . .	. . . .	4.62E+04
	1173.21	4.13E+04 +- 6.90E+02	2.71E+02	1.32E+02	4.62E+04
	1332.48	4.17E+04 +- 7.17E+02	1.52E+02	7.20E+01	4.62E+04
Hg-203	279.18	MDA . . . .	1.67E+02	8.23E+01	1.12E+03
Sn-113	391.68	MDA . . . .	2.63E+02	1.29E+02	2.76E+03
Y-88	898.02	MDA . . . .	3.32E+02	1.63E+02	2.56E+03

MEASURED TOTAL: 4.07E+05 +- 9.61E+03 pCi/L

UNKNOWN, SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
2	66.63	137.06	70	77	61	925	0.53	Unknown

## 170564D01.SPC Analyzed by

## =====

## UNKNOWN, SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
5	132.53	268.58	80	71	57	789	0.51	Unknown
6	136.36	276.24	254	103	81	1314	0.90	Unknown
7	154.78	313.00	23	68	55	746	0.44	Deleted
9	227.04	457.20	56	70	57	789	0.48	Deleted
10	270.17	543.26	33	76	62	850	0.66	Deleted
11	310.57	623.89	47	69	56	686	0.66	Deleted
12	351.03	704.65	55	54	43	448	0.54	Unknown
14	822.28	1645.10	44	70	57	590	1.30	Deleted

c:\SEEKER\BIN\170564d01.res Analysis Results Saved.

Gamma Spectrometer Run Log

Date: 5/15/17 / 5/16/17

Reviewed By/Date: JP 5/17/17

Sample ID	Ver <sup>1</sup>	Det. No.	Geo <sup>2</sup>	Count Dur. (min.) <sup>3</sup>	Start Time	Analyst	File ID.SPC	Saved?
1705271-19	JP	7	1	400	18:50	JP	170506007	JP
↓ -22		8					170508008	JP
↓ -24		9					170445009	JP
GS170513-1MB	↓	4	↓	500	↓	↓	170854004	JP
1705095-1	JP	1	1	300	7:01	JP	170548001	JP
1705158-1		2					170110002	JP
1705177-1		3			7:02		170606003	JP
↓ -2	JP	4		1000			170857004	JP
1705271-24D	JP	6		300			170456006	JP
↓ -26		7					170508007	JP
↓ -28	JP	8		270	7:03		170510008	JP
↓ -30	JP	9		300			170447009	JP
1705177-3	JP	5			7:05	↓	170512005	JP
GS170513-1CS	JP	8		30	11:35	JP	170511008	JP
1705067-1	JP	1	1	1000	12:16	JP	170549001	JP
↓ -2		2					170111002	JP
1705085-1		3					170607003	JP
1705132-1		5			12:17		170513005	JP
1705245-1		6					170457006	JP
1705246-1		7					170509007	JP
GS170513-2MB,AMB		8	↓				170512008	JP
1705202-1	↓	9	1	500	13:46	JP	170448009	JP

5/15/17  
5/16/17

<sup>1</sup> Analyst will verify the position, detector, and geometry when the sample is removed from the detector.  
<sup>2</sup> Calibration geometry.  
<sup>3</sup> Count duration.

**KEY:** \* sample was counted on a puck  
 ↑ sample was counted with air flow arrow pointing up

Gamma Spectrometer Run Log

Date: 5/17/17 / 5/18/17

Reviewed By/Date: JP 5/18/17

Sample ID	Ver <sup>1</sup>	Det. No.	Geo <sup>2</sup>	Count Dur. (min.) <sup>3</sup>	Start Time	Analyst	File ID.SPC	Saved?
051717-1	AL	1	NA	1000	13:58	JP	170562001	AL
2		2					170124002	AL
3		3					120621003	AL
4		4					170869004	AL
5		5			13:59		170525005	AL
6		6					170470006	AL
7		7					<del>170522007</del> 170523007	AL
8		8					170525008	AL
9		9					170460009	AL
1705177-2D	JP	6	1	300	8:29	JP	170473006	JP
1705203-1	JP	7	1	265			170526007	JP
240-1		8		240			170527008	JP
242-1		9					170462009	JP
65170513-2LCS	JP	1		30			170564001	JP
1705184-1	AL	2		240	8:30		170126002	JP
1704482-1	AL	3	17/26	30	8:42	JP	170629003	AL
65170427-1MB		4		30	8:43		170874004	AL
1705243-1	JP	5		240	9:24	JP	170530005	JP
1705184-2	JP	1			9:26	JP	170565001	JP
1704482-1DVP	AL	4	17/26	30	1:42	AL	170875004	AL
65170427-1LCS	AL	3		30	9:40	AL	170625003	AL
65170427-1ALCS	AL	4	17/26	30	10:26	AL	170876004	AL
65170513-3LCS	JP	2	1	30	12:36	JP	170627002	JP

5/17/17  
5/18/17

5/18/17

JP 5/18/17

<sup>1</sup> Analyst will verify the position, detector, and geometry when the sample is removed from the detector.  
<sup>2</sup> Calibration geometry.  
<sup>3</sup> Count duration.

**KEY:** \* sample was counted on a puck  
 ↑ sample was counted with air flow arrow pointing up

**Technical Comments Regarding Analysis using the  
Natural+Ra226(SubRa228).REV1 Gamma Spectroscopy Library**

Analysis using the **Natural+Ra226(SubRa228).REV1** library is limited to the list of gamma emitting radionuclides specified by ALS Laboratory Group. ALS Laboratory Group specifies all values assigned to the nuclides in this library. In cases where multiple gamma emissions are used to quantify activity, the most abundant emission is used for quantification in the absence of any supporting gamma emissions. It should be noted that the current software program used for gamma spectroscopic analysis is limited to a +/- 2.0 keV photo-peak resolution tolerance. Thus, any gamma emissions occurring within the same +/- 2.0 keV range will suffer interference, consequently preventing accurate quantification. Nuclide specific information regarding analysis using the **Natural+Ra226(SubRa228).REV1** library is as follows:

Nuclide:  $^{228}\text{Ra}$                                       Energy: various                                      Photon Abundance: various

All activity values for  $^{228}\text{Ra}$  are calculated using the emissions of the  $^{228}\text{Ac}$  daughter. It is assumed that secular equilibrium is achieved between the  $^{228}\text{Ra}$  parent and the  $^{228}\text{Ac}$  progeny.

Nuclide:  $^{212}\text{Bi}$ ,  $^{212}\text{Pb}$ ,  $^{208}\text{Tl}$                                       Energy: various                                      Photon Abundance: various

All activity values for  $^{212}\text{Bi}$ ,  $^{212}\text{Pb}$ , and  $^{208}\text{Tl}$  are calculated using the half-life,  $t_{1/2}=1.45\text{E}+10$  years, of the long-lived  $^{232}\text{Th}$  parent. It is assumed that secular equilibrium is achieved between the  $^{232}\text{Th}$  parent and the  $^{212}\text{Bi}$ ,  $^{212}\text{Pb}$ ,  $^{208}\text{Tl}$  progeny.

Nuclide:  $^{214}\text{Bi}$ ,  $^{214}\text{Pb}$                                       Energy: various                                      Photon Abundance: various

All activity values for  $^{214}\text{Bi}$  and  $^{214}\text{Pb}$  are calculated using the half-life,  $t_{1/2}=1600$  years, of the long-lived  $^{226}\text{Ra}$  parent. It is assumed that secular equilibrium is achieved between the  $^{226}\text{Ra}$  parent and the  $^{214}\text{Bi}$  and  $^{214}\text{Pb}$  progeny.

Nuclide:  $^{137}\text{Cs}$                                       Energy: 661.62 keV                                      Photon Abundance: 0.8512

$^{137}\text{Cs}$  does not emit any gamma photons useful for quantification. However, it can be assumed to be in secular equilibrium with the short-lived  $^{137\text{m}}\text{Ba}$  daughter product. Therefore, the activity for  $^{137}\text{Cs}$  is determined from the 661.62 keV gamma emission of the  $^{137\text{m}}\text{Ba}$  daughter product. The calculated gamma photon abundance used in the library is the product of the 0.8998 abundance of the 661.62 keV  $^{137\text{m}}\text{Ba}$  photon and the 0.946 branching ratio between  $^{137}\text{Ba}$  and  $^{137\text{m}}\text{Ba}$ .

Nuclide:  $^{40}\text{K}$                                       Energy: 1460.75 keV                                      Photon Abundance: 0.1100 ( $\gamma/\text{dis}$ )

The only gamma emission useful for quantification of this nuclide suffers from possible resolution interference due to the  $^{228}\text{Ac}$  gamma emission occurring at 1459.2 keV (0.0104, abundance). Therefore, a possibility of a high bias to the  $^{40}\text{K}$  results may occur in the presence of elevated  $^{228}\text{Ac}$  activity.

Nuclide:  $^{226}\text{Ra}$                                       Energy: 186.21                                      Photon Abundance: 0.0359

Quantifying  $^{226}\text{Ra}$  activity using the 186.21 keV photo-peak is vulnerable to a significant high bias due to interference from gamma emissions from  $^{235}\text{U}$  occurring at 185.72 keV (0.5720,

abundance). Therefore this nuclide will be "SI" flagged, indicating that significant spectral interference prohibits accurate quantification.

Nuclide:  $^{234}\text{Th}$  &  $^{234\text{m}}\text{Pa}$  Energy: various Photon Abundance: various

$^{234}\text{Th}$  and  $^{234\text{m}}\text{Pa}$  are assumed to be in secular equilibrium with their parent,  $^{238}\text{U}$ . The activities for these nuclides are therefore calculated using the half-life of the parent, which is  $t_{1/2}=4.468\text{E}+9$  years.

Nuclide:  $^{227}\text{Th}$  Energy: 236.00 Photon Abundance: 0.1230

All activity values for  $^{227}\text{Th}$  are calculated using the half-life,  $t_{1/2}=21.7$  yrs, of the long-lived  $^{227}\text{Ac}$  parent. It is assumed that secular equilibrium is achieved between the  $^{227}\text{Ac}$  parent and the  $^{227}\text{Th}$  progeny.

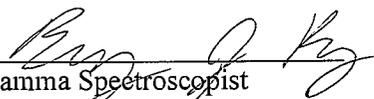
Nuclide:  $^{234}\text{Th}$  Energy: 92.50 Photon Abundance: 0.0553

The 92.50 keV photo-peak used in this library for  $^{234}\text{Th}$  quantification is actually two separate photo-peaks, occurring at 92.4 keV and 92.8 keV. The current software used for gamma spectroscopic analysis cannot resolve two photo-peaks that occur within the 2-keV resolution tolerance. Therefore, these two photopeaks are observed as a single photo-peak. Therefore, the average of the two photo-peak energies is used in this library. Also, the sum of the two photo-peak abundances, 0.0553, is used in the activity calculations for this observed 'single' photo-peak.

All activity values for  $^{234}\text{Th}$  are calculated using the half-life,  $t_{1/2}=4.468\text{E}+09$  yrs, of the long-lived  $^{238}\text{U}$  parent. It is assumed that secular equilibrium is achieved between the  $^{238}\text{U}$  parent and the  $^{234}\text{Th}$  progeny.

Nuclide:  $^{235}\text{U}$  Energy: 185.72 Photon Abundance: 0.5720

Quantifying  $^{235}\text{U}$  activity using the 185.72 keV photo-peak is vulnerable to a significant high bias due to interference from gamma emissions from  $^{226}\text{Ra}$  occurring at 186.21 keV (0.0328, abundance). Therefore, this emission will be used as an identifier only and not in the activity calculations for this nuclide.

  
Gamma Spectroscopist  
Radiochemistry Instrumentation Laboratory

10-5-12  
Date

  
Radiochemistry Manager

10-8-12  
Date

Pk. #	Energy (keV)	Isotope Name	2ndary Pk #	Type	Gamma Fraction	Halflife
1	59.54	Am-241	0	NET	0.3590	4.3310E+02 yrs
20	727.17	Bi-212	0	NET	0.0658	1.4500E+10 yrs
18	609.32	Bi-214	25	NET	0.4609	1.6000E+03 yrs
25	1120.28	Bi-214	18	QUANT	0.1510	1.6000E+03 yrs
26	1173.23	Co-60	27	QUANT	0.9997	5.2721E+00 yrs
27	1332.51	Co-60	26	NET	0.9998	5.2721E+00 yrs
19	661.62	Cs-137	0	NET	0.8512	3.0104E+01 yrs
28	1460.75	K-40	0	NET	0.1100	1.2800E+09 yrs
24	1001.03	Pa-234m	0	NET	0.0059	4.4680E+09 yrs
4	115.18	Pb-212	11	QUANT	0.0059	1.4500E+10 yrs
11	238.63	Pb-212	14	NET	0.4330	1.4500E+10 yrs
14	300.09	Pb-212	4	QUANT	0.0327	1.4500E+10 yrs
13	295.22	Pb-214	16	QUANT	0.1920	1.6000E+03 yrs
16	351.99	Pb-214	13	NET	0.3710	1.6000E+03 yrs
8	186.21	Ra-226	0	NET	0.0359	1.6000E+03 yrs
15	338.40	Ra-228	22	QUANT	0.1127	5.7500E+00 yrs
22	911.07	Ra-228	23	NET	0.2580	5.7500E+00 yrs
23	968.90	Ra-228	15	QUANT	0.1580	5.7500E+00 yrs
10	236.00	Th-227	0	NET	0.1230	2.1700E+01 yrs
2	63.29	Th-234	3	QUANT	0.0390	4.4680E+09 yrs
3	92.50	Th-234	2	NET	0.0553	4.4680E+09 yrs
12	277.36	Tl-208	17	QUANT	0.0631	1.4500E+10 yrs
17	583.14	Tl-208	21	NET	0.8450	1.4500E+10 yrs
21	860.47	Tl-208	12	QUANT	0.1242	1.4500E+10 yrs
5	143.76	U-235	6	NET	0.1096	7.0379E+08 yrs
6	163.35	U-235	7	QUANT	0.0508	7.0379E+08 yrs
7	185.72	U-235	9	ID	0.5720	7.0379E+08 yrs
9	205.31	U-235	5	QUANT	0.0501	7.0379E+08 yrs

## **TECHNICAL BULLETIN ADDENDUM**

The library used for analysis defines the gamma emission(s) to be used for analysis of each nuclide. If multiple gamma emissions are used for quantification, then a 'NET' quantification emission (or peak) must be defined in the library. This designation provides for the calculation of nuclide activity concentrations and detection limits in the case of non-presence of the nuclide. When the nuclide is not present, or the software is unable to resolve a peak at the library defined 'NET' energy, the software evaluates the 'NET' region of interest ('NET' peak energy +/- 2 keV) by performing a summation of the net counts above the background level. This 'NET' quantification can result in net negative, zero, or positive activity results, and is highly dependent on the spectral distribution in the region of interest of the 'NET' peak. In cases where only the 'NET' peak is found, and the software performs a net quantification, the nuclide result will be flagged with an 'NQ' qualifier on the final reports. This indicates that the nuclide is not detected or supported at any level above the reported MDC. Results are submitted without further qualification.

All nuclides specified in the library of analysis for gamma spectroscopy are evaluated for positive OR tentative identification on the following criteria:

- The individual abundances for the gamma emissions specified for each nuclide are summed to obtain a total nuclide abundance.
- From the total nuclide abundance, a positive identification criterion is set as 75% of this total nuclide abundance.
- For all nuclide peaks that are not net quantified, those peak abundances are summed. The total non-net quantified peak sum is compared to the calculated 75% abundance criterion. If this sum is greater than the 75% criterion, the nuclide is considered to be positively identified at the reported concentration. If the sum is less than the 75% criterion, the nuclide is tentatively identified at the reported concentration. These results will be flagged with a 'TI' qualifier on the final reports to indicate that the 75% abundance criterion was not met.

## Section 6

# QUALITY ASSURANCE SUMMARY REPORTS

**6**

**No *NON-CONFORMANCE REPORTS* or *QUALITY ASSURANCE SUMMARY SHEETS* are included in this data package.**

## Section 7

# LABORATORY BENCH SHEETS



# Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: GS170513-2

Prep Procedure: **GAMMASCAN**

Analytical QASS / NCR? Y **NA**

Prep Num	Lab ID	QC Type	Init Alq	Fin Alq	Units	Report Units	Cnt 1 File Cnt Dur (min)	Cnt 1 Inst/Det	Cnt 1 Count Date	Cnt 2 File Cnt Dur (min)	Cnt 2 Inst/Det	Cnt 2 Count Date	Cnt 3 File Cnt Dur (min)	Cnt 3 Inst/Det	Cnt 3 Count Date	Notes
611	1705067-1	SMP	1000	1000	ml	pCi/l	1000	1	5/16/17							
	1705067-2	SMP	1000	1000	ml	pCi/l		2								
612	1705085-1	SMP	990	990	ml	pCi/l		3								
5126	1705095-1	SMP	1000	1000	ml	pCi/l	300	1								
612	1705132-1	SMP	940	940	ml	pCi/l	1000	5								
5122	1705158-1	SMP	1000	1000	ml	pCi/l	300	2								DP 5/23/17
	1705177-1	SMP	1000	1000	ml	pCi/l		3								
	1705177-2	SMP	1000	1000	ml	pCi/l		4								
	1705177-2	DUP	1000	1000	ml	pCi/l	300	6	5/18/17							Count Duplicate
	1705177-3	SMP	1000	1000	ml	pCi/l	300	5	5/16/17							
5120	1705202-1	SMP	1000	1000	ml	pCi/l	500	9								
	1705203-1	SMP	1000	1000	ml	pCi/l		7	5/18/17							
	1705240-1	SMP	1000	1000	ml	pCi/l	240	8								
	1705242-1	SMP	1000	1000	ml	pCi/l		9								
	1705243-1	SMP	1000	1000	ml	pCi/l	240	5								
619	1705245-1	SMP	930	930	ml	pCi/l	1000	6	5/16/17							
	1705246-1	SMP	940	940	ml	pCi/l		7								
	GS170513-2A	MB	1000	1000	ml	pCi/l		8								
	GS170513-2	MB	1000	1000	ml	pCi/l		9								
	GS170513-2	LCS	1000	1000	ml	pCi/l	30	1	5/19/17							

067,095,132,245,246 -> NMED\_FANCLUB (5137 (5))  
 095,158,177, 202,203,240,242,243 Natural (Ra226 (Ra228)) LB  
 ↳ Do Not Decay Correct

Soln #	Nuclide	Conc	Prep Date	Exp Date	Units	Aliquot	Units	Pipet ID
S1	Am-241	221.090	05/13/17		DPM/ml	1000	ml	NA
S1	Co-60	92.721	05/13/17		DPM/ml	1000	ml	NA
S1	Cs-137	83.955	05/13/17		DPM/ml	1000	ml	NA

Sample Barcodes

1705067-1	1705067-2	1705085-1
GS170513-2PS1	GS170513-2PS2	GS170513-2PS3

# Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: GS170513-2

Prep Procedure: GAMMASCAN

Analytical QASS / NCR? Y **NA**

Prep Num	Lab ID	QC Type	Init Aliq	Fin Aliq	Units Geo.	Report Units	Cnt 1 File Cnt Dur (min)	Cnt 1 Inst/Det	Cnt 1 Count Date	Cnt 2 File Cnt Dur (min)	Cnt 2 Inst/Det	Cnt 2 Count Date	Cnt 3 File Cnt Dur (min)	Cnt 3 Inst/Det	Cnt 3 Count Date	Notes	
1705095-1	GS170513-2PS4							1705132-1 GS170513-2PS5						1705158-1 GS170513-2PS6			
1705177-1	GS170513-2PS7							1705177-2 GS170513-2PS8						1705177-2DUP GS170513-2PS9			
1705177-3	GS170513-2PS10							1705202-1 GS170513-2PS11						1705203-1 GS170513-2PS12			
1705240-1	GS170513-2PS13							1705242-1 GS170513-2PS14						1705243-1 GS170513-2PS15			
1705245-1	GS170513-2PS16							1705246-1 GS170513-2PS17						GS170513-2AMB GS170513-2PS18			
GS170513-2MB								GS170513-2LCS GS170513-2PS19									

## Reporting Units

LabID	TstGrpName	RptUnits
1705177-1	Gamma_NORM_Ra226_Peter	pCi/l
1705245-1	Gamma_NMED_FANP_low_2_1s	pCi/l
1705243-1	Gamma_NORM_Ra226_Peter	pCi/l
1705242-1	Gamma_NORM_Ra226_Peter	pCi/l
1705240-1	Gamma_NORM_Ra226_Peter	pCi/l
1705203-1	Gamma_NORM_Ra226_Peter	pCi/l
1705202-1	Gamma_NORM_Ra226_Peter	pCi/l
1705246-1	Gamma_NMED_FANP_low_2_1s	pCi/l
1705067-1	Gamma_NMED_FANP_low_2_1s	pCi/l
1705158-1	Gamma_NORM_Ra226_Peter	pCi/l
1705132-1	Gamma_NMED_FANP_low_2_1s	pCi/l
1705095-1	Gamma_NORM_Ra226_Peter	pCi/l
1705085-1	Gamma_NMED_FANP_low_2_1s	pCi/l
1705067-2	Gamma_NMED_FANP_low_2_1s	pCi/l
1705177-2	Gamma_NORM_Ra226_Peter	pCi/l
1705177-3	Gamma_NORM_Ra226_Peter	pCi/l

# Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: GS170513-2

Prep Procedure: **GAMMASCAN**

Reviewed By: *tdc* Review Date: 5/13/2017

Non-Routine Pre-Treatment?  Y  N Batch: *NA*

Re-Prep?  Y  N Batch: *NA* Prep QASS / NCR?  Y  N *NA*

Prep SOP: PAI 739 Rev: 12

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Tambræ Elhart

Prep Date: 5/13/2017

Prep Dept: GM

Balance:

Balance:

Sampl Num	Prep Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Geometry	Standards	Prep Notes
1	1	1705087-1	SMP	1000	1000	1000	Unfiltered	01		
2	1	1705087-2	SMP	1000	1000	1000	Unfiltered	01		
3	1	1705085-1	SMP	990	990	1000	Unfiltered	01		
4	1	1705095-1	SMP	1000	1000	940	Filtered	01		Diluted to 1000mL with DI water
5	1	1705132-1	SMP	940	940	1000	Unfiltered	01		
6	1	1705158-1	SMP	1000	1000	1000	Unfiltered	01		Diluted to 1000mL with DI water
7	1	1705177-1	SMP	1000	1000	1000	Filtered	01		
8	1	1705177-2	SMP	1000	1000	1000	Filtered	01		
9	1	1705177-2	DUP	1000	1000	1000	Filtered	01		
10	1	1705177-3	SMP	1000	1000	1000	Filtered	01		
11	1	1705202-1	SMP	1000	1000	1000	Filtered	01		
12	1	1705203-1	SMP	1000	1000	1000	Unfiltered	01		
13	1	1705240-1	SMP	1000	1000	1000	Unfiltered	01		
14	1	1705242-1	SMP	1000	1000	1000	Filtered	01		
15	1	1705243-1	SMP	1000	1000	1000	Filtered	01		
16	1	1705245-1	SMP	930	930	1000	Unfiltered	01		
17	1	1705246-1	SMP	940	940	1000	Unfiltered	01		
18	1	GS170513-2A	MB	1000	1000	1000	Unfiltered	01		Diluted to 1000mL with DI water
19	1	GS170513-2	MB	1000	1000	1000	Unfiltered	01		Diluted to 1000mL with DI water
20	1	GS170513-2	LCS	1000	1000	1000	Unfiltered	01	S1	

*19/5/17*

# Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: GS170513-2

Prep Procedure: **GAMMASCAN**

Reviewed By: tdc Review Date: 5/13/2017

Non-Routine Pre-Treatment?  Y  N Batch: NA

Prep QASS / NCR?  Y  N

Prep SOP: PAI 739 Rev: 12

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Tandrae Elhart

Prep Date: 5/13/2017

Prep Dept: GM

Balance:

Balance:

Sample Num	Prep Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Geometry	Standards	Prep Notes

Comments

Spiked By: N/A Date: N/A

Witnessed By: N/A Date: N/A

Spike Solution Information						
Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Pipet ID
S1	Am-241	999		221.090	DPM/ml	NA
S1	Co-60	999		92.721	DPM/ml	NA
S1	Cs-137	999		83.955	DPM/ml	NA

Sample Condition Form (Liquid)

Analyst: TE

Analysis Date: 5/13/17 Method: lep

		Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep)		
Work Order	Sample ID	pH	Color	Remarks
1705067	1	~2	clear	none
↓	2	↓	↓	↓
1705085	1	↓	↓	↓
1705095	1	~2	tan	oily, sediment
1705132	1	~2	clear	none
1705158	1	~2	↓	↓
1705177	1	~2	brown	light sediment, rotten egg smell
↓	2	~2	↓	↓
↓	3	↓	↓	↓
1705202	1	~2	brown	Sediment oily
1705203	1	~2	clear	none
1705240	1	~2	clear	none
1705242	1	~2	tan	light sediment
1705243	1	~2	brown	light sediment, oily
1705245	1	↓	clear	none
1705246	1	↓	↓	↓
				<del>TE 5/13/17</del>

## Section 8

# STANDARDS TRACEABILITY DOCUMENTS





**Eckert & Ziegler**  
Analytics

RSO #  
999

Received  
2/26/2014  
JP

1380 Seaboard Industrial Blvd.  
Atlanta, Georgia 30318  
Tel 404-352-8677  
Fax 404-352-2837  
www.analyticinc.com

**CERTIFICATE OF CALIBRATION**  
Standard Radionuclide Source

95548

1.0 Liter Solid in 138G GA-MA Beaker

**Customer:** ALS Laboratory Group  
**P.O. No.:** FC000236, Item 1 **Product Code** 8401-EG-SD  
**Reference Date:** 01-Jan-2014 12:00 PM EST **Grams of Master Source:** 0.011697

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solutions. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

Density of solid matrix 1.15 g/cc.

Nuclide	Gamma-Ray Energy (keV)	Half-Life, Days	Master Source* $\mu\text{ps}/\text{gram}$	This Source $\mu\text{ps}$	Uncertainty*, %			Calibration Method*
					$u_A$	$u_B$	U	
Am-241	59.5	1.580E+05	—	1.330E+03	0.1	1.6	3.2	4 $\pi$ LS
Cd-109	88.0	4.614E+02	1.627E+05	1.903E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	8.915E+04	1.043E+03	0.4	1.7	3.5	HPGe
Ce-139	165.9	1.376E+02	1.228E+05	1.436E+03	0.4	1.7	3.5	HPGe
Hg-203	279.2	4.689E+01	2.636E+05	3.083E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.736E+05	2.031E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.100E+05	1.287E+03	0.7	1.9	4.0	HPGe
Y-88	898.0	1.066E+02	4.166E+05	4.873E+03	0.5	1.7	3.5	HPGe
Co-60	1173.2	1.925E+03	2.055E+05	2.404E+03	0.6	1.8	3.8	HPGe
Co-60	1332.5	1.925E+03	2.057E+05	2.406E+03	0.7	1.8	3.9	HPGe
Y-88	1836.1	1.066E+02	4.410E+05	5.158E+03	0.7	1.7	3.7	HPGe

\* Master Source refers to Analytics' 8-isotope mixture which is calibrated quarterly.

**Calibration Methods:** 4 $\pi$  LS - 4  $\pi$  Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber. **Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

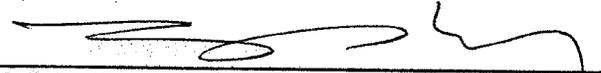
(Certificate continued on reverse side)

Std ReVerified  
3/2/17 JP  
New Exp Date  
=> 03/02/2018



This standard will expire one year after the reference date.

Source Prepared by:   
K. Eardley, Radiochemist

QA Approved:   
J.D. McCorvey, Counting Room Manager

Date: 24 Feb 14



## Section 9

# **ADDITIONAL SUPPORTING DOCUMENTATION**

## **Gamma Spectroscopy**

# **Initial Calibration Standards Traceability**

\*\*\*\*\*

SEEKER            G A M M A     A N A L Y S I S     R E S U L T S     PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

\*\*\*\*\*

Geo 1 / Water

Sample ID: 082216-1 FWHM CAL (1040)

```

-----
Sampling Start:   01/01/2016 10:00:00 | Counting Start:   08/22/2016 07:12:44
Sampling Stop:   01/01/2016 10:00:00 | Decay Time. . . . . 5.61E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 3600 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 3705 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 161017D01.SPC
-----
    
```

Detector #: 1 (Detector 1)

Energy(keV)= -1.99 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 08/22/2016

FWHM(keV) = 0.51 + 0.025\*En + 3.49E-04\*En^2 + 0.00E+00\*En^3 08/24/2015

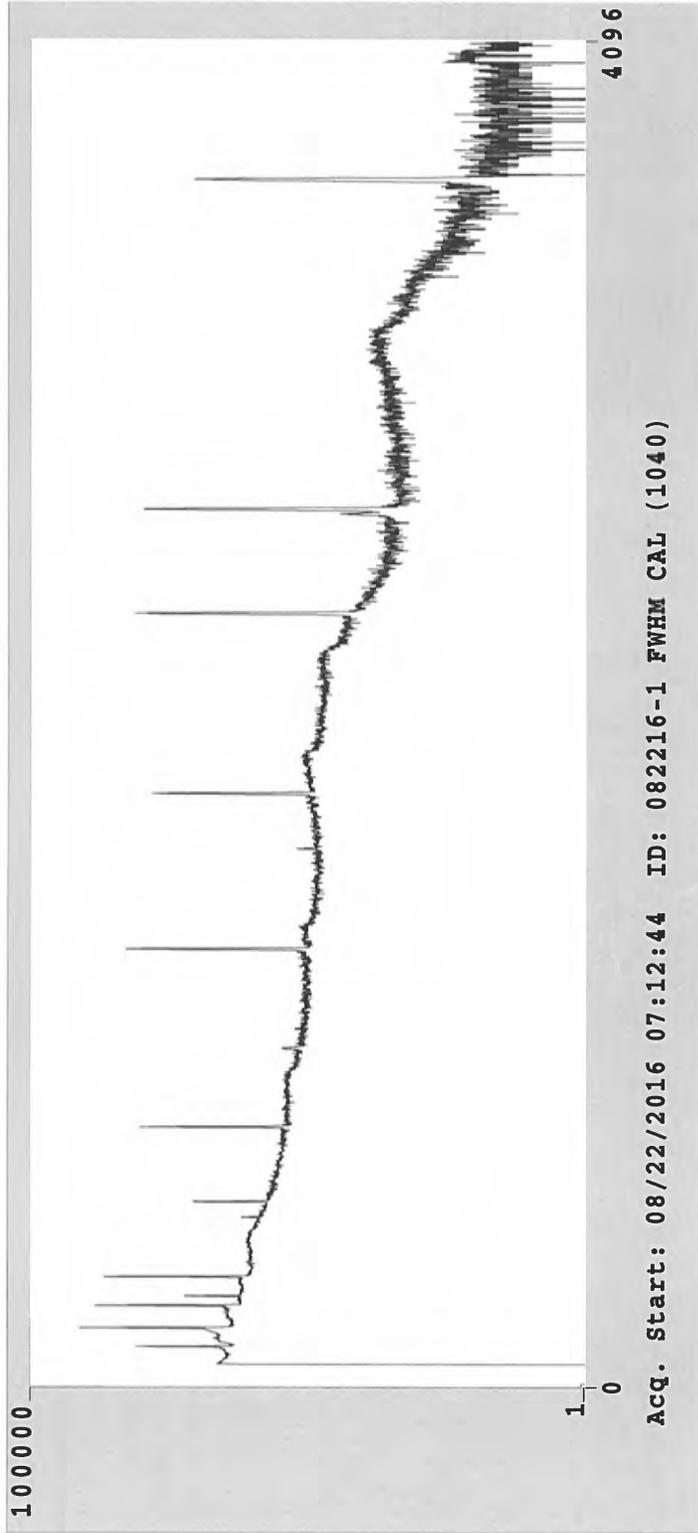
Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	59.44	122.68	16866	360	205	8512	0.78	a HiResid
2	72.63	149.03	313	275	224	10129	0.78	a
3	87.91	179.56	71779	606	233	10900	0.79	a Wide Pk
4	89.06	181.84	408	369	302	14452	1.26	b
5	91.92	187.56	273	130	103	2966	0.39	c
6	111.54	226.74	163	175	142	4971	0.41	a
7	122.04	247.71	48100	498	193	7542	0.85	a
8	136.44	276.47	6620	296	204	7662	0.91	a
9	165.81	335.14	39618	448	170	5820	0.90	a
10	255.15	513.57	877	187	146	4311	0.76	a
11	279.18	561.56	6686	249	154	4377	0.98	a
12	391.72	786.33	24603	360	145	3604	1.11	a
13	511.05	1024.67	914	270	217	5780	2.56	a Wide Pk
14	661.72	1325.61	41154	432	122	2736	1.36	a
15	814.04	1629.83	534	181	144	3057	1.92	a
16	898.14	1797.80	26780	362	127	2969	1.56	a
17	1173.34	2347.44	44457	436	90	1423	1.78	a HiResid
18	1325.26	2650.87	606	120	90	1132	3.28	a HiResid Wide Pk
19	1332.54	2665.41	40549	409	61	679	1.90	b HiResid
20	1836.03	3671.00	15774	254	31	166	2.27	a HiResid





#1040  
Rec'd  
2-25-16

**CERTIFICATE OF CALIBRATION**  
Standard Reference Source

SRS Number: 102366

Source Description: 1.0 Liter Solid in 138G GA-MA Beaker

Product Code: 8401-EG-SD

Customer: ALS Laboratory Group

P.O. Number: FC000928, Item 1

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Density of solid matrix: 1.17 g/cm<sup>3</sup> ± 3 %.

Reference Date: 01-January-2016 12:00 PM EST

**MGS Mixture**

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s <sup>-1</sup>	Uncertainty			Calibration Method**
					u <sub>A</sub> , %	u <sub>B</sub> , %	U, %*	
Am-241	59.5	1.580E+05	3.768E+03	1.353E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.156E+04	1.908E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.265E+03	1.083E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.831E+03	1.465E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.993E+03	3.257E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.181E+02	3.124E+03	2.030E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.531E+03	1.303E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.356E+03	5.018E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	_____	_____	5.313E+03	0.7	1.7	3.7	_____
Co-60	1173.2	1.925E+03	2.453E+03	2.450E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	_____	_____	2.453E+03	0.7	1.8	3.9	_____

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. \*Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." \*\*Calibration Methods: 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

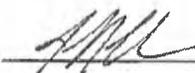
(Certificate continued on reverse side)

SRS Number: 102366

Expiration Date: 24-February-2017

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:   
A. Herron, Radiochemist

QC Approved by:  Date: 24-FEB-16  
J. Lahr, Spectroscopist

\*\*\*\*\*

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Geo.11 / Solid

Sample ID: 041817-8 FWHM CAL (1054)

```
-----
Sampling Start: 01/01/2017 10:00:00 | Counting Start: 04/18/2017 09:36:03
Sampling Stop: 01/01/2017 10:00:00 | Decay Time. . . . . 2.57E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1200 Sec
Sample Size . . . . . 1.00E+000 SAMPLE | Real Time . . . . . 1358 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170403D08.SPC
-----
```

Detector #: 8 (Detector 8)

Energy(keV) = -2.30 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 04/18/2017  
 FWHM(keV) = 0.65 + 0.010\*En + 6.94E-04\*En^2 + 0.00E+00\*En^3 04/18/2017  
 Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	41.81	88.00	0	328	270	10097	0.74	a NET< CL HiResid
2	43.50	91.38	421	436	357	14135	1.07	b HiResid
3	49.39	103.12	2156	385	307	17426	1.03	a
4	57.55	119.40	4721	745	602	40196	2.28	a HiResid Wide Pk
5	59.46	123.21	122041	757	240	11569	0.80	b HiResid
6	70.74	145.71	2823	371	293	15825	0.99	a
7	72.78	149.79	4356	338	256	13188	0.75	b
8	82.20	168.59	756	314	254	13047	0.84	a
9	87.98	180.11	135159	788	234	11009	0.78	a HiResid
10	121.97	247.93	65094	555	179	6465	0.83	a HiResid
11	136.39	276.70	8122	271	166	5558	0.85	a
12	165.81	335.40	58181	517	153	4688	0.89	a HiResid
13	199.06	401.74	-65	316	260	8813	1.72	a NET< CL Wide Pk
14	199.13	401.87	1683	213	161	4807	1.04	b
15	203.53	410.65	331	151	120	3205	0.66	c
16	255.12	513.57	1857	190	140	3606	0.99	a
17	268.62	540.51	108	104	84	1736	0.50	a
18	279.21	561.64	32069	394	136	3414	1.00	a HiResid

=====  
 PEAK SEARCH RESULTS  
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
19	391.77	786.22	38357	423	131	2937	1.13	a
20	427.44	857.39	73	102	83	1509	0.58	a NET< CL
21	510.90	1023.90	629	211	168	3986	2.16	a Wide Pk
22	512.65	1027.38	111	88	71	1227	0.62	b
23	628.14	1257.81	64	88	71	1236	0.68	a NET< CL
24	661.89	1325.14	29765	375	122	2742	1.37	a
25	687.85	1376.93	96	165	135	3158	1.41	a NET< CL
26	814.22	1629.06	758	134	100	1747	1.54	a
27	898.20	1796.62	40938	428	115	2445	1.57	a HiResid
28	912.17	1824.49	140	115	92	1852	1.09	a
29	1173.33	2345.52	32126	375	90	1441	1.79	a
30	1325.05	2648.22	788	129	95	1391	2.80	a HiResid
31	1332.47	2663.03	28731	350	73	982	1.92	b HiResid
32	1353.56	2705.11	63	77	62	768	1.58	a
33	1688.70	3373.76	71	76	61	637	2.24	a
34	1835.42	3666.49	23848	313	44	331	2.36	a HiResid
35	1850.26	3696.09	69	47	36	259	1.65	a

170403D08.SPC Analyzed by

\*\*\*\*\*  
 SEEKER                    C A L I B R A T I O N   R E S U L T S                    Version 2.0.4  
 \*\*\*\*\*

Sample ID: 041817-8 FWHM CAL (1054)

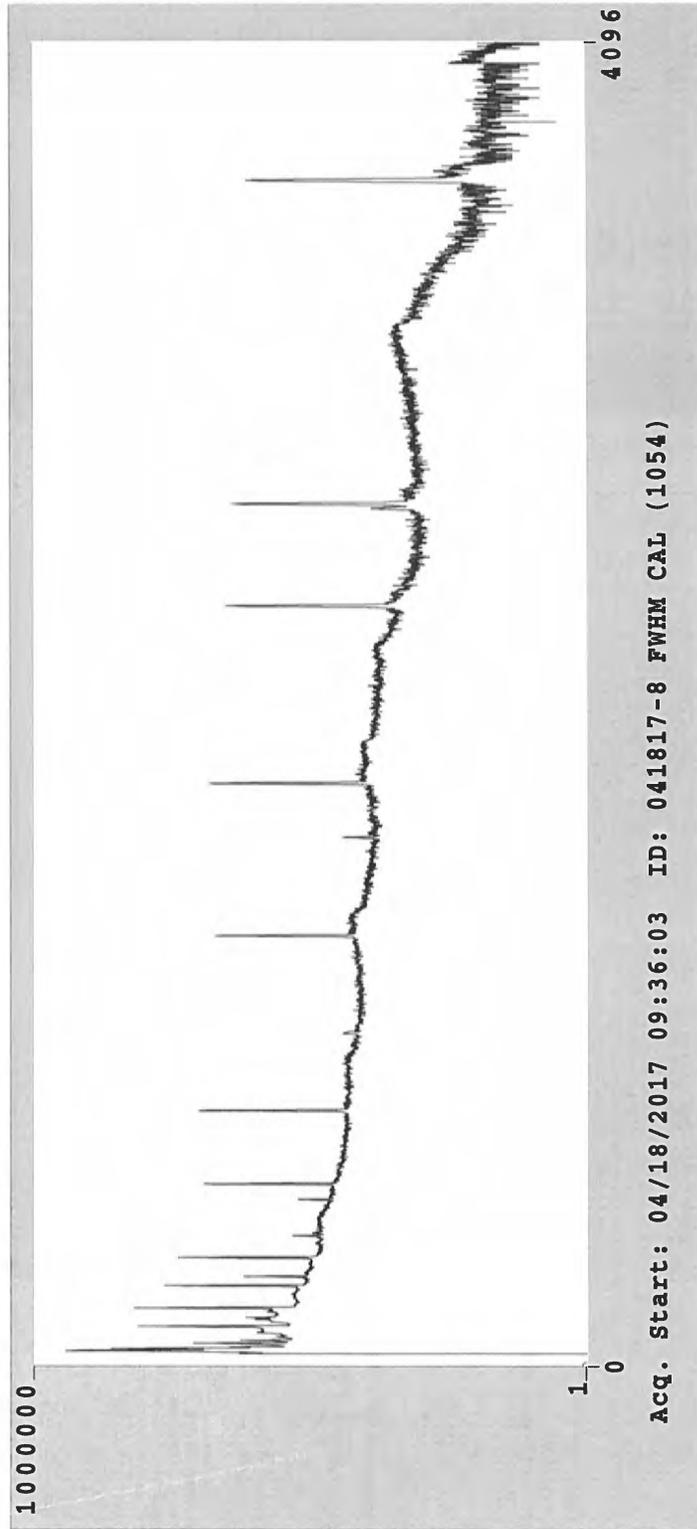
Stds. Match Tolerance: 2.00 keV

-----  
 Detector Number: 08                    Calibration Date. . . 04/18/2017 09:36:03  
 -----

FWHM(keV) = 0.66 + 0.008\*En + 7.24e-04\*En^2 + 0.00e+00\*En^3  
 (Where En = SQR(Energy in keV))  
 -----

Pk. #	Energy (keV)	Measured FWHM(keV)	% Diff.	Calculated FWHM(keV)	% Diff.	Prev.Calc. FWHM(keV)
1	59.50	0.797	-3.38	0.771	-0.88	0.764
2	88.04	0.782	2.82	0.805	-0.62	0.800
3	122.06	0.831	1.55	0.844	-0.40	0.840
4	165.85	0.891	-0.08	0.891	-0.20	0.889
5	279.00	0.997	0.80	1.005	0.09	1.005
6	391.68	1.128	-1.41	1.112	0.21	1.114
7	661.64	1.370	-0.94	1.357	0.27	1.361
8	898.02	1.567	-0.21	1.564	0.22	1.567
9	1173.21	1.788	0.56	1.799	0.11	1.801
10	1332.48	1.919	0.70	1.933	0.04	1.933
11	1836.01	2.359	-0.39	2.350	-0.18	2.346

Calibration Results Saved.



250 #  
1054  
Received  
3/1/2017

**CERTIFICATE OF CALIBRATION**  
Standard Reference Source

**SRS Number:** 105116A  
**Source Description:** Sand in 16 Ounce PP MRP Jar  
**Product Code:** 8401-EG-SAN  
**Customer:** ALS Laboratory Group  
**P.O. Number:** FC001290, Item 3

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

**Reference Date:** 01-January-2017 12:00 PM EST

**MGS Mixture**

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s <sup>-1</sup>	Uncertainty			Calibration Method**
					u <sub>A</sub> , %	u <sub>B</sub> , %	U, %*	
Am-241	59.5	1.580E+05	4.020E+03	1.443E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.131E+04	1.899E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.196E+03	1.024E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.810E+03	1.448E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.932E+03	3.207E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	3.137E+03	2.038E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.557E+03	1.325E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.199E+03	4.872E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	————	————	5.158E+03	0.7	1.7	3.7	————
Co-60	1173.2	1.925E+03	2.448E+03	2.444E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	————	————	2.447E+03	0.7	1.8	3.9	————

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. **\*Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." **\*\*Calibration Methods:** 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 105116A

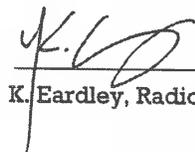
**Comments:**

~56 mL / 100.00 g of sand

Expiration Date: 27-February-2018

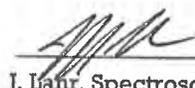
This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:



K. Eardley, Radiochemist

QC Approved by:



J. Lahr, Spectroscopist

Date: 26-FEB-17

\*\*\*\*\*  
 SEEKER            G A M M A    A N A L Y S I S    R E S U L T S    P S Version 1.8.4

ALS Laboratory Group - Fort Collins  
 GammaScan

\*\*\*\*\*

Geo.9 / CHARC. FLTR

Sample ID: 110416-9 FWHM Cal (1047)

```
-----
Sampling Start:   07/01/2016 10:00:00 | Counting Start:   11/04/2016 07:43:31
Sampling Stop:   07/01/2016 10:00:00 | Decay Time. . . . . 3.02E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00E+000 SAMPLE | Real Time . . . . . 2168 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 161086D09.SPC
-----
```

Detector #: 9 (Detector 9)

Energy(keV)= -2.18 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 11/04/2016  
 FWHM(keV) = 0.68 + 0.012\*En + 5.65E-04\*En^2 + 0.00E+00\*En^3 11/06/2015  
 Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	43.29	90.69	12949	744	583	57924	1.11	a HiResid
2	46.22	96.53	678	249	200	11098	0.40	b HiResid
3	49.66	103.40	1567	393	317	20222	0.88	c HiResid
4	59.44	122.90	160720	882	302	18372	0.86	a HiResid
5	66.64	137.27	6449	593	469	27118	2.04	a HiResid Wide Pk
6	70.64	145.23	5713	438	338	18079	1.35	b HiResid
7	72.52	149.00	4720	357	271	13559	1.05	c HiResid
8	80.32	164.56	0	202	166	6780	0.42	d NET< CL HiResid
9	82.10	168.11	311	290	237	11299	0.81	e HiResid
10	87.99	179.84	188844	941	297	17748	0.87	a HiResid
11	109.29	222.33	1703	347	277	11360	1.46	a HiResid Wide Pk
12	112.52	228.78	150	153	124	3787	0.44	b HiResid
13	121.97	247.63	80138	613	194	6943	0.93	a HiResid
14	136.37	276.35	10060	279	160	5164	0.88	a HiResid
15	143.62	290.81	432	219	177	5759	0.91	a
16	145.72	295.00	28	132	108	2880	0.46	b NET< CL
17	165.81	335.06	59837	531	170	5355	0.91	a HiResid
18	187.26	377.86	413	241	196	6068	1.29	a

=====  
 PEAK SEARCH RESULTS  
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
19	199.16	401.59	4906	254	174	5160	1.13	a
20	203.82	410.88	1118	222	174	5160	1.12	b
21	255.14	513.24	1715	199	149	3764	1.10	a
22	279.22	561.27	28091	380	147	3677	1.12	a HiResid
23	300.30	603.31	232	221	180	4488	1.71	a
24	310.83	624.32	104	87	69	1187	0.54	a
25	372.25	746.83	68	133	108	2163	0.93	a NET< CL
26	374.86	752.03	160	166	135	2884	1.32	b
27	391.80	785.83	37692	430	151	3621	1.24	a HiResid
28	413.13	828.38	-0	125	103	2118	0.81	a NET< CL
29	413.57	829.25	316	181	146	3389	1.34	b
30	510.34	1022.26	85	88	71	1247	0.62	a Wide Pk
31	511.31	1024.20	371	222	180	4363	2.30	b
32	524.34	1050.19	105	164	134	2958	1.66	a NET< CL
33	538.09	1077.62	86	123	100	1977	1.14	a NET< CL
34	661.93	1324.64	30460	389	142	3509	1.50	a HiResid
35	682.56	1365.79	235	205	167	4323	1.87	a
36	683.84	1368.34	91	99	80	1572	0.69	b
37	814.23	1628.41	596	135	103	1855	1.54	a
38	898.26	1796.02	33553	401	134	3307	1.63	a HiResid
39	912.35	1824.12	1424	189	142	3557	1.87	a
40	1173.41	2344.82	30487	374	110	2042	1.92	a HiResid
41	1194.92	2387.73	307	146	116	1998	2.53	a
42	1325.17	2647.52	696	126	94	1303	2.91	a HiResid Wide Pk
43	1332.53	2662.21	26932	346	91	1459	2.05	b HiResid
44	1354.24	2705.51	260	126	100	1540	2.85	a
45	1576.96	3149.75	90	114	93	1461	2.28	a NET< CL
46	1835.51	3665.46	18147	287	81	1065	2.40	a HiResid
47	1849.83	3694.01	932	102	67	694	2.85	a Wide Pk
48	1856.46	3707.24	257	113	89	980	3.92	b

161086D09.SPC Analyzed by

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 SEEKER                    C A L I B R A T I O N   R E S U L T S                    Version 2.0.4  
 \*\*\*\*\*

Sample ID: 110416-9 FWHM Cal (1047)  
 Stds. Match Tolerance: 2.00 keV

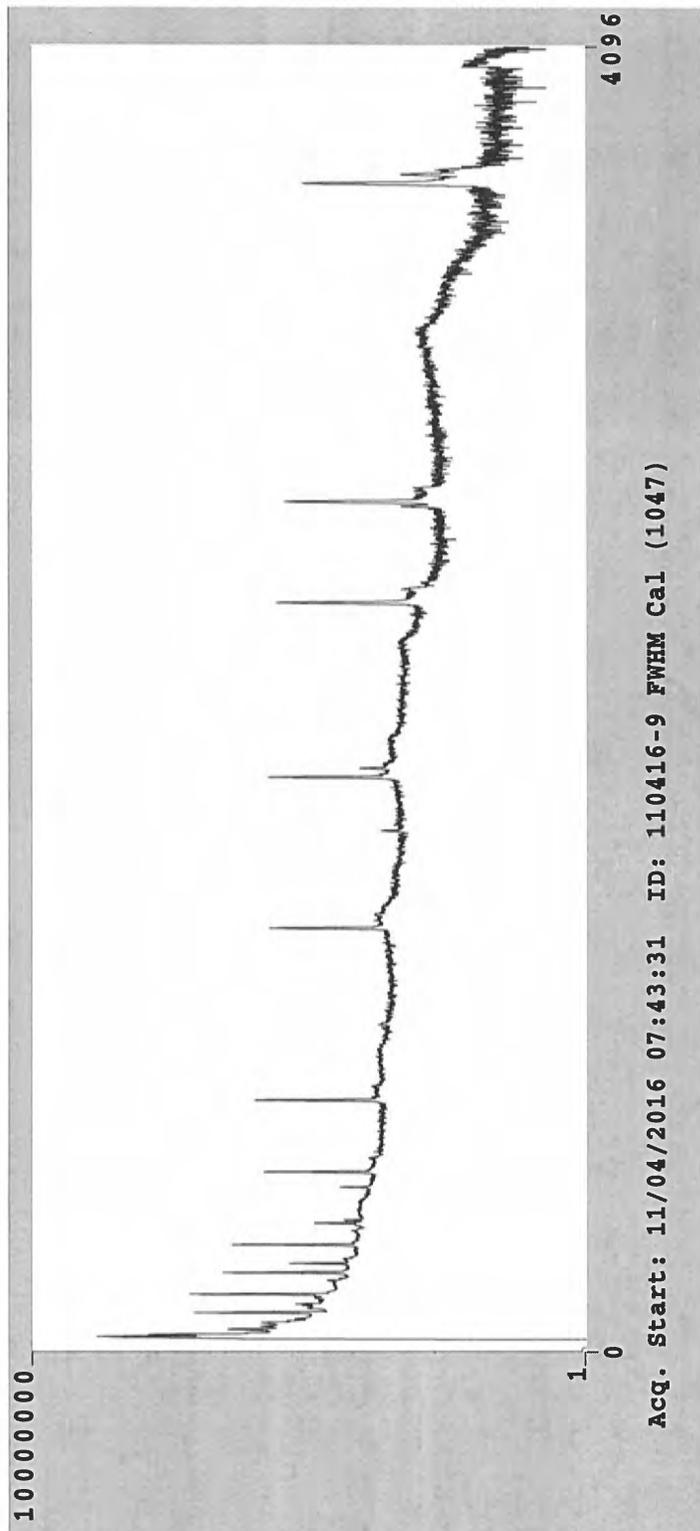
-----  
 Detector Number: 09                    Calibration Date. . . 11/04/2016 07:43:31  
 -----

FWHM(keV) = 0.66 + 0.018\*En + 5.48e-04\*En^2 + 0.00e+00\*En^3  
 (Where En = SQR(Energy in keV))  
 -----

Pk. #	Energy (keV)	Measured FWHM(keV)	% Diff.	Calculated FWHM(keV)	% Diff.	Prev.Calc. FWHM(keV)
1	59.50	0.856	-3.11	0.830	-2.61	0.809
2	88.04	0.872	0.24	0.875	-3.49	0.845
3	122.06	0.931	-0.98	0.922	-4.27	0.885
4	165.85	0.915	6.48	0.978	-5.01	0.932
5	279.00	1.119	-1.03	1.107	-6.24	1.042
6	391.68	1.241	-1.49	1.223	-6.95	1.144
7	661.64	1.499	-1.67	1.475	-7.76	1.368
8	898.02	1.626	3.14	1.678	-8.02	1.554
9	1173.21	1.923	-1.01	1.904	-8.09	1.762
10	1332.48	2.054	-1.17	2.031	-8.07	1.879
11	1836.01	2.404	0.57	2.418	-7.88	2.241

Calibration Results Saved.

*OK DP 11/4/16*



RSO  
# 1047  
Rec'd 8/18/16

**CERTIFICATE OF CALIBRATION**  
Standard Reference Source

SRS Number: 103836

Source Description: Face Loaded Yellow Plastic Hi-Q Charcoal Cartridge

Product Code: 8401-EG-CH

Customer: ALS Laboratory Group

P.O. Number: FC001106, Item 2

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Reference Date: 01-July-2016      12:00 PM EST

**MGS Mixture**

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s <sup>-1</sup>	Uncertainty			Calibration Method**
					u <sub>A</sub> , %	u <sub>B</sub> , %	U, %*	
Am-241	59.5	1.580E+05	1.873E+03	6.726E+02	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	2.593E+04	9.596E+02	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	6.076E+02	5.201E+02	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	9.068E+02	7.254E+02	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	2.002E+03	1.633E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.575E+03	1.023E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	7.742E+02	6.588E+02	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	2.619E+03	2.454E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	-----	-----	2.598E+03	0.7	1.7	3.7	-----
Co-60	1173.2	1.925E+03	1.225E+03	1.223E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	-----	-----	1.225E+03	0.7	1.8	3.9	-----

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. \*Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." \*\*Calibration Methods: 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 103836

**Comments:**

Active material deposited on first 5 mm

Expiration Date: 16-August-2017

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:   
Z. Dimitrova, Radiochemist

QC Approved by:  Date: 15-AUG-16  
J. Lahr, Spectroscopist

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SEEKER            G A M M A     A N A L Y S I S     R E S U L T S     P S Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: 082216-1 GEO1 EFF CAL (1040)

```
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Sampling Start:   01/01/2016 10:00:00 | Counting Start:   08/22/2016 07:12:44
Sampling Stop:    01/01/2016 10:00:00 | Decay Time. . . . . 5.61E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 3600 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 3705 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . .161017D01.SPC
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```

Detector #: 1 (Detector 1)

Energy(keV)= -1.99 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 08/22/2016

FWHM(keV) = 0.71 + -0.000\*En + 1.20E-03\*En^2 +-8.09E-06\*En^3 08/22/2016

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	59.44	122.68	16866	360	205	8512	0.78	a HiResid
2	72.63	149.02	313	275	224	10129	0.78	a
3	87.91	179.56	71963	606	232	10834	0.80	a
4	122.04	247.71	48100	498	193	7542	0.85	a
5	136.44	276.47	6620	296	204	7662	0.91	a
6	165.81	335.14	39618	448	170	5820	0.90	a
7	255.15	513.57	877	187	146	4311	0.76	a
<i>A</i> 8	279.18	561.56	6686	249	154	4377	0.98	a
9	391.72	786.33	24603	360	145	3604	1.11	a
10	511.05	1024.67	914	270	217	5780	2.56	a Wide Pk
11	661.72	1325.61	41154	432	122	2736	1.36	a
12	814.04	1629.83	534	181	144	3057	1.92	a
13	898.14	1797.80	26780	362	127	2969	1.56	a
14	1173.34	2347.44	44457	436	90	1423	1.78	a HiResid
15	1325.26	2650.87	606	120	90	1132	3.28	a HiResid Wide Pk
16	1332.54	2665.41	40549	409	61	679	1.90	b HiResid
17	1836.03	3671.00	15774	254	31	166	2.27	a HiResid

*A 10,000 cts not met due to more than 5 half lives exp.*

161017D01.SPC Analyzed by

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SEEKER BACKGROUND SUBTRACT RESULTS Version 1.8.2

ALS Laboratory Group - Fort Collins

GammaScan

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Background File: . . . . . DET010818.BKG (081816-1 WEEKLY BKG)

Bkg.File Detector #: 1

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
7	255.15	877	187	146	874	188	146	
10	511.05	914	270	217	837	271	217	

\*\*\*\*\*  
 SEEKER                      C A L I B R A T I O N   R E S U L T S                      Version 2.0.4  
 \*\*\*\*\*

Sample ID: 082216-1 GEO1 EFF CAL (1040)  
 Stds. Match Tolerance: 2.00 keV

-----  
 Detector Number: 01                      Calibration Date. . . 08/22/2016 07:12:44  
 Geometry File (D01)(Sh01).EFF ID. Geo 1 Eff Cal  
 Amount of Std. in Calib. Source: 1.000000 gm

-----  
 Crossover: 300.00 keV

Below Crossover Efficiency Fit:

Eff = 10 ^ [-7.58e+01 + 9.57e+01\*En +-4.10e+01\*En^2 + 5.81e+00\*En^3]  
 (Where En = LOG(Energy in keV)) (Polynomial)

Above Knee Efficiency Fit:

Eff = 10 ^ [ 2.34e+00 +-2.89e+00\*En + 6.89e-01\*En^2 +-7.66e-02\*En^3]  
 (Where En = LOG(Energy in keV)) (Polynomial)

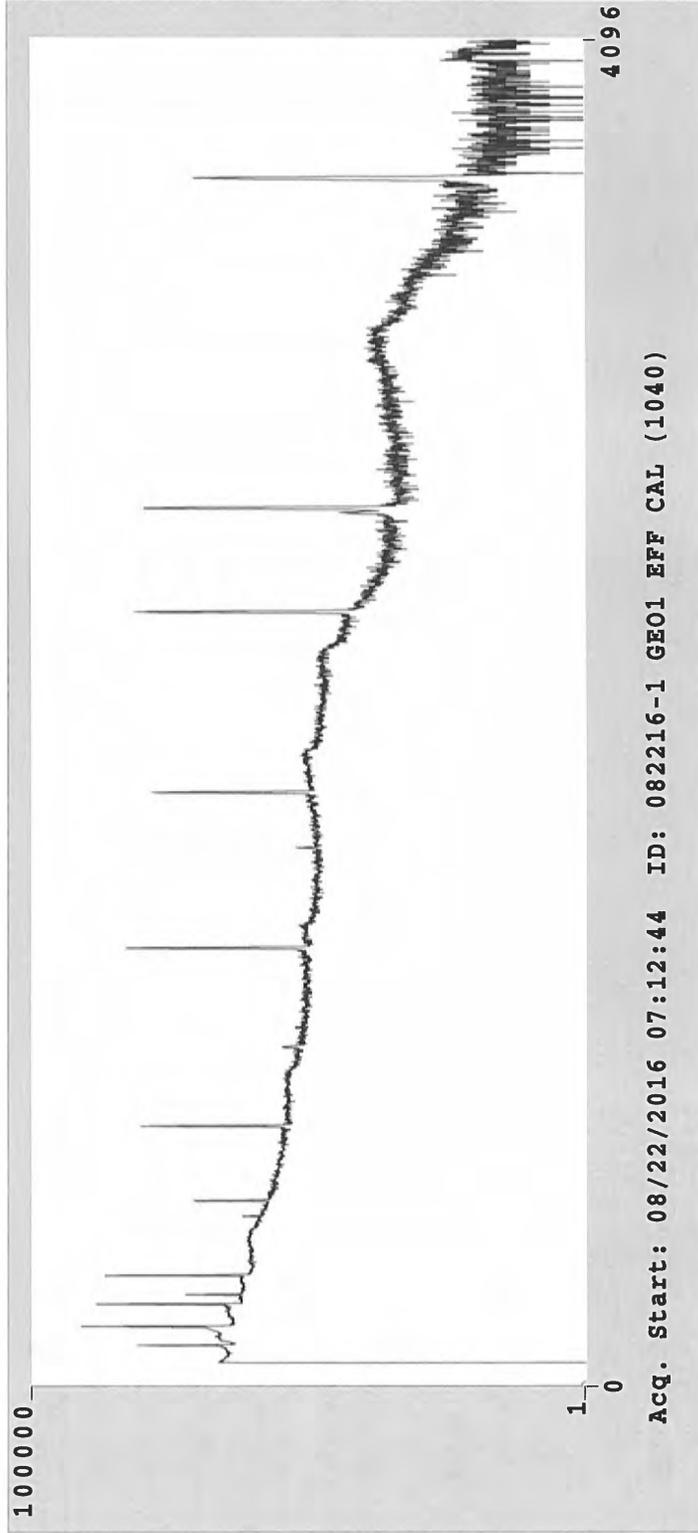
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Pk. #	Energy (keV)	Measured Efficiency	% Difference	Calculated Efficiency	% Difference	Prev.Calc. Efficiency
1	59.50	3.47e-03	0.40	3.48e-03	2.76	3.58e-03
2	88.04	1.49e-02	-1.91	1.46e-02	-6.86	1.37e-02
3	122.06	2.24e-02	2.93	2.31e-02	1.79	2.35e-02
4	165.85	2.44e-02	-1.72	2.40e-02	0.15	2.40e-02
5	279.00	1.85e-02	0.23	1.85e-02	-7.41	1.72e-02
6	391.68	1.38e-02	0.11	1.38e-02	-3.93	1.33e-02
7	661.64	8.90e-03	-0.76	8.84e-03	-0.71	8.77e-03
8	898.02	6.78e-03	1.14	6.86e-03	0.54	6.89e-03
9	1173.21	5.48e-03	0.24	5.50e-03	1.54	5.58e-03
10	1332.48	5.00e-03	-1.00	4.95e-03	2.03	5.05e-03
11	1836.01	3.77e-03	0.26	3.78e-03	3.48	3.92e-03

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Calibration Results Saved.

*OK JM elzdk*



**Gamma Efficiency Calibration - Crossover energy efficiency difference**

Calibration 8/22/2016  
 Detector 1  
 Geometry 1  
 Crossover energy=300 keV

	<u>EFF @ CROSSOVER</u>	<u>% DIFF*</u>	<u>MEETS ALS ACCEPTANCE CRITERIA?</u>
LOWER EFFICIENCY CURVE	0.018043	3.63%	OK
UPPER EFFICIENCY CURVE	0.017411	-3.51%	OK

\*When a single calibration curve does not meet ALS acceptance criteria, a split-fit efficiency calibration may be employed. This entails the use of two separate energy range calibrations, a low energy efficiency curve and a high energy efficiency curve. A crossover energy must be specified that marks where the software will use either the low energy efficiency curve or the high energy efficiency curve. It should be noted that if a nuclide is specified that has a gamma photon energy that is equal to **OR** within 15 keV of the crossover energy, the potential exists for the calculated efficiencies at the crossover energy to be significantly different than the true detection efficiency of the detector. At times by as much as 20%. This is an artifact of the non-equivalency of the calibration equations specified for each energy range. This may result in an effective high or low bias to the analytical results. This bias is reflected in the above calculated % difference. ALS Environmental Fort Collins will not accept any calibration with an effective % difference of greater than 5% without supervisory approval. Results are submitted without further qualification.

**Efficiency equations**

**Polynomial**  $10^{(A+B*(LOG(En))+C*(LOG(En))^2+D*(LOG(En))^3)}$   
 A -7.577468E+01  
 B 9.574310E+01  
 C -4.098912E+01  
 D 5.814385E+00  
 Calculated efficiency 0.018043

En is energy in keV  
 Crossover energy 300

**Polynomial**  $10^{(A+B*(LOG(En))+C*(LOG(En))^2+D*(LOG(En))^3)}$   
 A 2.344397E+00  
 B -2.893446E+00  
 C 6.890168E-01  
 D -7.658324E-02  
 Calculated efficiency 0.017411

En is energy in keV  
 Crossover energy 300

*OK JP etzolk*

Standards File. . . . . Gsstd01.std  
 Assay Date . . . . . 01/01/2016 10:00  
 ID.: Geo 1 Std#1040 1 L Mari. Mixed Gamma

Pk #	Nuclide	Energy	Halflife	Br.Ratio	dps/gm
1	Am-241	59.50	4.322E+02 yrs	0.35900	3768.80
2	Cd-109	88.04	4.626E+02 dys	0.03700	51567.57
3	Co-57	122.06	2.718E+02 dys	0.85510	1266.52
4	Ce-139	165.85	1.376E+02 dys	0.80350	1823.27
5	Hg-203	279.00	4.660E+01 dys	0.77300	4213.45
6	Sn-113	391.68	1.151E+02 dys	0.64900	3127.89
7	Cs-137	661.64	3.017E+01 yrs	0.85120	1530.78
8	Y-88	898.02	1.066E+02 dys	0.93400	5372.59
9	Co-60	1173.21	5.271E+00 yrs	0.99980	2450.49
10	Co-60	1332.48	5.271E+00 yrs	0.99990	2453.25
11	Y-88	1836.01	1.066E+02 dys	0.99380	5346.15



#1040  
Rec'd  
2-25-16

**CERTIFICATE OF CALIBRATION**  
Standard Reference Source

SRS Number: 102366  
Source Description: 1.0 Liter Solid in 138G GA-MA Beaker  
Product Code: 8401-EG-SD  
Customer: ALS Laboratory Group  
P.O. Number: FC000928, Item 1

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytix (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Density of solid matrix: 1.17 g/cm<sup>3</sup> ± 3 %.

Reference Date: 01-January-2016 12:00 PM EST

**MGS Mixture**

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s <sup>-1</sup>	Uncertainty			Calibration Method**
					u <sub>A</sub> , %	u <sub>B</sub> , %	U, %*	
Am-241	59.5	1.580E+05	3.768E+03	1.353E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.156E+04	1.908E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.265E+03	1.083E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.831E+03	1.465E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.993E+03	3.257E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	3.124E+03	2.030E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.531E+03	1.303E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.356E+03	5.018E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	_____	_____	5.313E+03	0.7	1.7	3.7	_____
Co-60	1173.2	1.925E+03	2.453E+03	2.450E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	_____	_____	2.453E+03	0.7	1.8	3.9	_____

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. \*Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." \*\*Calibration Methods: 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 102366

Expiration Date: 24-February-2017

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:   
A. Herron, Radiochemist

QC Approved by:  Date: 24-FEB-16  
J. Lahr, Spectroscopist

**Geometry 1 Calibration Verification: Gamma Mixed Nuclide Source**  
 1-Liter Water/Liquid Geometry  
 Detector 1

FROM CALIBRATION CERTIFICATE				FROM ANALYTICAL LIB		EXPECTED ACTIVITY				# of Half Lives Expired	
Isotope	KeV	Half Life(y)	Gammas/Sec.	Gamma Fraction:	Mass of Standard	DPS	pCi/L	Activity	Recovery		Pass/Fail
Am-241	59.5	432.0000	1330	0.3590	1	3704.7	100128.0	101000	101%	Pass	0.01
Cd-109	88	1.2666	1903	0.0372	L	51155.9	1382592.3	1410000	102%	Pass	2.08
Co-57	122	0.7441	1043	0.8551		1219.7	32966.0	33500	102%	Pass	3.55
Ce-139	166	0.3768	1436	0.8035		1787.2	48302.2	46400	96%	Pass	7.00
Hg-203	279	0.1276	3083	0.7730		3988.4	107793.4	NC	>5 h-lives	>5 h-lives	20.69
Sn-113	392	0.3151	2031	0.6490		3129.4	84579.2	NC	>5 h-lives	>5 h-lives	8.38
Cs-137	662	30.0700	1287	0.8512		1512.0	40864.4	42200	103%	Pass	0.09
Y-88	898	0.2919	4873	0.9340		5217.3	141009.3	NC	>5 h-lives	>5 h-lives	9.04
Co-60	1173	5.2714	2404	0.9998		2404.5	64986.0	64200	99%	Pass	0.50
Co-60	1332	5.2714	2406	0.9999		2406.2	65033.5	65200	100%	Pass	0.50
Y-88	1836	0.2919	5158	0.9938		5190.2	140275.1	NC	>5 h-lives	>5 h-lives	9.04

Count Date: 8/22/2016

REF DATE : 1/1/2014

999

NC=NOT CALCULATED DUE TO ACTIVITY<MDCa

*OK JP 8/26/16*

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SEEKER            G A M M A     A N A L Y S I S     R E S U L T S     P S Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: 082216-1A GEO1 CAL VER (999)

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-----
Sampling Start:   01/01/2014 10:00:00 | Counting Start:   08/22/2016 08:51:43
Sampling Stop:   01/01/2014 10:00:00 | Decay Time. . . . . 2.31E+004 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 1842 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 161018D01.SPC
-----
```

Detector #: 1 (Detector 1)

Energy(keV)= -1.99 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 08/22/2016  
FWHM(keV) = 0.71 + -0.000\*En + 1.20E-03\*En^2 +-8.09E-06\*En^3 08/22/2016  
Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	58.21	120.24	326	191	154	3764	1.27	a Wide Pk
2	59.44	122.68	8438	221	101	2057	0.74	b
3	87.90	179.53	12059	250	98	1939	0.80	a
4	122.04	247.72	3735	158	83	1383	0.83	a
5	124.19	252.02	73	102	83	1383	0.86	b NET< CL
6	136.45	276.50	412	83	59	868	0.52	a
7	165.80	335.11	465	95	70	1083	0.73	a
8	344.53	692.09	61	78	63	803	0.88	a NET< CL
9	391.75	786.39	68	57	45	497	0.56	a
10	400.49	803.85	59	54	43	445	0.57	a
11	510.57	1023.71	66	79	63	788	1.11	a
12	661.72	1325.61	19896	291	58	614	1.35	a
13	772.49	1546.83	49	80	64	683	1.70	a NET< CL
14	800.95	1603.67	13	51	42	394	0.74	a NET< CL
15	807.54	1616.84	32	59	47	473	0.98	b NET< CL
16	1044.32	2089.75	14	136	112	1532	3.20	a NET< CL Wide Pk
17	1058.55	2118.18	65	65	52	554	1.37	a
18	1173.36	2347.47	16617	264	48	397	1.76	a
19	1332.56	2665.44	15186	248	21	85	1.87	a HiResid
20	1835.85	3670.65	57	18	8	14	1.82	a

161018D01.SPC Analyzed by

\*\*\*\*\*

SEEKER            B A C K G R O U N D    S U B T R A C T   R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Background File: . . . . . DET010818.BKG (081816-1 WEEKLY BKG)

Bkg.File Detector #: 1

=====

BACKGROUND SUBTRACT RESULTS

=====

PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
11	510.57	66	79	63	28	79	64	NET<CL
14	800.95	13	51	42	10	51	42	NET<CL

\*\*\*\*\*

SEEKER                      F I N A L   A C T I V I T Y   R E P O R T                      Version 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Geo 1 / Water

Sample ID: 082216-1A GEO1 CAL VER (999)

```

-----
Sampling Start: 01/01/2014 10:00:00 | Counting Start: 08/22/2016 08:51:43
Sampling Stop: 01/01/2014 10:00:00 | Decay Time. . . . . 2.31e+004 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 1842 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 161018D01.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
-----
    
```

Detector #: 1 (Detector 1)

Efficiency File: (D01)(Sh01).EFF (Geo 1 Eff Cal)

Eff=10^[-7.58E+01 +9.57E+01\*L +-4.10E+01\*L^2 +5.81E+00\*L^3] 08/22/2016  
 Eff.=10^[2.34E+00 +-2.89E+00\*L +6.89E-01\*L^2 +-7.66E-02\*L^3] Above 300.00 keV

Library File: . . . .ANALYTICAL.LIB (Analytical)

MEASURED or MDA CONCENTRATIONS

Nuclide	ENERGY E (keV)	N T	Concentration (pCi/L)	MDA	Critical Level	Half-life (hrs)
Am-241	59.54	1.01E+05	+ - 2.66E+03	2.46E+03	1.21E+03	3.79E+06
Cd-109	88.02	1.41E+06	+ - 2.92E+04	2.32E+04	1.14E+04	1.11E+04
Co-57	122.07	3.35E+04	+ - 1.42E+03	1.51E+03	7.42E+02	6.50E+03
Ce-139	165.85	4.64E+04	+ - 9.51E+03	1.42E+04	6.98E+03	3.30E+03
Cs-137	661.62	4.22E+04	+ - 6.16E+02	2.50E+02	1.22E+02	2.64E+05
Co-60	Average:x	6.47E+04	+ - 7.37E+02	. . . .	. . . .	4.62E+04
	1173.21	6.42E+04	+ - 1.02E+03	3.78E+02	1.84E+02	4.62E+04
	1332.48	6.52E+04	+ - 1.06E+03	1.92E+02	9.04E+01	4.62E+04
Hg-203	279.18	MDA	. . . .	2.88E+08	1.42E+08	1.12E+03
Sn-113	391.68	MDA	. . . .	6.07E+04r	2.96E+04	2.76E+03
Y-88	898.02	MDA	. . . .	1.81E+05	8.91E+04	2.56E+03

MEASURED TOTAL: 1.70E+06 +- 4.41E+04 pCi/L

UNKNOWN, SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	58.21	120.24	326	191	154	3764	1.27	Unknown

161018D01.SPC Analyzed by

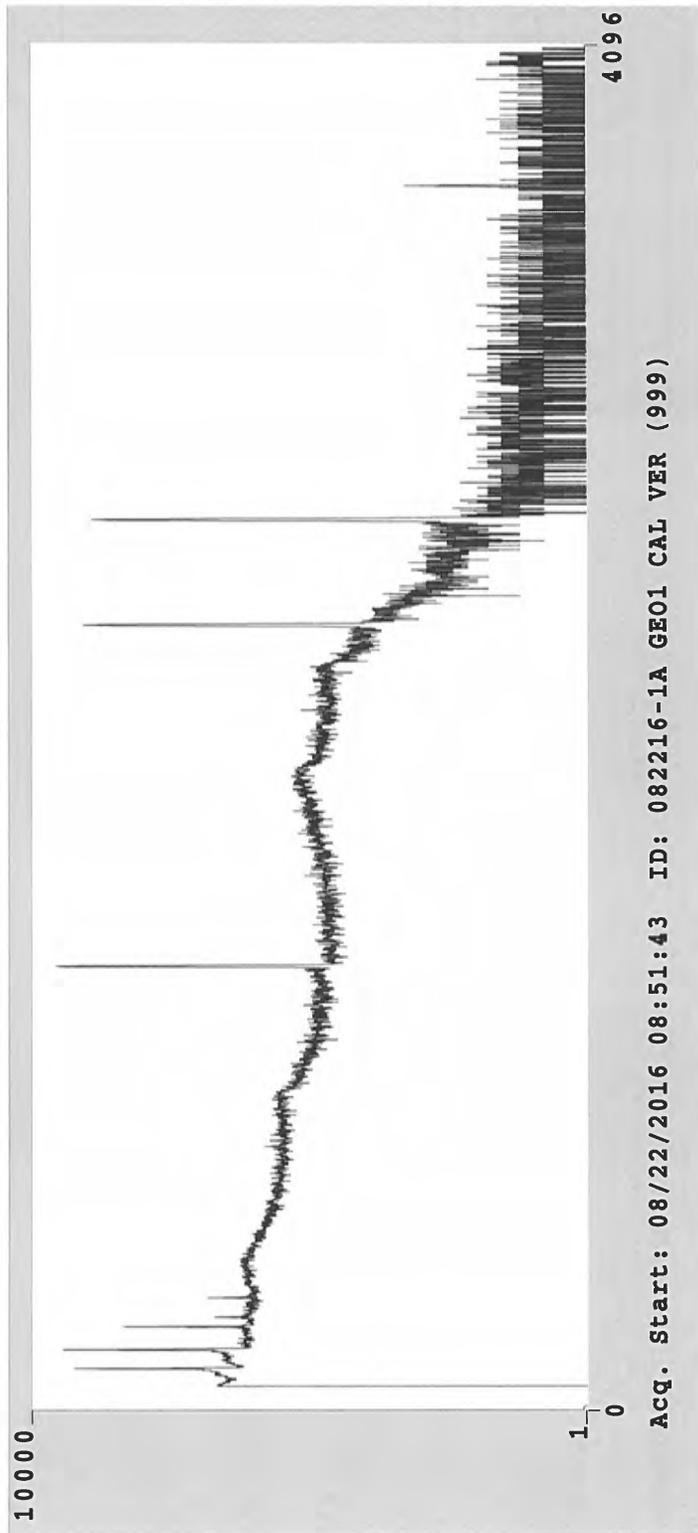
=====

UNKNOWN,SUM or ESCAPE PEAKS

=====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
5	124.19	252.02	73	102	83	1383	0.86	Deleted
6	136.45	276.50	412	83	59	868	0.52	Unknown
8	344.53	692.09	61	78	63	803	0.88	Deleted
9	391.75	786.39	68	57	45	497	0.56	Unknown
10	400.49	803.85	59	54	43	445	0.57	Unknown
11	510.57	1023.71	28	79	64	788	1.11	Deleted
13	772.49	1546.83	49	80	64	683	1.70	Deleted
14	800.95	1603.67	10	51	42	394	0.74	Deleted
15	807.54	1616.84	32	59	47	473	0.98	Deleted
16	1044.32	2089.75	14	136	112	1532	3.20	Deleted
17	1058.55	2118.18	65	65	52	554	1.37	Unknown
20	1835.85	3670.65	57	18	8	14	1.82	Unknown

c:\SEEKER\BIN\161018d01.res Analysis Results Saved.





**Eckert & Ziegler**  
Analytics

RSO #  
999

Received  
2/26/2014  
JP

1380 Seaboard Industrial Blvd.  
Atlanta, Georgia 30318  
Tel 404-352-8677  
Fax 404-352-2837  
www.analyticinc.com

**CERTIFICATE OF CALIBRATION**  
Standard Radionuclide Source

95548

1.0 Liter Solid in 138G GA-MA Beaker

**Customer:** ALS Laboratory Group  
**P.O. No.:** FC000236, Item 1 **Product Code** 8401-EG-SD  
**Reference Date:** 01-Jan-2014 **12:00 PM EST Grams of Master Source:** 0.011697

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solutions. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

Density of solid matrix 1.15 g/cc.

Nuclide	Gamma-Ray Energy (keV)	Half-Life, Days	Master Source* yps/gram	This Source yps	Uncertainty*, %			Calibration Method*
					u <sub>A</sub>	u <sub>B</sub>	U	
Am-241	59.5	1.580E+05	—	1.330E+03	0.1	1.6	3.2	4π LS
Cd-109	88.0	4.614E+02	1.627E+05	1.903E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	8.915E+04	1.043E+03	0.4	1.7	3.5	HPGe
Ce-139	165.9	1.376E+02	1.228E+05	1.436E+03	0.4	1.7	3.5	HPGe
Hg-203	279.2	4.659E+01	2.636E+05	3.083E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.736E+05	2.031E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.100E+05	1.287E+03	0.7	1.9	4.0	HPGe
Y-88	898.0	1.066E+02	4.166E+05	4.873E+03	0.5	1.7	3.5	HPGe
Co-60	1173.2	1.925E+03	2.055E+05	2.404E+03	0.6	1.8	3.8	HPGe
Co-60	1332.5	1.925E+03	2.057E+05	2.406E+03	0.7	1.8	3.9	HPGe
Y-88	1836.1	1.066E+02	4.410E+05	5.158E+03	0.7	1.7	3.7	HPGe

\* Master Source refers to Analytics' 8-isotope mixture which is calibrated quarterly.

Calibration Methods: 4π LS - 4 pi Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber. Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

(Certificate continued on reverse side)

Standard Re-Verified  
3/7/16.

New Expiration  
Date => 03/07/2017.

JP3/18/k



MGS Certificate Rev 5, 1 October 2013

Corporate Office

24937 Avenue Tibbitts Valencia, California 91355

Laboratory

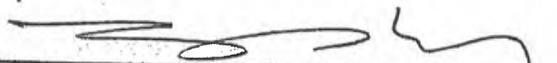
1380 Seaboard Industrial Blvd. Atlanta, Georgia 30318

Page 1 of 2

10 27  
10 11

This standard will expire one year after the reference date.

Source Prepared by:   
K. Eardley, Radiochemist

QA Approved:   
J.D. McCorvey, Counting Room Manager

Date: 24 Feb 14



\*\*\*\*\*

SEEKER            G A M M A     A N A L Y S I S     R E S U L T S     PS Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: 031517-8 GEO1 EFF CAL (1056)

```
-----
Sampling Start:   01/01/2017 10:00:00 | Counting Start:   03/15/2017 09:18:29
Sampling Stop:   01/01/2017 10:00:00 | Decay Time. . . . . 1.75E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1200 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 1310 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170288D08.SPC
-----
```

Detector #: 8 (Detector 8)

Energy(keV) = -2.41 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 03/15/2017

FWHM(keV) = 0.57 + 0.015\*En + 6.11E-04\*En^2 + 0.00E+00\*En^3 02/01/2017

Where En = Sqrt(Energy in keV)

-----  
Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000  
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=====

PEAK SEARCH RESULTS

=====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	49.46	103.50	3195	541	435	26258	1.65	a Wide Pk
2	59.41	123.35	62224	570	227	11438	0.73	a
3	70.71	145.91	2555	358	283	14774	0.93	a
4	72.75	149.97	3714	284	211	9849	0.69	b
5	82.49	169.40	1837	368	294	14759	1.08	a HiResid Wide Pk
6	85.00	174.42	3005	623	504	28164	2.23	b HiResid
7	87.95	180.30	85035	633	203	8319	0.83	c HiResid
8	88.57	181.53	0	548	451	22564	2.30	d NET< CL HiResid
9	121.96	248.16	39677	452	175	6172	0.81	a HiResid
10	136.35	276.89	4514	218	141	4399	0.73	a HiResid
11	165.80	335.64	41397	445	147	4385	0.87	a HiResid
12	199.01	401.91	693	218	174	5140	1.15	a
13	255.06	513.75	1232	160	118	2807	0.84	a
14	279.21	561.93	31770	387	124	2824	0.99	a
15	391.78	786.55	28896	366	111	2111	1.10	a
16	511.34	1025.13	613	184	146	2984	2.20	a Wide Pk
17	661.92	1325.60	18781	302	104	2007	1.34	a
18	696.98	1395.56	78	77	62	941	0.70	a
19	814.43	1629.91	582	123	93	1416	1.64	a

## =====

## PEAK SEARCH RESULTS

=====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
20	836.25	1673.44	53	83	67	973	1.20	a NET< CL
21	898.24	1797.15	32621	377	89	1531	1.55	a
22	950.34	1901.11	82	74	59	863	0.85	a
23	1173.40	2346.19	20639	301	73	935	1.75	a
24	1325.07	2648.83	748	114	83	1008	2.91	a HiResid
25	1332.54	2663.73	18724	282	57	616	1.88	b HiResid
26	1835.52	3667.38	19283	281	33	189	2.29	a HiResid

170288D08.SPC Analyzed by

\*\*\*\*\*

SEEKER BACKGROUND SUBTRACT RESULTS Version 1.8.2

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Background File: . . . . . DET080308.BKG (030817-8 WEEKLY BKG)

Bkg.File Detector #: 8

=====

BACKGROUND SUBTRACT RESULTS

=====

PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
3	70.71	2555	358	283	2555	358	283	
5	82.49	1837	368	294	1835	368	294	
7	87.95	85035	633	203	85033	633	203	
12	199.01	693	218	174	689	218	174	
16	511.34	613	184	146	578	184	146	
21	898.24	32621	377	89	32620	377	89	

\*\*\*\*\*  
 SEEKER                      C A L I B R A T I O N   R E S U L T S                      Version 2.0.4  
 \*\*\*\*\*

Sample ID: 031517-8 GEO1 EFF CAL (1056)  
 Stds. Match Tolerance: 2.00 keV

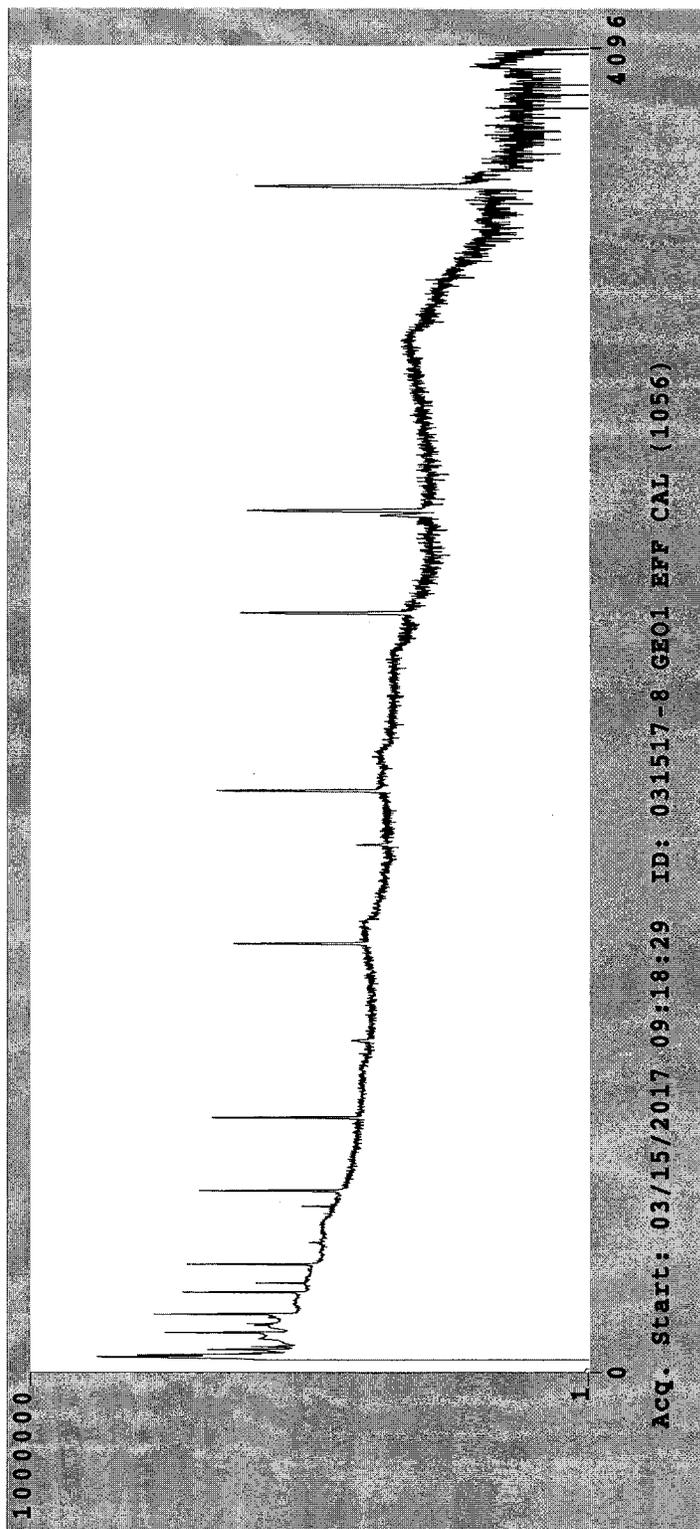
-----  
 Detector Number: 08                      Calibration Date. . . 03/15/2017 09:18:29  
 Geometry File (D08)(Sh01).EFF ID. Geo 1 Eff Cal  
 Amount of Std. in Calib. Source: 1.000000 gm

-----  
 Eff = 1 / [ 2.49e-01\*En^-1.50e+00 + 1.19e+02\*En^ 8.64e-01]  
 (Where En = Energy in MeV) (Exponential)  
 -----

Pk. #	Energy (keV)	Measured Efficiency	% Difference	Calculated Efficiency	% Difference	Prev.Calc. Efficiency
1	59.50	3.60e-02	0.29	3.62e-02	3.33	3.74e-02
2	88.04	4.18e-02	-1.10	4.13e-02	1.97	4.21e-02
3	122.06	3.90e-02	1.40	3.96e-02	1.59	4.02e-02
4	165.85	3.45e-02	-0.14	3.45e-02	1.60	3.50e-02
5	279.00	2.45e-02	-1.36	2.42e-02	1.83	2.46e-02
6	391.68	1.84e-02	0.32	1.85e-02	1.94	1.88e-02
7	661.64	1.19e-02	-0.05	1.19e-02	2.01	1.21e-02
8	898.02	8.99e-03	1.84	9.16e-03	2.02	9.35e-03
9	1173.21	7.25e-03	0.53	7.28e-03	2.02	7.43e-03
10	1332.48	6.57e-03	-0.57	6.53e-03	2.01	6.66e-03
11	1836.01	5.02e-03	-1.43	4.95e-03	2.00	5.05e-03

Calibration Results Saved.

*OK JP 3/16/17*



Standards File. . . . . Gsstd01.std

Assay Date . . . . . 01/01/2017 10:00

ID.: Geo 1 Std#1056 1 L Mari. Mixed Gamma

Pk #	Nuclide	Energy	Halflife	Br.Ratio	dps/gm
1	Am-241	59.50	4.322E+02 yrs	0.35900	4008.36
2	Cd-109	88.04	4.626E+02 dys	0.03700	51162.16
3	Co-57	122.06	2.718E+02 dys	0.85510	1194.01
4	Ce-139	165.85	1.376E+02 dys	0.80350	1795.67
5	Hg-203	279.00	4.660E+01 dys	0.77300	4135.83
6	Sn-113	391.68	1.151E+02 dys	0.64900	3129.43
7	Cs-137	661.64	3.017E+01 yrs	0.85120	1551.93
8	Y-88	898.02	1.066E+02 dys	0.93400	5199.14
9	Co-60	1173.21	5.271E+00 yrs	0.99980	2437.49
10	Co-60	1332.48	5.271E+00 yrs	0.99990	2440.24
11	Y-88	1836.01	1.066E+02 dys	0.99380	5173.07

RSO#  
1056

Received  
3/1/2017

**CERTIFICATE OF CALIBRATION**  
Standard Reference Source

**SRS Number:** 105114  
**Source Description:** 1.0 Liter Solid in 138G GA-MA Beaker  
**Product Code:** 8401-EG-SD  
**Customer:** ALS Laboratory Group  
**P.O. Number:** FC001290, Item 1

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Density of solid matrix: 1.17 g/cm<sup>3</sup> ± 3 %.

**Reference Date:** 01-January-2017 12:00 PM EST

**MGS Mixture**

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s <sup>-1</sup>	Uncertainty			Calibration Method**
					u <sub>A</sub> , %	u <sub>B</sub> , %	U, %*	
Am-241	59.5	1.580E+05	4.008E+03	1.439E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.115E+04	1.893E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.193E+03	1.021E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.804E+03	1.443E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.919E+03	3.197E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	3.127E+03	2.031E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.553E+03	1.321E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.183E+03	4.856E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	—————	—————	5.141E+03	0.7	1.7	3.7	—————
Co-60	1173.2	1.925E+03	2.440E+03	2.437E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	—————	—————	2.440E+03	0.7	1.8	3.9	—————

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. **\*Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." **\*\*Calibration Methods:** 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

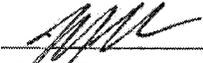
SRS Number: 105114

0743  
0103

Expiration Date: 27-February-2018

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:   
K. Eardley, Radiochemist

QC Approved by:  Date: 26-FEB-17  
J. Lahr, Spectroscopist

**Geometry 1 Calibration Verification: Gamma Mixed Nuclide Source**  
 1-Liter Water/Liquid Geometry  
 Detector 1

VERIF SCE: 1021				REF DATE: 1/1/2015				Count Date: 3/15/2017			
FROM CALIBRATION CERTIFICATE				FROM ANALYTICS.LIB				EXPECTED ACTIVITY			
Isotope	KeV	Half Life(y)	Gammas/Sec.	Gamma Fraction:	Mass of Standard	DPS	pCi/L	Activity	Recovery	Pass/Fail	# of Half Lives Expired
Am-241	59.5	432.0000	1353	0.3590	1	3768.8	101859.5	103000	101%	Pass	0.01
Cd-109	88	1.2666	1935	0.0372	L	52016.1	1405841.3	1350000	96%	Pass	1.74
Co-57	122	0.7441	1054	0.8551		1232.6	33313.6	32800	98%	Pass	2.96
Ce-139	166	0.3768	1482	0.8035		1844.4	49849.5	50400	101%	Pass	5.84
Hg-203	279	0.1276	3177	0.7730		4110.0	111080.0	NC	>5 h-lives	>5 h-lives	17.26
Sn-113	392	0.3151	2087	0.6490		3215.7	86911.3	86500	100%	Pass	6.99
Cs-137	662	30.0700	1323	0.8512		1554.3	42007.5	41800	100%	Pass	0.07
Y-88	898	0.2919	4901	0.9340		5247.3	141819.5	133000	94%	Pass	7.54
Co-60	1173	5.2714	2503	0.9998		2503.5	67662.2	66600	98%	Pass	0.42
Co-60	1332	5.2714	2506	0.9999		2506.3	67736.5	67400	100%	Pass	0.42
Y-88	1836	0.2919	5189	0.9938		5221.4	141118.2	148000	105%	Pass	7.54

NC=NOT CALCULATED DUE TO ACTIVITY<MDCa

*OK JF 3/16/17*

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SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: 031517-8A GEO1 EFF CAL VER (1021)

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-----
Sampling Start: 01/01/2015 10:00:00 | Counting Start: 03/15/2017 09:45:04
Sampling Stop: 01/01/2015 10:00:00 | Decay Time. . . . . 1.93E+004 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 1856 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170289D08.SPC
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```

Detector #: 8 (Detector 8)

Energy(keV) = -2.41 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 03/15/2017  
 FWHM(keV) = 0.57 + 0.015\*En + 6.11E-04\*En^2 + 0.00E+00\*En^3 02/01/2017  
 Where En = Sqrt(Energy in keV)

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 Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000  
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PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	49.14	102.85	3217	407	322	17656	1.19	a
2	59.43	123.39	88714	640	193	8264	0.71	a
3	65.96	136.41	172	104	83	1914	0.38	a Wide Pk
4	67.11	138.71	505	297	241	8615	1.50	b
5	77.24	158.92	170	182	148	4436	0.84	a
6	87.98	180.36	41666	435	123	3351	0.74	a
7	103.00	210.33	63	86	69	1179	0.42	a NET< CL
8	122.00	248.25	9443	218	82	1475	0.73	a HiResid
9	136.43	277.04	1317	143	101	1886	0.91	a
10	165.85	335.75	1624	132	86	1507	0.85	a
11	226.76	457.27	56	97	79	1367	0.57	a NET< CL
12	342.69	688.60	46	62	50	605	0.54	a NET< CL
13	391.89	786.79	545	116	87	1294	1.16	a
14	505.60	1013.67	39	60	49	584	0.61	a NET< CL
15	552.99	1108.24	52	78	63	778	1.12	a NET< CL
16	662.11	1325.97	26803	338	68	864	1.31	a
17	781.24	1563.69	42	80	65	776	1.29	a NET< CL
18	898.47	1797.60	409	97	72	1070	1.38	a
19	1173.73	2346.86	24200	318	55	532	1.73	a
20	1332.90	2664.46	21930	298	26	128	1.86	a HiResid
21	1836.09	3668.51	260	36	13	29	2.12	a

170289D08.SPC Analyzed by

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SEEKER            B A C K G R O U N D    S U B T R A C T    R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

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Background File: . . . . . DET080308.BKG (030817-8 WEEKLY BKG)

Bkg.File Detector #: 8

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
3	65.96	172	104	83	167	104	83	
5	77.24	170	182	148	164	182	148	
6	87.98	41666	435	123	41663	435	123	
18	898.47	409	97	72	408	97	72	

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SEEKER                      F I N A L     A C T I V I T Y     R E P O R T                      Version 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: 031517-8A GEO1 EFF CAL VER (1021)

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Sampling Start: 01/01/2015 10:00:00 | Counting Start: 03/15/2017 09:45:04
Sampling Stop: 01/01/2015 10:00:00 | Decay Time. . . . . 1.93e+004 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 1856 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 170289D08.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
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```

Detector #: 8 (Detector 8)

Efficiency File: (D08)(Sh01).EFF (Geo 1 Eff Cal)

Eff.=1/[2.49E-01\*En^-1.50E+00 + 1.19E+02\*En^8.64E-01] 03/15/2017

Library File: . . . .ANALYTICAL.LIB (Analytical)

MEASURED or MDA CONCENTRATIONS

Nuclide	ENERGY E (keV)	Concentration (pCi/L)	MDA	Critical Level	Halflife (hrs)
Am-241	59.54	1.03E+05 +- 7.43E+02	4.51E+02	2.24E+02	3.79E+06
Cd-109	88.02	1.35E+06 +- 1.41E+04	8.08E+03	3.99E+03	1.11E+04
Co-57	122.07	3.28E+04 +- 7.57E+02	5.76E+02	2.83E+02	6.50E+03
Ce-139	165.85	5.04E+04 +- 4.11E+03	5.45E+03	2.68E+03	3.30E+03
Sn-113	391.68	8.65E+04 +- 1.84E+04	2.81E+04	1.38E+04	2.76E+03
Cs-137	661.62	4.18E+04 +- 5.26E+02	2.17E+02	1.07E+02	2.64E+05
Y-88	Average:x	1.43E+05 +- 1.71E+04	. . . .	. . . .	2.56E+03
	898.02	1.33E+05 +- 3.16E+04	4.81E+04	2.36E+04	2.56E+03
	1836.01	1.48E+05 +- 2.03E+04	1.61E+04	7.29E+03	2.56E+03
Co-60	Average:x	6.70E+04 +- 6.33E+02	. . . .	. . . .	4.62E+04
	1173.21	6.66E+04 +- 8.76E+02	3.10E+02	1.51E+02	4.62E+04
	1332.48	6.74E+04 +- 9.15E+02	1.67E+02	7.93E+01	4.62E+04
Hg-203	279.18	MDA . . . .	2.34E+07	1.15E+07	1.12E+03

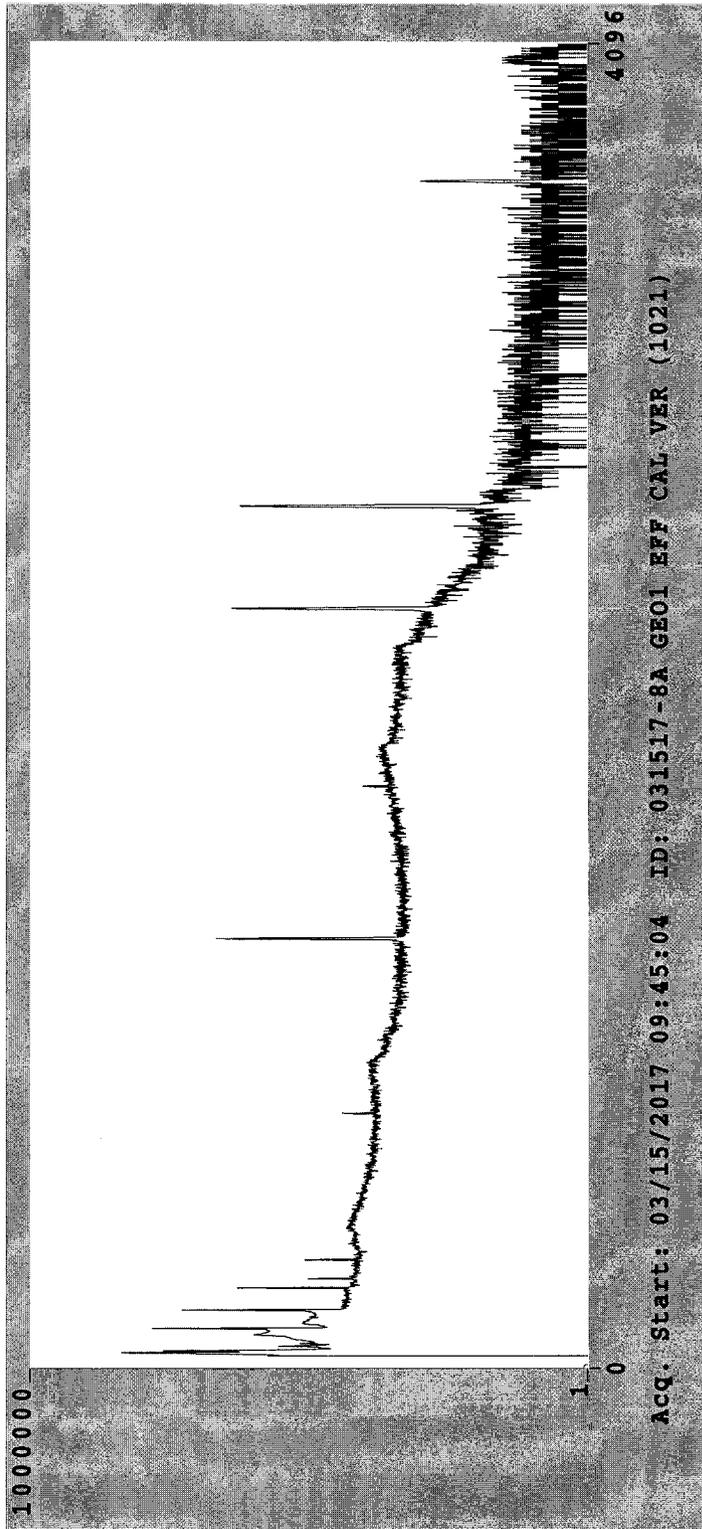
MEASURED TOTAL: 1.88E+06 +- 5.64E+04 pCi/L

170289D08.SPC Analyzed by

UNKNOWN, SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	49.14	102.85	3217	407	322	17656	1.19	Unknown
3	65.96	136.41	167	104	83	1914	0.38	Unknown
4	67.11	138.71	505	297	241	8615	1.50	Unknown
5	77.24	158.92	164	182	148	4436	0.84	Unknown
7	103.00	210.33	63	86	69	1179	0.42	Deleted
9	136.43	277.04	1317	143	101	1886	0.91	Unknown
11	226.76	457.27	56	97	79	1367	0.57	Deleted
12	342.69	688.60	46	62	50	605	0.54	Deleted
14	505.60	1013.67	39	60	49	584	0.61	Deleted
15	552.99	1108.24	52	78	63	778	1.12	Deleted
17	781.24	1563.69	42	80	65	776	1.29	Deleted

c:\SEEKER\BIN\170289d08.res Analysis Results Saved.



RSO # 1021  
Received  
2/26/2015

**CERTIFICATE OF CALIBRATION**  
Standard Reference Source

99579

1.0 Liter Solid in 138G GA-MA Beaker

**Customer:** ALS Laboratory Group  
**P.O. No.:** FC000629, Item 1 **Product Code:** 8401-EG-SD  
**Reference Date:** 01-Jan-2015 12:00 PM EST **Grams of Master Source:** 0.011886

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solutions. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." Density of solid matrix 1.15 g/cc.

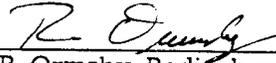
Nuclide	Gamma-Ray Energy (keV)	Half-Life, Days	Master Source* yps/gram	This Source yps	Uncertainty* , %			Calibration Method*
					u <sub>A</sub>	u <sub>B</sub>	U	
Am-241	59.5	1.580E+05	—	1.353E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	1.628E+05	1.935E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	8.868E+04	1.054E+03	0.4	1.7	3.5	HPGe
Ce-139	165.9	1.376E+02	1.246E+05	1.482E+03	0.4	1.7	3.5	HPGe
Hg-203	279.2	4.659E+01	2.673E+05	3.177E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.756E+05	2.087E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.113E+05	1.323E+03	0.7	1.9	4.0	HPGe
Y-88	898.0	1.066E+02	4.123E+05	4.901E+03	0.7	1.7	3.7	HPGe
Co-60	1173.2	1.925E+03	2.106E+05	2.503E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	1.925E+03	2.109E+05	2.506E+03	0.7	1.8	3.9	HPGe
Y-88	1836.1	1.066E+02	4.365E+05	5.189E+03	0.7	1.7	3.7	HPGe

\* Master Source refers to Analytics' 8-isotope mixture which is calibrated quarterly.

**Calibration Methods:** 4π LS - 4 pi Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber. **Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

(Certificate continued on reverse side)

This standard will expire one year after the reference date.

Source Prepared by:   
R. Ormsby, Radiochemist

QC Approved:   
J. S. Ahr, Spectroscopist

Date: 20 FEB 15

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SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

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Geo 1 / Water

Sample ID: 110416-9 Geo 1 Eff Cal (1040)

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Sampling Start: 01/01/2016 10:00:00 | Counting Start: 11/04/2016 09:16:55
Sampling Stop: 01/01/2016 10:00:00 | Decay Time. . . . . 7.39E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 3600 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 3784 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 161088D09.SPC
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```

Detector #: 9 (Detector 9)

Energy(keV) = -2.18 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 11/04/2016  
 FWHM(keV) = 0.66 + 0.018\*En + 5.48E-04\*En^2 + 0.00E+00\*En^3 11/04/2016

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	49.64	103.36	9343	773	616	52578	1.59	a Wide Pk
2	59.46	122.94	159864	905	348	24378	0.83	a HiResid
3	66.70	137.39	2076	519	420	28001	1.34	a
4	78.03	159.99	370	300	245	13313	0.58	a
5	88.02	179.92	155324	859	281	15896	0.85	a
6	122.03	247.74	61448	545	187	7046	0.87	a HiResid
7	136.45	276.51	7091	263	167	5589	0.84	a
8	165.89	335.22	33054	409	154	4777	0.88	a HiResid
9	199.35	401.96	555	260	211	7023	1.24	a
10	220.24	443.63	109	133	108	2878	0.53	a
11	255.12	513.21	821	194	153	4311	0.99	a
12	279.35	561.53 <i>Δ</i>	2442	200	143	3758	1.01	a
13	310.69	624.04	106	144	117	2778	0.86	a NET< CL
14	322.05	646.70	92	120	98	2113	0.70	a NET< CL
15	391.93	786.09	17119	305	129	3280	1.14	a
16	439.48	880.93	111	123	99	2246	0.80	a
17	511.40	1024.39	494	204	164	3978	1.95	a
18	629.14	1259.22	43	175	143	3196	0.42	NET< CL
19	662.11	1324.99	42636	437	116	2500	1.29	a HiResid
20	814.46	1628.87	285	125	99	2018	1.33	a
21	898.48	1796.46	17141	300	121	2838	1.49	a

*A less than 10,000 counts achieved due to greater than 5 1/2-lives elapsed. JP 11/8/16*

## =====

## PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	1173.71	2345.42	44460	435	87	1460	1.75	a HiResid
23	1195.33	2388.56	63	61	48	573	0.96	a
24	1327.66	2652.49	587	184	146	1930	6.06	a HiResid Wide Pk
25	1332.87	2662.88	40091	406	55	574	1.85	b HiResid
26	1835.94	3666.31	10053	203	27	124	2.22	a HiResid

161088D09.SPC Analyzed by

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SEEKER BACKGROUND SUBTRACT RESULTS Version 1.8.2

ALS Laboratory Group - Fort Collins

GammaScan

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Background File: . . . . . DET091103.BKG (110316-9 WEEKLY BKG)

Bkg.File Detector #: 9

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
3	66.70	2076	519	420	2068	519	421	
4	78.03	370	300	245	354	301	245	
5	88.02	155324	859	281	155320	859	281	
9	199.35	555	260	211	546	260	211	
17	511.40	494	204	164	411	205	165	



Standards File. . . . . Gsstd01.std  
Assay Date . . . . . 01/01/2016 10:00  
ID.: Geo 1 Std#1040 1 L Mari. Mixed Gamma

Pk #	Nuclide	Energy	Halflife	Br.Ratio	dps/gm
1	Am-241	59.50	4.322E+02 yrs	0.35900	3768.80
2	Cd-109	88.04	4.626E+02 dys	0.03700	51567.57
3	Co-57	122.06	2.718E+02 dys	0.85510	1266.52
4	Ce-139	165.85	1.376E+02 dys	0.80350	1823.27
5	Hg-203	279.00	4.660E+01 dys	0.77300	4213.45
6	Sn-113	391.68	1.151E+02 dys	0.64900	3127.89
7	Cs-137	661.64	3.017E+01 yrs	0.85120	1530.78
8	Y-88	898.02	1.066E+02 dys	0.93400	5372.59
9	Co-60	1173.21	5.271E+00 yrs	0.99980	2450.49
10	Co-60	1332.48	5.271E+00 yrs	0.99990	2453.25
11	Y-88	1836.01	1.066E+02 dys	0.99380	5346.15

#1040  
Rec'd  
2-25-16

**CERTIFICATE OF CALIBRATION**  
Standard Reference Source

SRS Number: 102366  
Source Description: 1.0 Liter Solid in 138G GA-MA Beaker  
Product Code: 8401-EG-SD  
Customer: ALS Laboratory Group  
P.O. Number: FC000928, Item 1

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Density of solid matrix: 1.17 g/cm<sup>3</sup> ± 3 %.

Reference Date: 01-January-2016 12:00 PM EST

**MGS Mixture**

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s <sup>-1</sup>	Uncertainty			Calibration Method**
					u <sub>A</sub> , %	u <sub>B</sub> , %	U, %*	
Am-241	59.5	1.580E+05	3.768E+03	1.353E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.156E+04	1.908E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.265E+03	1.083E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.831E+03	1.465E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.993E+03	3.257E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	3.124E+03	2.030E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.531E+03	1.303E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.356E+03	5.018E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	_____	_____	5.313E+03	0.7	1.7	3.7	_____
Co-60	1173.2	1.926E+03	2.453E+03	2.450E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	_____	_____	2.453E+03	0.7	1.8	3.9	_____

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. \*Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." \*\*Calibration Methods: 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 102366

Expiration Date: 24-February-2017

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:   
A. Herron, Radiochemist

QC Approved by:  Date: 24-FEB-16  
J. Lahr, Spectroscopist

**Geometry 1 Calibration Verification:** Gamma Mixed Nuclide Source  
 1-Liter Water/Liquid Geometry  
 Detector 9

VERIF SCE: 999				REF DATE: 1/1/2014				Count Date: 11/4/2016				
FROM CALIBRATION CERTIFICATE				FROM ANALYTICS.LIB				EXPECTED ACTIVITY				
Isotope	KeV	Half Life(y)	Gammas/Sec.	Gamma Fraction:	Mass of Standard		DPS	pCi/L	Activity	Recovery	Pass/Fail	# of Half Lives Expired
Am-241	59.5	432.0000	1330	0.3590	1	L	3704.7	100128.0	101000	101%	Pass	0.01
Cd-109	88	1.2666	1903	0.0372			51155.9	1382592.3	1370000	99%	Pass	2.24
Co-57	122	0.7441	1043	0.8551			1219.7	32966.0	33300	101%	Pass	3.82
Ce-139	166	0.3768	1436	0.8035			1787.2	48302.2	43500	90%	Pass	7.54
Hg-203	279	0.1276	3083	0.7730			3988.4	107793.4	NC	>5 h-lives	>5 h-lives	22.28
Sn-113	392	0.3151	2031	0.6490			3129.4	84579.2	NC	>5 h-lives	>5 h-lives	9.02
Cs-137	662	30.0700	1287	0.8512			1512.0	40864.4	40800	100%	Pass	0.09
Y-88	898	0.2919	4873	0.9340			5217.3	141009.3	NC	>5 h-lives	>5 h-lives	9.73
Co-60	1173	5.2714	2404	0.9998			2404.5	64986.0	65900	101%	Pass	0.54
Co-60	1332	5.2714	2406	0.9999			2406.2	65033.5	66100	102%	Pass	0.54
Y-88	1836	0.2919	5158	0.9938			5190.2	140275.1	NC	>5 h-lives	>5 h-lives	9.73

NC=NOT CALCULATED DUE TO ACTIVITY<MDCa

*OK TO 11/4/16*



\*\*\*\*\*  
 SEEKER            G A M M A     A N A L Y S I S     R E S U L T S     P S Version 1.8.4

ALS Laboratory Group - Fort Collins  
 GammaScan

Geo 1 / Water

Sample ID: 110416-9A Geo 1 Cal Ver (999)

```
-----
Sampling Start: 01/01/2014 10:00:00 | Counting Start: 11/04/2016 10:25:29
Sampling Stop: 01/01/2014 10:00:00 | Decay Time. . . . . 2.49E+004 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 1841 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 161089D09.SPC
-----
```

Detector #: 9 (Detector 9)

Energy(keV) = -2.18 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 11/04/2016  
 FWHM(keV) = 0.66 + 0.018\*En + 5.48E-04\*En^2 + 0.00E+00\*En^3 11/04/2016  
 Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	43.61	91.32	880	475	388	16666	2.34	a Wide Pk
2	49.33	102.74	6356	583	461	24853	2.15	b
3	51.10	106.27	975	334	270	13438	1.01	c
4	59.47	122.97	78975	614	203	8323	0.82	a
5	66.56	137.10	259	221	180	5109	1.27	a
6	88.02	179.92	26210	351	111	2497	0.84	a
7	122.04	247.76	4559	170	85	1455	0.85	a
8	125.67	255.00	35	89	72	1164	0.70	b NET< CL
9	136.49	276.59	496	97	71	1111	0.69	a
10	165.87	335.20	368	114	88	1431	0.97	a
11	190.06	383.43	37	71	57	805	0.51	a NET< CL
12	311.14	624.95	65	92	75	1032	0.92	a NET< CL
13	392.04	786.30	90	63	50	608	0.73	a
14	462.66	927.16	91	105	85	1335	1.30	a
15	510.56	1022.72	64	79	63	793	1.11	a
16	662.15	1325.07	20560	295	59	635	1.35	a
17	922.21	1843.78	58	89	72	1019	1.44	a NET< CL
18	1173.73	2345.47	16965	266	45	412	1.72	a HiResid
19	1332.92	2662.98	15141	248	25	118	1.82	a HiResid
20	1836.02	3666.48	24	16	10	21	1.88	a

161089D09.SPC Analyzed by

\*\*\*\*\*  
SEEKER            B A C K G R O U N D   S U B T R A C T   R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Background File: . . . . . DET091103.BKG (110316-9 WEEKLY BKG)

Bkg.File Detector #: 9

=====

BACKGROUND SUBTRACT RESULTS

=====

PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
5	66.56	259	221	180	255	221	180	
6	88.02	26210	351	111	26208	351	111	
15	510.56	64	79	63	23	79	65	NET<CL

\*\*\*\*\*

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Geo 1 / Water

Sample ID: 110416-9A Geo 1 Cal Ver (999)

```

-----
Sampling Start: 01/01/2014 10:00:00 | Counting Start: 11/04/2016 10:25:29
Sampling Stop: 01/01/2014 10:00:00 | Decay Time. . . . . 2.49e+04 Hrs
Buildup Time. . . . . 0.00e+00 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00e+00 L | Real Time . . . . . 1841 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 161089D09.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
-----
    
```

Detector #: 9 (Detector 9)

Efficiency File: (D09)(Sh01).EFF (Geo 1 Eff Cal)

Eff.=1/[3.89E-01\*En^-1.38E+00 + 1.53E+02\*En^9.21E-01] 11/04/2016

Library File: . . . .ANALYTICAL.LIB (Analytical)

MEASURED or MDA CONCENTRATIONS

Nuclide	ENERGY E (keV)	Concentration (pCi/L)	MDA	Critical Level	Half-life (hrs)
Am-241	59.54	1.01E+05 +- 7.88E+02	5.25E+02	2.61E+02	3.79E+06
Cd-109	88.02	1.37E+06 +- 1.84E+04	1.18E+04	5.83E+03	1.11E+04
Co-57	122.07	3.33E+04 +- 1.24E+03	1.26E+03	6.20E+02	6.50E+03
Ce-139	165.85	4.35E+04 +- 1.34E+04	2.11E+04	1.04E+04	3.30E+03
Cs-137	661.62	4.08E+04 +- 5.87E+02	2.38E+02	1.16E+02	2.64E+05
Co-60	Average:x	6.60E+04 +- 7.48E+02	. . . .	. . . .	4.62E+04
	1173.21	6.59E+04 +- 1.03E+03	3.62E+02	1.76E+02	4.62E+04
	1332.48	6.61E+04 +- 1.08E+03	2.28E+02	1.08E+02	4.62E+04
Hg-203	279.18	MDA . . . .	8.89E+08	4.38E+08	1.12E+03
Sn-113	391.68	MDA . . . .	8.19E+04r	3.99E+04	2.76E+03
Y-88	898.02	MDA . . . .	2.90E+05	1.42E+05	2.56E+03

MEASURED TOTAL: 1.66E+06 +- 3.52E+04 pCi/L

UNKNOWN,SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	43.61	91.32	880	475	388	16666	2.34	Unknown
2	49.33	102.74	6356	583	461	24853	2.15	Unknown

161089D09.SPC Analyzed by

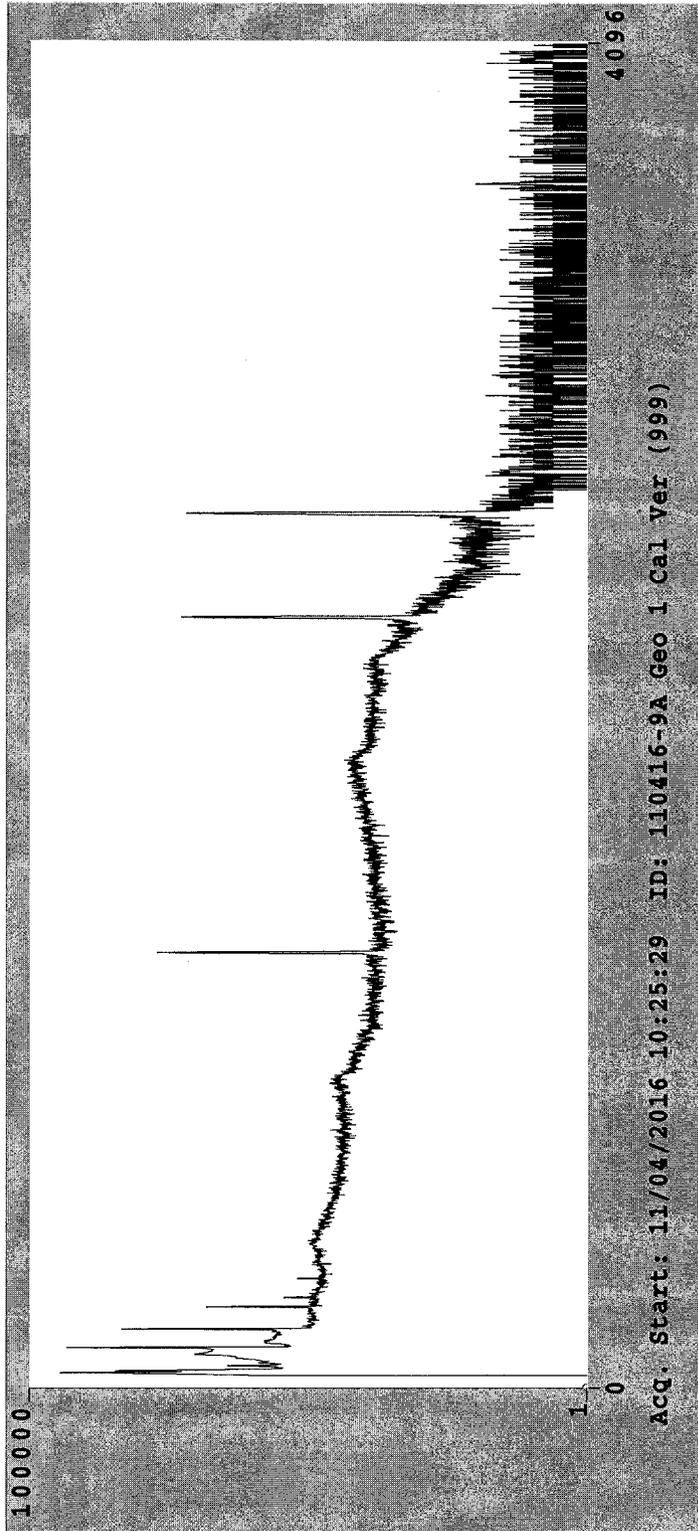
=====

UNKNOWN, SUM or ESCAPE PEAKS

=====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
3	51.10	106.27	975	334	270	13438	1.01	Unknown
5	66.56	137.10	255	221	180	5109	1.27	Unknown
8	125.67	255.00	35	89	72	1164	0.70	Deleted
9	136.49	276.59	496	97	71	1111	0.69	Unknown
11	190.06	383.43	37	71	57	805	0.51	Deleted
12	311.14	624.95	65	92	75	1032	0.92	Deleted
13	392.04	786.30	90	63	50	608	0.73	Unknown
14	462.66	927.16	91	105	85	1335	1.30	Unknown
15	510.56	1022.72	23	79	65	793	1.11	Deleted
17	922.21	1843.78	58	89	72	1019	1.44	Deleted
20	1836.02	3666.48	24	16	10	21	1.88	Unknown

c:\SEEKER\BIN\161089d09.res Analysis Results Saved.





**Eckert & Ziegler**  
Analytics

RSO #  
999

Received  
2/26/2014  
JP

1380 Seaboard Industrial Blvd.  
Atlanta, Georgia 30318  
Tel 404-352-8677  
Fax 404-352-2837  
www.analyticinc.com

**CERTIFICATE OF CALIBRATION**  
Standard Radionuclide Source

95548

1.0 Liter Solid in 138G GA-MA Beaker

**Customer:** ALS Laboratory Group  
**P.O. No.:** FC000236, Item 1 **Product Code** 8401-EG-SD  
**Reference Date:** 01-Jan-2014 12:00 PM EST **Grams of Master Source:** 0.011697

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solutions. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

Density of solid matrix 1.15 g/cc.

Nuclide	Gamma-Ray Energy (keV)	Half-Life, Days	Master Source* $\mu\text{ps}/\text{gram}$	This Source $\mu\text{ps}$	Uncertainty*, %			Calibration Method*
					$u_A$	$u_B$	U	
Am-241	59.5	1.580E+05	1.330E+03	1.330E+03	0.1	1.6	3.2	4 $\pi$ LS
Cd-109	88.0	4.614E+02	1.627E+05	1.903E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	8.915E+04	1.043E+03	0.4	1.7	3.5	HPGe
Ce-139	165.9	1.376E+02	1.228E+05	1.436E+03	0.4	1.7	3.5	HPGe
Hg-203	279.2	4.659E+01	2.636E+05	3.083E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.736E+05	2.031E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.100E+05	1.287E+03	0.7	1.9	4.0	HPGe
Y-88	898.0	1.066E+02	4.166E+05	4.873E+03	0.5	1.7	3.5	HPGe
Co-60	1173.2	1.925E+03	2.055E+05	2.404E+03	0.6	1.8	3.8	HPGe
Co-60	1332.5	1.925E+03	2.057E+05	2.406E+03	0.7	1.8	3.9	HPGe
Y-88	1836.1	1.066E+02	4.410E+05	5.158E+03	0.7	1.7	3.7	HPGe

\* Master Source refers to Analytics' 8-isotope mixture which is calibrated quarterly.

**Calibration Methods:** 4 $\pi$  LS - 4  $\pi$  Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber. **Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

(Certificate continued on reverse side)

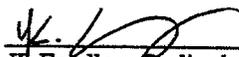
Standard Re-Verified  
3/7/16.  
New Expiration  
Date => 03/07/2017.

JP 3/18/16

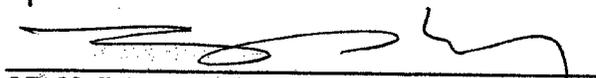


This standard will expire one year after the reference date.

Source Prepared by:

  
K. Eardley, Radiochemist

QA Approved:

  
J.D. McCorvey, Counting Room Manager

Date: 24 Feb 14



**Gamma Spectroscopy**

**Quality Control Data**

**Weekly Background Calibrations**

ALS

### Gamma Spectrometer Calibration Log

Date: 5/10/17

Reviewed By/Date: JP 5/11/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.		JP	JP	JP	JP					
2.			JP		JP					
3.			JP		JP					
4.			JP		JP					
5.			JP		JP					
6.			JP		JP					
7.			JP		JP	1332 FWHM	JP			
8.			JP		JP					
9.			JP		JP					
10.	JP		JP		JP					

\*\* Corrective Action:

Δ Recount Peak Shift

\*\*\* Due to detector \_\_\_\_\_ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector \_\_\_\_\_ is online for the date of \_\_\_\_\_

471541 A

Form 754r16a.doc (10/27/11)

ALS

### Gamma Spectrometer Calibration Log

Date: 5/11/07

Reviewed By/Date: JP 5/11/07

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.				JP	JP					
2.				JP	JP					
3.				JP	JP					
4.				/		1332 FWHM	JP			
5.				JP	JP					
6.				JP	JP					
7.				/		1332 FWHM	JP			
8.				JP	JP					
9.		JP	JP	/	JP					
10.	JP			/	/					

\*\* Corrective Action:

\*\*\* Due to detector \_\_\_\_\_ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector \_\_\_\_\_ is online for the date of \_\_\_\_\_

471542 A

Form 754r16a.doc (10/27/11)

\*\*\*\*\*

SEEKER                    G A M M A     A N A L Y S I S     R E S U L T S     PS Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Weekly Background Check

Sample ID: 051017-8 WEEKLY BKG

```
-----
Sampling Start:   05/10/2017 13:00:00 | Counting Start:   05/10/2017 13:50:23
Sampling Stop:   05/10/2017 13:00:00 | Decay Time. . . . . 8.40E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 60000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 60060 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170498D08.SPC
-----
```

Detector #: 8 (Detector 8)

Energy(keV)= -2.27 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 05/10/2017

FWHM(keV) = 0.66 + 0.008\*En + 7.24E-04\*En^2 + 0.00E+00\*En^3 04/18/2017

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	46.42	97.14	322	73	52	605	0.69	a
2	53.32	110.92	112	72	57	648	0.77	a
3	63.17	130.56	608	79	51	571	0.61	a
4	66.34	136.89	202	87	68	856	0.92	b
5	74.85	153.87	265	72	52	609	0.73	a
6	76.98	158.11	215	80	61	762	0.77	b
7	84.44	173.00	145	84	66	807	0.97	a
8	87.14	178.38	99	63	49	538	0.71	b
9	92.63	189.34	875	100	66	804	0.96	a
10	98.24	200.55	85	50	38	353	0.42	a
11	112.49	228.97	37	59	47	493	0.73	a NET< CL
12	120.24	244.44	47	77	62	713	1.04	a NET< CL
13	139.66	283.17	193	78	60	656	0.95	a
14	143.53	290.91	76	66	52	547	0.87	b
15	163.42	330.58	51	64	51	529	0.77	a
16	185.69	375.03	292	73	53	558	0.80	a
17	198.26	400.11	201	71	54	583	0.78	a
18	238.62	480.63	342	72	51	520	0.86	a
19	294.96	593.04	82	57	44	395	0.88	a
20	338.21	679.35	74	70	55	525	1.16	a
21	352.08	707.01	118	58	44	393	0.86	a

=====  
 PEAK SEARCH RESULTS  
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	463.30	928.92	26	36	28	200	0.67	a NET< CL
23	511.13	1024.37	1683	133	86	920	2.68	a Wide Pk
24	537.30	1076.59	66	62	49	399	1.58	a
25	558.68	1119.24	233	54	36	259	1.13	a
26	569.86	1141.54	84	46	34	249	1.05	a
27	583.53	1168.82	139	56	42	329	1.27	a
28	609.51	1220.67	139	75	58	559	1.59	a
29	651.63	1304.69	62	43	33	217	1.11	a
30	693.09	1387.43	35	34	27	174	0.71	a Wide Pk
31	693.77	1388.78	70	93	75	696	2.68	b NET< CL
32	803.11	1606.95	139	53	39	264	1.43	a
33	898.52	1797.32	20	82	67	492	3.94	a NET< CL Wide Pk
34	911.34	1822.90	77	39	29	170	1.32	a
35	962.43	1924.83	51	45	35	231	1.63	a
36	1009.40	2018.54	30	38	30	174	1.55	a NET< CL
37	1120.39	2240.00	36	46	36	221	2.03	a NET< CL
38	1460.52	2918.65	231	42	24	115	1.84	a

170498D08.SPC Analyzed by

\*\*\*\*\*

SEEKER BACKGROUND Q. C. ANALYSIS Version 2.2.2

\*\*\*\*\*

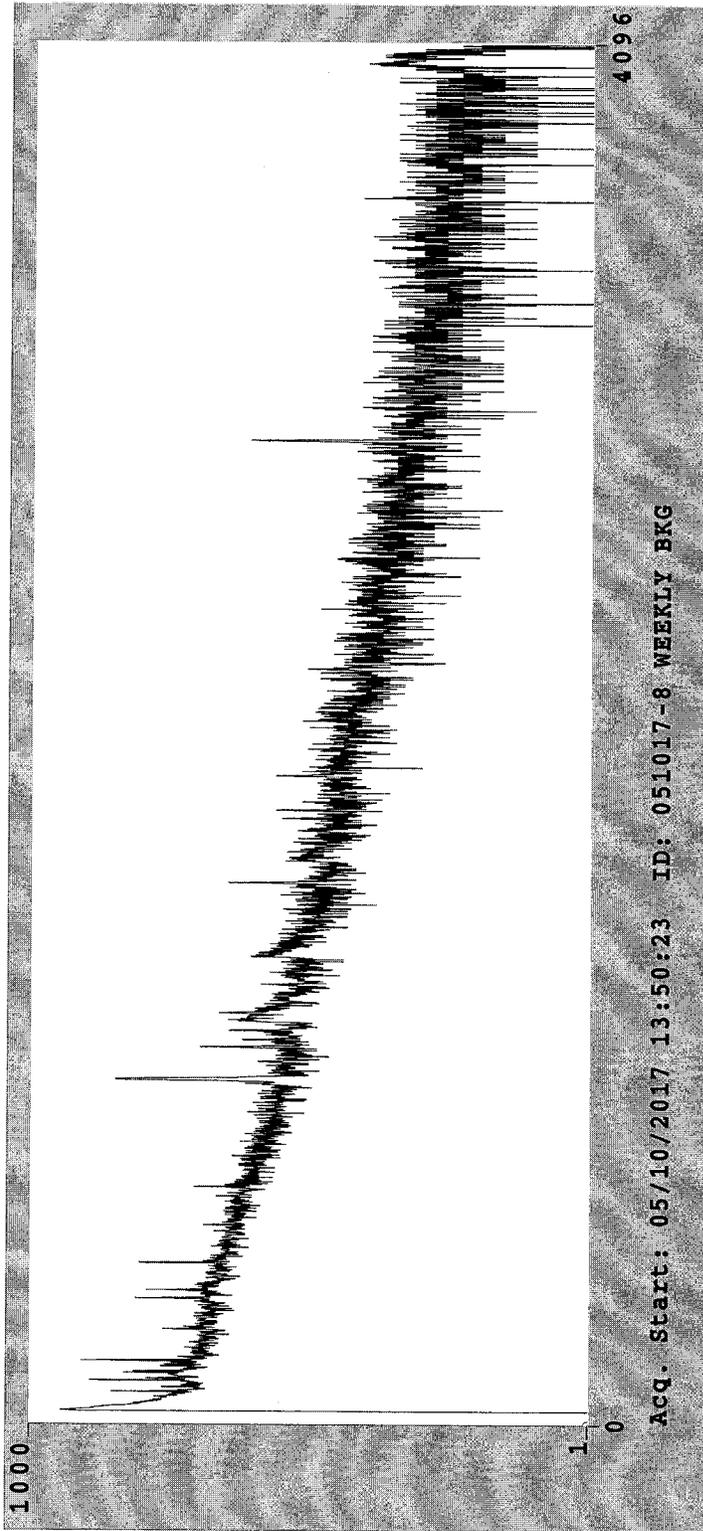
ID: 051017-8 WEEKLY BKG

Detector # 8 Background Q.C. Analysis for 05/10/2017 13:50:23

-----

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
10	50-> 150 keV Bkg	28.025	N.A.	Pass	N.A.
11	150-> 250 keV Bkg	21.782	N.A.	Pass	N.A.
12	250-> 500 keV Bkg	32.832	N.A.	Pass	N.A.
13	500->1000 keV Bkg	35.947	N.A.	Pass	N.A.
14	1000->2000 keV Bkg	20.356	N.A.	Pass	N.A.
15	40-> 50 keV Bkg	3.572	N.A.	Pass	N.A.

Q.C. Results Saved.





\*\*\*\*\*  
 SEEKER            G A M M A    A N A L Y S I S    R E S U L T S    P S Version 1.8.4

ALS Laboratory Group - Fort Collins  
 GammaScan

\*\*\*\*\*

Weekly Background Check

Sample ID: 051117-9 WEEKLY BKG

```
-----
Sampling Start:   05/11/2017 09:00:00 | Counting Start:   05/11/2017 09:08:26
Sampling Stop:   05/11/2017 09:00:00 | Decay Time. . . . . 1.41E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 60000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 60081 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170436D09.SPC
-----
```

Detector #: 9 (Detector 9)

Energy(keV)= -2.38 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 05/11/2017  
 FWHM(keV) = 0.66 + 0.018\*En + 5.48E-04\*En^2 + 0.00E+00\*En^3 11/04/2016

Where En = Sqrt(Energy in keV)

-----  
 Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000  
 -----

=====

PEAK SEARCH RESULTS

=====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	41.72	88.00	17	38	30	255	0.40	a NET< CL
2	46.36	97.25	414	88	64	766	1.03	b
3	63.27	130.98	516	82	56	641	0.79	a
4	66.23	136.88	250	94	73	897	1.21	b
5	69.87	144.15	67	99	80	1025	1.30	c NET< CL
6	74.93	154.24	142	65	50	548	0.73	a
7	77.12	158.62	178	76	58	685	0.83	b
8	84.31	172.96	118	97	78	961	1.35	a
9	87.18	178.68	54	49	38	361	0.57	b
10	92.61	189.51	681	92	62	709	0.95	a
11	108.98	222.18	36	63	51	524	0.87	a NET< CL
12	134.02	272.14	61	78	63	670	1.18	a NET< CL
13	139.88	283.84	113	64	50	495	0.81	a
14	143.65	291.35	58	79	64	693	1.16	b NET< CL
15	159.02	322.02	29	78	64	692	1.07	a NET< CL
16	185.83	375.50	364	77	55	558	0.93	a
17	198.29	400.35	143	64	49	474	0.85	a
18	209.09	421.91	55	59	47	440	0.89	a
19	238.72	481.01	267	67	48	463	0.80	a
20	295.25	593.79	103	61	47	416	0.95	a
21	338.52	680.12	49	43	34	253	0.58	a

=====  
 PEAK SEARCH RESULTS  
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	352.01	707.03	177	55	40	335	1.05	a
23	467.71	937.86	25	38	30	208	0.85	a NET< CL
24	511.23	1024.70	1460	116	72	660	2.49	a Wide Pk
25	558.74	1119.48	191	50	34	232	1.22	a
26	570.13	1142.20	36	47	37	272	1.07	a NET< CL
27	583.51	1168.89	96	53	40	298	1.32	a
28	609.57	1220.88	120	58	44	360	1.32	a
29	670.24	1341.94	15	69	57	431	2.30	a NET< CL
30	693.81	1388.94	51	61	49	388	1.71	a
31	803.45	1607.69	145	48	34	217	1.67	a
32	911.37	1823.01	39	25	18	82	0.84	a
33	1120.78	2240.79	40	37	29	160	1.73	a
34	1460.72	2918.98	185	40	24	109	1.97	a
35	1764.34	3524.72	28	20	14	43	1.18	a

170436D09.SPC Analyzed by

\*\*\*\*\*  
SEEKER            B A C K G R O U N D    Q . C .    A N A L Y S I S    Version 2.2.2  
\*\*\*\*\*

ID: 051117-9 WEEKLY BKG

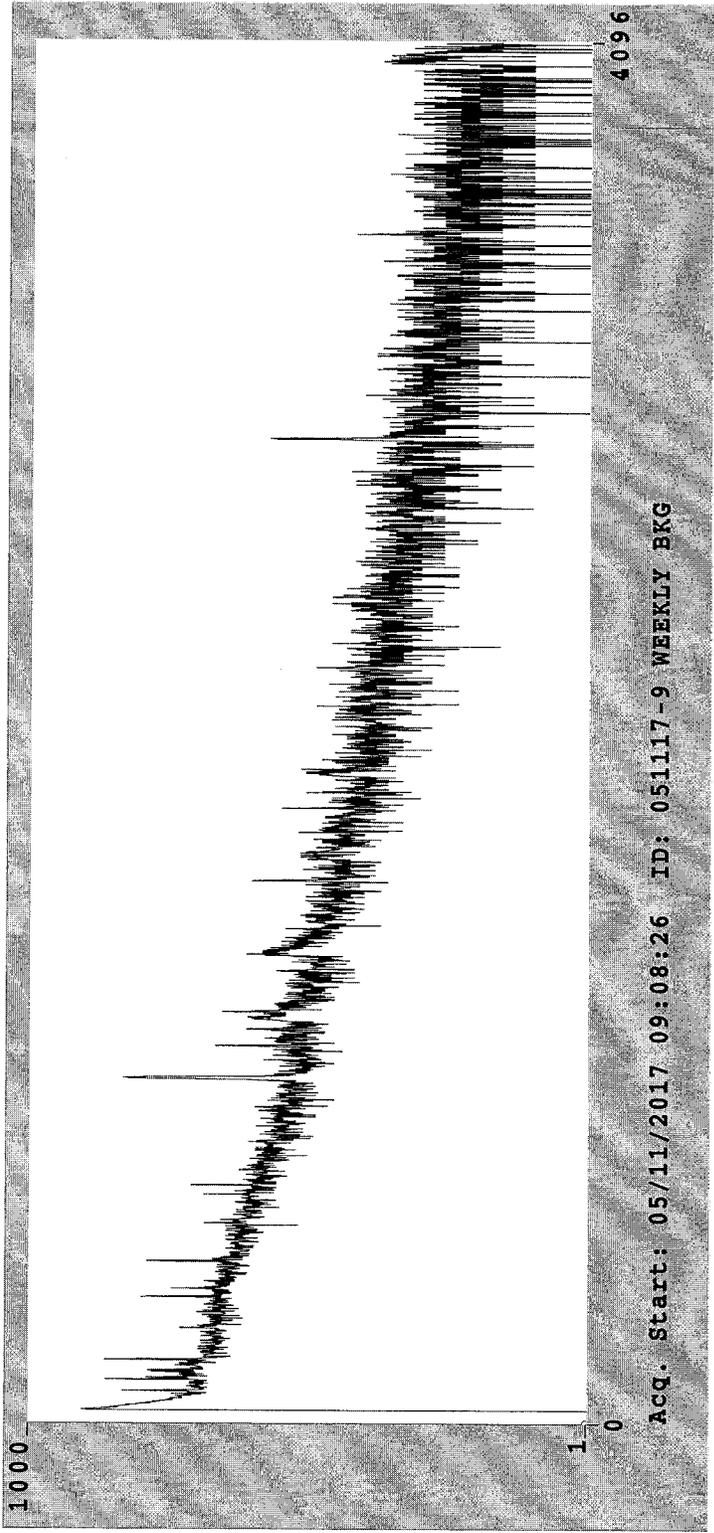
Detector # 9 Background Q.C. Analysis for 05/11/2017 09:08:26

---

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
10	50-> 150 keV Bkg	24.670	N.A.	Pass	N.A.
11	150-> 250 keV Bkg	18.858	N.A.	Pass	N.A.
12	250-> 500 keV Bkg	28.121	N.A.	Pass	N.A.
13	500->1000 keV Bkg	29.768	N.A.	Pass	N.A.
14	1000->2000 keV Bkg	17.080	N.A.	Pass	N.A.
15	40-> 50 keV Bkg	3.068	N.A.	Pass	N.A.

---

Q.C. Results Saved.



ALS

Gamma Spectrometer Calibration Log

Date: 5/17/17

Reviewed By/Date: AZ 5/18/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.		JP	AZ	JP	JP					
2.					JP					
3.					JP	1332 FWHM	JP			
4.					JP					
5.					JP					
6.					JP	1332 FWHM	JP			
7.					JP					
8.					JP					
9.					JP					
10.	JP	/	/	/	/					

\*\* Corrective Action:

\*\*\* Due to detector \_\_\_ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector \_\_\_ is online for the date of \_\_\_

471547 A

\*\*\*\*\*

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins  
GammaScan

\*\*\*\*\*

Weekly Background Check

Sample ID: 051717-1 WEEKLY BKG

```
-----
Sampling Start: 05/17/2017 13:00:00 | Counting Start: 05/17/2017 13:58:21
Sampling Stop: 05/17/2017 13:00:00 | Decay Time. . . . . 9.73E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 60000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 60095 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170562D01.SPC
-----
```

Detector #: 1 (Detector 1)

Energy(keV)= -2.04 + 0.501\*Ch + 0.00E+00\*Ch^2 + 0.00E+00\*Ch^3 05/17/2017

FWHM(keV) = 0.71 + -0.000\*En + 1.20E-03\*En^2 +-8.09E-06\*En^3 08/22/2016

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN-CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	50.39	104.64	61	65	52	591	0.67	a
2	66.19	136.17	101	79	63	793	0.86	a
3	69.32	142.41	53	44	34	317	0.40	b
4	74.82	153.39	30	55	44	477	0.42	a NET< CL
5	84.08	171.88	45	59	47	497	0.65	a NET< CL
6	87.33	178.36	43	49	39	373	0.44	b
7	92.59	188.86	172	100	79	995	1.23	c
8	138.76	281.00	19	46	37	333	0.44	a NET< CL
9	139.90	283.28	168	86	67	777	1.07	b
10	144.30	292.06	64	75	60	666	0.92	c
11	172.70	348.74	59	65	52	553	0.89	a
12	185.74	374.78	226	95	74	865	1.36	a
13	198.47	400.17	157	85	67	771	1.12	a
14	224.24	451.61	26	53	43	401	0.71	a NET< CL
15	238.67	480.42	194	73	55	569	0.96	a
16	250.59	504.20	34	51	41	377	0.67	a NET< CL
17	285.06	573.00	13	40	32	254	0.50	a NET< CL
18	295.05	592.95	75	57	44	395	0.77	a
19	338.24	679.14	31	52	42	349	0.85	a NET< CL
20	351.86	706.33	89	68	54	499	1.13	a
21	383.19	768.84	48	55	43	349	1.04	a

=====  
 PEAK SEARCH RESULTS  
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	508.83	1019.60	68	39	29	205	0.61	a Wide Pk
23	511.03	1023.99	1124	107	69	666	2.08	b
24	513.61	1029.14	62	65	52	461	1.40	c
25	558.45	1118.64	202	56	40	294	1.26	a
26	569.67	1141.03	85	61	47	392	1.40	a
27	583.29	1168.22	50	66	53	436	1.86	a NET< CL
28	597.20	1195.99	25	53	43	361	1.15	a NET< CL
29	609.09	1219.71	83	49	38	297	1.05	a
30	669.67	1340.62	48	33	25	137	0.79	a
31	693.47	1388.11	79	75	60	499	2.06	a
32	803.09	1606.89	113	48	36	223	1.56	a
33	911.38	1823.02	42	43	33	206	1.69	a
34	1460.89	2919.76	423	50	23	98	2.16	a
35	1764.41	3525.52	30	24	18	61	1.74	a

170562D01.SPC Analyzed by

\*\*\*\*\*  
SEEKER            B A C K G R O U N D    Q . C .        A N A L Y S I S    Version 2.2.2  
\*\*\*\*\*

ID: 051717-1 WEEKLY BKG

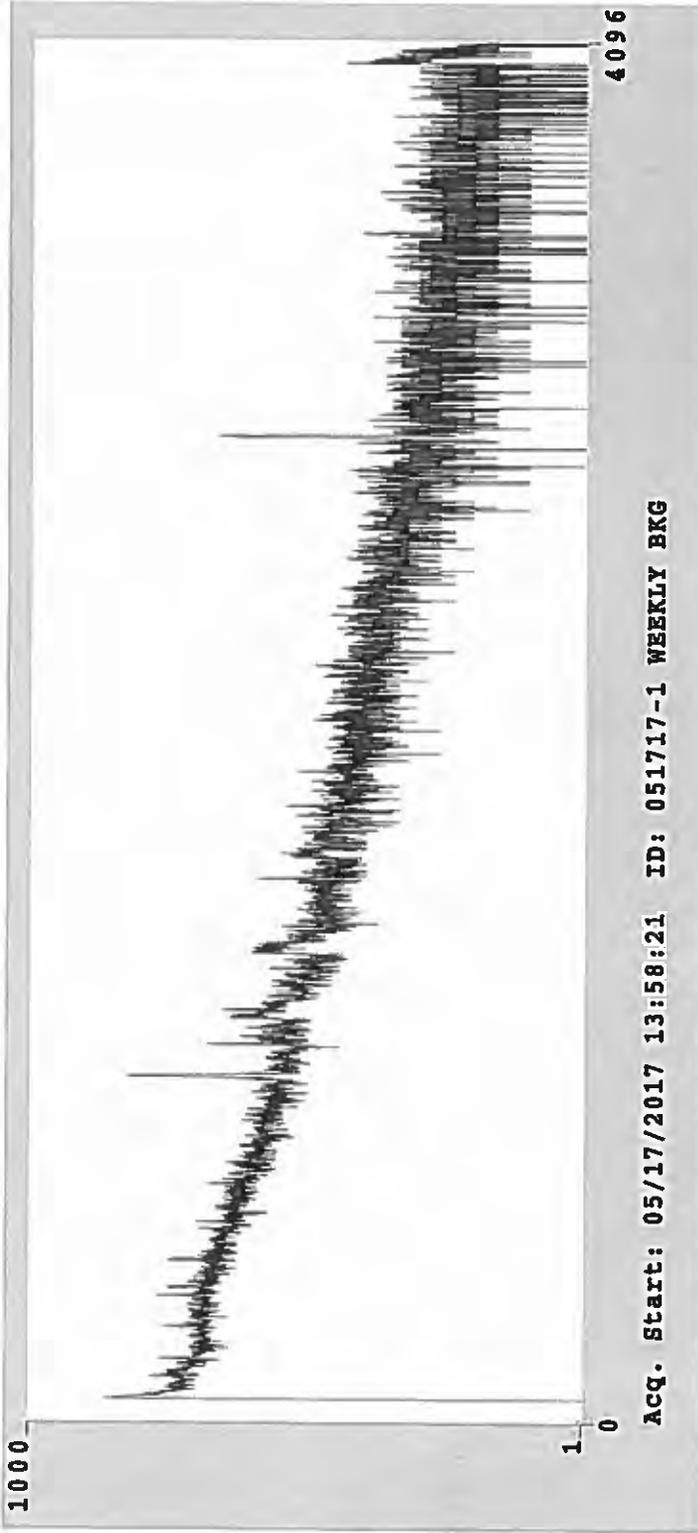
Detector # 1 Background Q.C. Analysis for 05/17/2017 13:58:21

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#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
10	40-> 50 keV Bkg	3.587	N.A.	Pass	N.A.
11	50-> 150 keV Bkg	26.014	N.A.	Pass	N.A.
12	250-> 500 keV Bkg	32.382	N.A.	Pass	N.A.
13	500->1000 keV Bkg	32.121	N.A.	Pass	N.A.
14	1000->2000 keV Bkg	17.664	N.A.	Pass	N.A.
15	150-> 250 keV Bkg	22.080	N.A.	Pass	N.A.

-----

Q.C. Results Saved.



## **Gamma Spectroscopy**

### **Quality Control Data**

### **Daily Instrument Performance Checks**

## CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

PAIIP0720

66354A-307

215 Grams of Sand in Metal Can

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solution sources. The Am-241 was calibrated by 4 pi alpha liquid scintillation counting. All other radionuclides were calibrated using a germanium gamma spectrometer system. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Analytix maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Rev. 1, February, 1979.

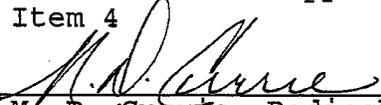
Calibration date: July 1, 2003 12:00 EST

ISOTOPE	GAMMA-RAY ENERGY	HALF-LIFE	GAMMA-RAYS PER SECOND	TOTAL UNCERTAINTY %
Am-241	59.5	432 y	1316	3.0
Cd-109	88	462.6 d	1879	3.3
Co-57	122	271.79 d	1042	2.8
Ce-139	166	137.6 d	1432	2.8
Hg-203	279	46.61 d	3223	2.7
Sn-113	392	115.1 d	1978	2.6
Cs-137	662	30.07 y	1272	3.0
Y-88	898	106.6 d	5106	2.6
Co-60	1173	5.2714 y	2424	2.7
Co-60	1332	5.2714 y	2449	2.6
Y-88	1836	106.6 d	5335	2.6

Approximately 126.5 mL of customer supplied sand.

P O NUMBER EW060303, Item 4

SOURCE PREPARED BY:

  
 M. D. Currie, Radiochemist

Q A APPROVED:

  
 8-1-03

This standard will expire one year after the calibration date.

*RSO # 767*  
*Rec'd 8/13/04*  
*JJB*



**CERTIFICATE OF CALIBRATION**  
**Standard Radionuclide Source**

68681-307

215 Grams of Sand in Metal Can

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solution sources. The Am-241 was calibrated by 4 pi alpha liquid scintillation counting. All other radionuclides were calibrated using a germanium gamma spectrometer system. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Analytical maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Rev. 1, February, 1979.

Calibration date: July 1, 2004 12:00 EST

ISOTOPE	GAMMA-RAY ENERGY	HALF-LIFE	GAMMA-RAYS PER SECOND	TOTAL UNCERTAINTY %
Am-241	59.5	432 y	1355	3.0
Cd-109	88	462.6 d	1900	3.3
Co-57	122	271.79 d	995.1	3.0
Ce-139	166	137.6 d	1411	2.8
Hg-203	279	46.61 d	3241	2.7
Sn-113	392	115.1 d	1939	2.6
Cs-137	662	30.07 y	1247	3.0
Y-88	898	106.6 d	4853	2.6
Co-60	1173	5.2714 y	2457	2.7
Co-60	1332	5.2714 y	2474	2.6
Y-88	1836	106.6 d	5064	2.6

140 mL of customer supplied sand.

P O NUMBER 70564, Item 4

SOURCE PREPARED BY: *M. D. Currie*  
 M. D. Currie, Radiochemist

Q A APPROVED: *M. D. Currie 8-9-04*

This standard will expire one year after the calibration date.

*≈ 203µCi*



PAT ID 0636  
recd 8-02-02  
Phone (404) 352-8677  
Fax (404) 352-2837

# CERTIFICATE OF CALIBRATION

## Standard Radionuclide Source

64122-307

215 Grams of Sand in Metal Can

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solution sources. The Am-241 was calibrated by 4 pi alpha liquid scintillation counting. All other radionuclides were calibrated using a germanium gamma spectrometer system. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Analytical maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Rev. 1, February, 1979.

Calibration date: July 1, 2002 12:00 EST

ISOTOPE	GAMMA-RAY ENERGY	HALF-LIFE		GAMMA-RAYS PER SECOND	TOTAL UNCERTAINTY %
Am-241	59.5	432	y	1301	5.0
Cd-109	88	462.6	d	1882	5.0
Co-57	122	271.79	d	994.2	4.7
Ce-139	166	137.6	d	1420	4.3
Hg-203	279	46.61	d	3085	4.1
Sn-113	392	115.1	d	2094	4.1
Cs-137	662	30.07	y	1320	4.8
Y-88	898	106.6	d	4847	4.2
Co-60	1173	5.2714	y	2354	4.1
Co-60	1332	5.2714	y	2382	4.2
Y-88	1836	106.6	d	5068	4.0

Approximately 140 mL customer supplied sand.

P O NUMBER EW060602, Item 4

SOURCE PREPARED BY: M. Taskaeva  
M. Taskaeva RadiochemistQ A APPROVED: recd 7/31/02

This standard will expire one year after the calibration date.

RSO # 720 was opened and split into multiple LSC vials, as shown

720.3020.47	-1	35.8071 g	(Bal 12)
	-2	36.1586 g	
	-3	36.1325	
	-4	36.0040	
	-5	36.4197	
	-6	34.5663	

These will be used as  $\delta$  daily check sources

*JLB*  
10/30/06

Continued on Page

Read and Understood By

*JLB*

10/30/06

Signed

Date

Signed

Date

RSO #969 was opened and split into multiple LSC vials, to be used as check sources, as shown

767.3020.48-7	36.6640g	(Bal 12)
↓	8 36.1856g	↓
	9 36.3396g	
	10 35.9931g	
	11 36.7952g	
	12 33.1100g	

JSS  
10/30/06

Continued on Page

*[Signature]*

10/30/06

Read and Understood By

Signed

Date

Signed

RSO # 636 was opened and split into multiple LSC vials, to be used as daily check sources, as shown

636.3020.49-13	34.2237 g	(Bal 12)
14	33.7917	
15	34.6628	
16	34.1622	
17	34.2401	
18	34.6838	

The remaining 9.1386g was transferred to a 200 ml plastic beaker and marked for disposal.

*[Signature]*  
10/30/06

Continued On Page \_\_\_\_\_

Read and Understood By \_\_\_\_\_

*[Signature]* 10/30/06

Signed

Date

Signed

Date

ALS

### Gamma Spectrometer Calibration Log

Date: 5/16/17

Reviewed By/Date: JP 5/16/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.				JP	JP					
2.				JP	JP					
3.				JP	JP					
4.				JP	JP					
5.				JP	JP	1332 FWHM	JP			
6.				JP	JP					
7.				JP	JP					
8.				JP	JP					
9.				JP	JP					
10.	JP			JP	JP					

\*\* Corrective Action:

\*\*\* Due to detector \_\_\_ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector \_\_\_ is online for the date of \_\_\_\_\_

471546 A

Form 754r16a.doc (10/27/11)

\*\*\*\*\*  
**SEEKER**                    **D E T E C T O R**    **Q . C .**            **A N A L Y S I S**    **Version 2.2.2**  
 \*\*\*\*\*

ID: DAILY CHECK

Detector # 8 Detector Q.C. Analysis for 05/16/2017 06:23:42

Standards File #: 97 (Daily Performance Check( S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T-Test
1	60 keV Centroid	123.049	N.A.	Pass	N.A.
2	60 keV FWHM	7.196E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	5.808E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1325.134	N.A.	Pass	N.A.
5	662 keV FWHM	1.312	N.A.	Pass	N.A.
6	662 keV Efficiency	1.681E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2663.113	N.A.	Pass	N.A.
8	1332 keV FWHM	1.873	N.A.	Pass	N.A.
9	1332 keV Efficiency	9.515E-03	N.A.	Pass	N.A.

\*\*\*\*\*  
**SEEKER                    D E T E C T O R   Q . C .                    A N A L Y S I S    Version 2.2.2**  
 \*\*\*\*\*

**ID: DAILY CHECK**

Detector # 9 Detector Q.C. Analysis for 05/16/2017 06:23:52

Standards File #: 97 (Daily Performance Check( S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T-Test
1	60 keV Centroid	123.179	N.A.	Pass	N.A.
2	60 keV FWHM	8.475E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	5.538E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1324.605	N.A.	Pass	N.A.
5	662 keV FWHM	1.384	N.A.	Pass	N.A.
6	662 keV Efficiency	1.476E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2661.825	N.A.	Pass	N.A.
8	1332 keV FWHM	1.993	N.A.	Pass	N.A.
9	1332 keV Efficiency	8.051E-03	N.A.	Pass	N.A.

ALS

### Gamma Spectrometer Calibration Log

Date: 5/17/17

Reviewed By/Date: JP 5/17/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.				JP	JP					
2.					JP					
3.					JP	1332 FWHM	JP			
4.					JP					
5.					JP					
6.					JP	1332 FWHM	JP			
7.					JP					
8.					JP					
9.					JP					
10.	JP				JP					

\*\* Corrective Action:

\*\*\* Due to detector \_\_\_ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector \_\_\_ is online for the date of \_\_\_\_\_

471547 A

Form 754r16a.doc (10/27/11)



\*\*\*\*\*  
 SEEKER            D E T E C T O R    Q . C .        A N A L Y S I S    V e r s i o n   2 . 2 . 2  
 \*\*\*\*\*

ID: DAILY CHECK

Detector # 8 Detector Q.C. Analysis for 05/17/2017 05:49:31

Standards File #: 97 (Daily Performance Check( S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T-Test
1	60 keV Centroid	123.116	N.A.	Pass	N.A.
2	60 keV FWHM	7.087E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	5.659E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1325.194	N.A.	Pass	N.A.
5	662 keV FWHM	1.311	N.A.	Pass	N.A.
6	662 keV Efficiency	1.643E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2663.201	N.A.	Pass	N.A.
8	1332 keV FWHM	1.879	N.A.	Pass	N.A.
9	1332 keV Efficiency	9.576E-03	N.A.	Pass	N.A.

\*\*\*\*\*  
 SEEKER            D E T E C T O R    Q . C .    A N A L Y S I S    V e r s i o n   2 . 2 . 2  
 \*\*\*\*\*

ID: DAILY CHECK

Detector # 9 Detector Q.C. Analysis for 05/17/2017 05:49:40

Standards File #: 97 (Daily Performance Check( S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T-Test
1	60 keV Centroid	123.205	N.A.	Pass	N.A.
2	60 keV FWHM	8.517E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	5.711E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1324.190	N.A.	Pass	N.A.
5	662 keV FWHM	1.404	N.A.	Pass	N.A.
6	662 keV Efficiency	1.408E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2661.055	N.A.	Pass	N.A.
8	1332 keV FWHM	1.883	N.A.	Pass	N.A.
9	1332 keV Efficiency	8.011E-03	N.A.	Pass	N.A.

ALS

### Gamma Spectrometer Calibration Log

Date: 5/18/17

Reviewed By/Date: JP 5/18/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.		<del>AK</del>		<del>AK</del>	AK					
2.					AK					
3.					✓	1332 FWHM	JP			
4.					—	1332 FWHM	JP			
5.					—	1332 FWHM	JP	1332 ECF		
6.					AK					
7.					AK					
8.					AK					
9.					AK					
10.	AK	✓	✓	✓	✓					

\*\* Corrective Action: JP 5/18/17

\*\*\* Due to detector \_\_\_\_\_ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector \_\_\_\_\_ is online for the date of \_\_\_\_\_

471551 A

\*\*\*\*\*  
SEEKER            D E T E C T O R    Q . C .        A N A L Y S I S    V e r s i o n 2 . 2 . 2  
\*\*\*\*\*

ID: DAILY CHECK

Detector # 1 Detector Q.C. Analysis for 05/18/2017 07:36:57

Standards File #: 97 (Daily Performance Check( S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T-Test
1	60 keV Centroid	122.801	N.A.	Pass	N.A.
2	60 keV FWHM	7.508E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	6.012E-03	N.A.	Pass	N.A.
4	662 keV Centroid	1324.595	N.A.	Pass	N.A.
5	662 keV FWHM	1.441	N.A.	Pass	N.A.
6	662 keV Efficiency	1.537E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2663.252	N.A.	Pass	N.A.
8	1332 keV FWHM	2.089	N.A.	Pass	N.A.
9	1332 keV Efficiency	6.797E-03	N.A.	Pass	N.A.

ALS

### Gamma Spectrometer Calibration Log

Date: 5/19/17

Reviewed By/Date: JP 5/19/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.				JP	JP					
2.				JP	JP					
3.				JP	JP					
4.				JP	JP					
5.				JP	JP					
6.				JP	JP					
7.				JP	JP					
8.				JP	JP					
9.				JP	JP					
10.	JP			JP	JP					

\*\* Corrective Action:

\*\*\* Due to detector \_\_\_\_\_ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector \_\_\_\_\_ is online for the date of \_\_\_\_\_

471555 A

Form 754r16a.doc (10/27/11)

\*\*\*\*\*  
 SEEKER                    D E T E C T O R    Q . C .        A N A L Y S I S    V e r s i o n 2 . 2 . 2  
 \*\*\*\*\*

ID: DAILY CHECK

Detector # 1 Detector Q.C. Analysis for 05/19/2017 06:15:25

Standards File #: 97 (Daily Performance Check( S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T-Test
1	60 keV Centroid	122.679	N.A.	Pass	N.A.
2	60 keV FWHM	8.194E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	5.957E-03	N.A.	Pass	N.A.
4	662 keV Centroid	1324.389	N.A.	Pass	N.A.
5	662 keV FWHM	1.493	N.A.	Pass	N.A.
6	662 keV Efficiency	1.533E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2662.818	N.A.	Pass	N.A.
8	1332 keV FWHM	2.209	N.A.	Pass	N.A.
9	1332 keV Efficiency	7.149E-03	N.A.	Pass	N.A.