Omaha Public Power District

10 CFR 50.90
10 CFR 50.82

LIC-26-0010
July 07, 2026

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Fort Calhoun Station, Unit No. 1
Renewed Facility License No. DPR-40
NRC Docket No. 50-285

Subject: Response to Request for Confirmatory Information Re: Fort Calhoun – License Amendment to Approve Revision 3 of the License Termination Plan – L-20256-LLA-0045

References:

1. Letter from OPPD (B. Pearson) to USNRC, "License Amendment Request (LAR) To Revise License Termination Plan (LTP)" (ML26061A204), dated February 24, 2026.
2. Email from USNRC to OPPD (B. Pearson), "Request for Confirmatory Information Re: Fort Calhoun – License Amendment to Approve Revision 3 of the License Termination Plan – L-20256-LLA-0045" (ML26149A337), dated May 28, 2026.

On February 24, 2026 (Reference 1) OPPD submitted a License Amendment Request to revise the License Termination Plan, Revision 3. On May 21, 2026, the NRC staff sent the licensee DRAFT requests for confirmatory information (RCIs) to ensure that the questions were understandable, the regulatory basis was clear, there is no proprietary information contained in the RAIs, and to determine if the information was previously docketed. On May 28, 2026, OPPD and the NRC staff held a clarification call to discuss the DRAFT RCIs. Following the clarification call, an email was sent containing the final version of the RCIs and to ensure the request was docketed (Reference 2).

The response to the request for confirmatory information is enclosed with this submission.

Attachment 1: Responses to NRC Requests for Confirmatory Information, Fort Calhoun Station License Termination Plan Revision 3
Attachment 2: FCSD-RA-LT-301, *Survey Unit Classification*
Attachment 3: Kd Sampling Report
Attachment 4: Revised Pages for FCS LTP Chapters 1, 5, and 6

There are no regulatory commitments contained within this letter.

If you should have any questions regarding this submittal or require additional information, please contact Mr. Benjamin P. Pearson – Regulatory Assurance & Emergency Planning Manager at (531) 226-7249.

U. S. Nuclear Regulatory Commission
LIC-26-0010

Respectfully,

Benjamin P. Pearson
Regulatory Assurance and Emergency Planning Manager

BPP/bpp

c: M. V. Doell, NRC Senior Project Manager

ATTACHMENT 1

Responses to NRC Requests for Confirmatory Information, Fort Calhoun Station
License Termination Plan Revision 3

8 Pages Follow

RCI 1: Completion of Backfilling Activities

Please clarify the completion dates of backfilling for the Auxiliary and Containment Buildings, where remediation attempts led to revision of the DCGLs and submittal of FCS LTP Revision 2. Section 3.4.5 indicates that the Containment Building was not backfilled at the time Revision 3 of the LTP was submitted, and that backfilling was completed for the Auxiliary Building, but no date was provided.

This information is needed for the NRC staff's safety assessment of the FCS groundwater monitoring plan, where OPPD stated the program would continue for two years after the last licensed material was removed from the site. The approach of using the last licensed material removal for determining the period of monitoring for FCS groundwater input, instead of monitoring until license termination, was incorporated into LTP Revision 1 following the response to Request for Additional Information (RAI) TE-4 in 2023 (ML23236A478). This was prior to implementation of the grouting approach incorporated in LTP Revision 2 for the Auxiliary and Containment Buildings.

For the safety assessment of LTP Revision 3, the staff considers both the magnitude of the radioactivity entombed by grout in the Auxiliary and Containment Buildings and the potential for mechanical perturbations during the backfilling process. The staff also notes that for other more recent decommissioning sites, the soil disturbing approach was preferred instead of the vague license material approach. In addition, Section 5.3.4 of the draft NEI 22-01 guidance (September 15, 2025, ML25258A229) incorporated the soil disturbing approach.

FCS RCI 1 Response:

The following are the dates that backfilling was completed for the Containment Building (CB) and Auxiliary Building (AB):

- AB to 3 ft below grade: April – June 2025
- CB to 1003' elevation: June 2025
- AB/CB Footprint (including the Containment Waste Structure): February 2026

The technical basis for discontinuing groundwater monitoring after the 3rd Quarter of 2026 is supported by groundwater monitoring results, conservative dose modeling assumptions, subsurface sampling data, and an evaluation of the potential for backfilling-related foundation disturbance to result in a significant radionuclide release.

- Extensive FSS groundwater monitoring over the past two years has shown low residual radioactivity in existing groundwater, with resulting dose consequences that are limited and below the 0.5 mrem/yr allocation. The monitoring results also indicate that residual radioactivity is stable or decreasing, and no radionuclide concentrations have approached or exceeded EPA MCLs.
- Because the existing groundwater dose calculation uses conservative maximum concentrations, assumes worst-case annual water consumption at the highest quarterly concentration, and applies a dose-doubling factor, any potential release from the backfilled basements would be bounded by the existing groundwater dose calculation.
- Subsurface sampling identified only low concentrations of H-3 and Sr-90 beneath the AB 989-ft Elevation. The majority of residual radioactivity in the AB basements consists of Cs-137; however, Cs-137 was not detected above the critical level in the subsurface groundwater samples and has not been detected in any FSS groundwater monitoring result during the past two years.

- Based on discussions with Dr. Terry Sullivan, the likelihood that backfilling would result in through-fracturing of the foundation and a significant radionuclide release to groundwater is considered low.

The existing groundwater dose calculation is conservative for the following reasons:

- The dose allocated to Existing Groundwater is 0.5 mrem/yr (a priori fraction = 2%).
- The maximum detectable groundwater concentration for each ROC is used.
- A positive result is defined as a sample result greater than or equal to the laboratory-reported, sample-specific critical value (Lc). Actual analytical result values are reported and used for dose estimates.
- The dose calculation assumes that the entire annual water consumption occurs at the worst-case quarterly concentration. Because positive results are episodic, this assumption conservatively estimates dose.
- Groundwater dose estimates are increased by a factor of 2 to account for the relationship between monitoring-well results and groundwater conditions below the Deconstruction Area, conservatively compensating for uncertainty associated with dispersion and unsaturated-zone processes.

Table 1 – Maximum Dose per Radionuclide and Total Existing Groundwater Dose Through 1st Quarter 2026

ROC Dose (mrem/yr)		Location	Quarter
C-14	0.1004	MW-13A	1Q 2025
H-3	0.0363	MW-17	1Q 2024
Fe-55	0.1215	MW-1A	2Q 2024
Ni-63	0.0099	MW-13B	3Q 2025
Sr-90	0.2054	MW-6	3Q 2024
Sum	0.4736		

Section 6.12.7.4 of the LTP Revision 1 Safety Evaluation Report states that the staff found two years of quarterly groundwater monitoring data to be sufficient based on site hydrogeologic flow characteristics and historical Sr-90 concentration trends.

The table below summarizes the maximum and average Sr-90 concentrations above the lower limit of detection (LLD) for all wells reported in Table III.9 of the ARERRs for 2007 through 2023. It also presents Sr-90 results from FSS groundwater monitoring for the period 2024–2025, based on all 17 wells that have been sampled quarterly since the first quarter of 2024.

Table 2 – Maximum and Average Sr-90 Results and Percentage of MCLs

Timeframe	Max. Sr-90 Result (pCi/l)	Percentage of MCL	Avg. Sr-90 Result (pCi/l)	Percentage of MCL
2007 - 2021	2.810	0.35	0.642	0.08
2011 - 2018	0.890	0.11	0.535	0.07
2019 - 2021	0.878	0.11	0.710	0.09
2022 - 2023	0.777	0.10	0.647	0.09
2023 - 2024	0.923	0.12	0.064	0.008

Subsurface sampling beneath AB and CB

LTP Section 2.5 discusses the requirements for continuing characterization sampling beneath the concrete of the CB basement and Spent Fuel Pool. In addition, NRC staff requested that subsurface sampling be performed near the AB East Trenches.

In March 2026, samples were collected to evaluate soil and groundwater below the CB and AB foundations. Three locations were selected: one beneath the CB foundation and two beneath the AB foundation. Figure 1 shows the sampling locations in relation to a drone photo of the AB 989-ft Elevation.

Figure 1 – Subsurface Sampling Locations

The soil and water samples were sent to GEL Laboratories for analysis of the full suite of radionuclides listed in LTP Table 5-2. The positive results for the sampling are contained in Tables 3 and 4 below.

Table 3 – Subsurface Groundwater Sampling Positive Results

Sample ID	Location	Parameter	Lab Result (pCi/l)	TPU (pCi/l)	MDC (pCi/l)	Critical Level (Lc) (pCi/l)	DCF (mrem/yr per pCi/l)	Dose (mrem/yr)
7000X-1-CJ-LWTX-035	AB 989' East	Sr-90	0.359	0.387	0.637	0.281	1.10E-01	0.0396
7000X-1-CJ-LWTX-035	AB 989' East	H-3	134	116	174	70.1	4.55E-05	0.0061
7000X-1-CJ-LWTX-036	AB 989' West	Sr-90	0.357	0.446	0.75	0.338	1.10E-01	0.0393
7000X-1-CJ-LWTX-036	AB 989" West	H-3	101	109	175	70.5	4.55E-05	0.0046

Table 4 – Subsurface Soil Sampling Positive Results

Sample ID	Location	Parameter	Lab Result (pCi/g)	TPU (pCi/g)	MDC (pCi/g)	Subsurface BcDCGL (pCi/g)	Fraction of Subsurface BcDCGL	Dose (mrem)	EPA MOU Trigger Level (pCi/g)	Fraction of Trigger Level
7000X-1-CJ-GSBX-033	AB 989' West	H-3	13	4.73	4.52	8.66E+02	1.50E-02	0.3755	228	5.70E-02

Conclusions of Subject Matter Expert on the Likelihood of a Significant Release Due to Backfilling

The potential for backfilling to result in a groundwater release pathway was discussed with Dr. Terry Sullivan, formerly of Brookhaven National Laboratory. Based on those discussions, while through-fracturing is physically possible, the likelihood that such fracturing would result in a significant radionuclide release to groundwater is considered low.

This conclusion was based on the following observations:

- The AB 989-ft Elevation basemat is 5.5 ft thick and is designed to withstand loads during and after backfilling.
- A large number of cracks penetrating the full basemat thickness is not expected.
- If limited cracking were to occur, the cracks would be expected to be small apertures and limited hydraulic transmissivity, thereby limiting the amount of water that could contact and transport residual radioactivity.
- Given the small potential crack aperture and the large areas with little or no contamination, any crack that did form would be expected to intersect a low-contamination area.
- Before entering groundwater, residual contamination would need to diffuse from the concrete matrix, further limiting release potential.

Based on these considerations, the available groundwater and subsurface data demonstrate that residual radioactivity is limited, stable or decreasing, and bounded by conservative dose assumptions; therefore, continued groundwater monitoring beyond the third quarter of 2026 is not expected to provide additional information necessary to demonstrate compliance.

RCI 2: Instances of Contamination

Section 3.5.2.2 of the LTP Revision 3 identifies instances of contamination and remediation on the heavy haul path and in areas of the Waste Processing Structure.

(1) Provide information describing the nature, extent, and frequency of instances of contamination and remediation in the affected areas.
(2) Clarify if routine surveys of the Waste Haul Path included surveys of the bordering Waste Haul Path Buffer Zones and discuss if any instances of contamination were found in these areas.
(3) Confirm that stockpiled clean fill material, stored adjacent to survey units 8501-8508, was unimpacted by instances of contamination.

FCS RCI 2 Response:

(1) The affected areas experienced low level contamination that was typically localized and identified quickly during routine surveys and job coverage activities. These instances occurred roughly once every other week, or less frequently, and were promptly remediated at the time of discovery, preventing further spread or impact. Overall, the nature and extent of contamination remained minor, with conditions addressed immediately upon detection. During the demolition period, two contamination events occurred that required additional review, thorough investigation, and documenting in the site's corrective action program to ensure appropriate follow-up and corrective actions were put in place to minimize future events or risk to the project and site.

(2) Routine surveys of the Waste Haul Path did not typically include the bordering Waste Haul Path Buffer Zones. These buffer areas were not part of the standard survey scope; however, on occasion the tractor-mounted detectors would extend their reach slightly into the buffer zones while scanning the main haul path. Due to the configuration of the detectors and the topography of the buffer areas, performing routine scans likely would have damaged the detectors. Surveys of the buffer areas were conducted at the direction of Site Supervision to determine if the buffer areas were impacted. Low-level contamination was identified and remediated in affected areas.

(3) The clean fill material stockpile area is located approximately 70 meters up gradient from the Class 1 heavy haul path (HHP) and 225 meters from the waste processing structure (WPS) which is comprised of survey units 8501 – 8506. There are Class 2 and 3 survey units in between the clean fill stockpile and the HHP and CWS. Routine surveillances were performed of the clean fill stockpile in accordance with FCSD-RA-LT-303, *Final Status Survey Isolation and Control Measures*, prior to removing soil to fill basements and excavations. Samples collected during surveillances only showed the presence of naturally occurring radioactive material (NORM), thus the stockpile area has not been impacted by instances of contamination on the HHP and WPS.

RCI 3: Survey Unit Reclassification

Section 3.5.2.2 of the LTP Revision 3 describes the identification of contamination in several survey units in the southern Owner Controlled Area (OCA), which were remediated and reclassified. Tables 2-3, 2-4, and 2-5 of the LTP Revision 3 do not indicate which survey units were reclassified. Approved LTP Revision 2, Section 5.5.5.2, "Remediation, Reclassification, and Resurvey," notes that reclassification of a survey unit from a less restrictive classification to a more restrictive classification may be done without prior NRC approval. However, reclassification to a less restrictive classification requires prior NRC approval.

Identify the contaminated survey units in the OCA and provide original and updated classifications to ensure that LTP Revision 3 Tables 2-3 through 2-5 reflect the most up to date information. Furthermore, if the survey units were reclassified to a less restrictive MARSSIM classification (i.e. Class 1 to Class 2), provide the justification for this, including any survey data and results as applicable, for NRC review and approval.

FCS RCI 3 Response:

Tables 2-3 through 2-5 in LTP Revision 3 represent a snapshot of survey units and their classifications at the time of initial radiological characterization. The Chapter 2 tables are not intended to reflect ongoing classification status. As such, these tables are not revised to reflect changes in survey unit classification or size, or to reflect the addition of new survey units.

Survey unit classification updates are formally controlled through procedure FCSD-RA-LT-301, *Survey Unit Classification*. To support NRC's review, the most current revision of FCSD-RA-LT-301 is being provided with this response. The revision reflects the current and complete listing of survey units for FSS and their classifications. To further aid in NRC reviews, a final version of FCSD-RA-LT-301 will be submitted along with the site's request for partial site release.

All reclassification activities to date, where performed, involved movement to more restrictive classifications.

TYPO/MISC RCI 1: Assessment of Water Levels in Wells

Section 1.3.[6], third paragraph: Edits made by OPPD for the purpose of consistency with other parts of the LTP Revision 3 (e.g., Section 6.2.2) and other documents, while now consistent, do not appear to be technically correct all the time.

The driver for water levels in wells is whether the river is rising or falling and not whether the river stage is relatively high or low. For example, regardless of the season, river stage responds to precipitation or changes in upstream dam operation by rising, which leads to groundwater gradients to the south (away from the river). Stated in another way, in the spring when the river stage may be relatively high, gradients toward the river can occur when the river stage drops to lower levels after a period of no precipitation over several days to several weeks.

Assessment of water levels in wells that had corresponding river stage measurements indicated that water levels in wells differed from river stage by a foot or less; and river stage in the spring could vary by 5 feet up or down in one day or a range of 15 feet or more up or down in over the season. Water levels in wells across the site responded on a time scale of a day (hours to a few days) to river stage rising or falling. The NRC staff previously described this nuance in the safety evaluation for FCS LTP Revision 1 and ignored the inconsistency and likely misconception in the conceptual site model description in the LTPs, and instead relied on the description as a bank storage model.

FCS TYPO/MISC RCI 1 Response:

LTP Sections 1.3.6 and 6.2.2 will be revised to state:

> The groundwater in the saturated zone under the site is in strong communication with the stage level of the Missouri River, i.e., the groundwater flows both towards the river and away from the river depending on whether the river stage is declining or rising. This results in a bank storage effect.

Revised LTP text:

1.3.6 Hydrology

> According to the DSAR, groundwater flow directions have been reported to be both toward the Missouri River (northeasterly) and away from the Missouri River (south-southwesterly). The groundwater in the saturated zone under the site is in strong communication with the stage level of the Missouri River, i.e., the groundwater flows both towards the river and away from the river depending on whether the river stage is declining or rising. This results in a bank storage effect.

6.2.2 Hydrogeology

> Groundwater flow directions have been reported to be both toward the Missouri River (northeasterly) and away from the Missouri River (south-southwesterly) depending on the river stage. The groundwater in the saturated zone under the site is in strong communication with the stage level of the Missouri River, i.e., the groundwater flows both towards the river and away from the river depending on whether the river stage is declining or rising. This results in a bank storage effect. Based on the groundwater depth to water data and corresponding groundwater elevation data, groundwater contours are consistent with historical data and flow towards the river.

TYPO/MISC RCI 2: Sorption Coefficient Report Provided for License Condition

In accordance with the license condition approving the FCS LTP Revision 1 and OPPD's response to RAI TE2-11, OPPD collected surface and subsurface soil samples to determine site-specific soil Kd values. This work and the findings are documented in the "Distribution Coefficient (Kd) Sampling Report," dated June 19, 2024. Please submit the report to the docket for inclusion to ADAMS so that the NRC staff can close out the associated license condition.

In addition, the NRC staff noted that the samples were collected from the area between the guard house and the loading area. OPPD, however, did not provide a basis for how these values are representative of the backfill fill soil to be used for basement fill, the contaminated zone, and the unsaturated zone soil. OPPD notes in their response to RAI TE2-11 that after reanalysis is completed, a report would be developed that would include a table of reanalyzed DCGLs for soil, basement surfaces, embedded pipe, buried pipe, and the existing groundwater dose factors. The NRC staff did not find this table included in the identified Kd report. To fulfill the identified license condition, OPPD should clarify the basis for using surface and subsurface samples collected from that specific location, identify how these samples are representative of the different media on the site, and provide the updated table of DCGLs for each media calculated using the updated Kd values discussed in the response to RAI TE2-11.

FCS TYPO/MISC RCI 2 Response:

The document entitled *Distribution Coefficient (Kd) Sampling Report, Fort Calhoun Station, Blair, Nebraska*, Dated June 2024, is included with this response. Soil samples were collected from different types and depths to best represent the structural fill and backfill materials. Soil samples were comprised of 5-part composites so that the results would better represent overall site conditions.

Samples were collected from the shallow unsaturated soils, from deeper saturated soils, and from stockpiled materials that were then used for backfilling.

It should be noted that although site specific values were identified, the default or published values were more conservative and therefore used in DCGL development.

ATTACHMENT 2

FCSD-RA-LT-301, *Survey Unit Classification*

25 Pages Follow

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Survey Unit Classification

Revision 4

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- ☐ Non-Proprietary
- ☒ Proprietary
- ☐ Restricted Information
- ☐ Safeguards Information
- ☐ Sensitive Security Information

- ☐ New
- ☐ Title Change
- ☒ Revision
- ☐ Rewrite
- ☐ Cancellation

Effective Date: 6/24/2026 | 9:42 AM CDT

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RECORD OF REVISIONS

Revision	Revision Title Description and Reason for Change
0	Initial issue.
1	Update to survey unit table and maps. Expanded on changing survey unit classification to a more restrictive classification.
2	Expanded upon Survey Unit Surface Area Limits
3	Updated survey unit classification tables.
4	Updated survey unit classification tables. Updated Attachment 5.1 Structure Survey Units for FSS. Administrative updates and changes.

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1 PURPOSE AND SCOPE

1.1 Purpose

This procedure defines the decision process for identifying and classifying survey units in accordance with applicable U.S. Nuclear Regulatory Commission (NRC) regulations and guidance documents, specifically NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) (Reference 2.1.1) and Chapter 5 of the Fort Calhoun Station (FCS) Decommissioning Project License Termination Plan (LTP) (Reference 2.2.1).

1.2 Scope

All areas of the FCS site do not have the same potential for residual contamination; therefore, they will not require the same magnitude of survey coverage to achieve an acceptable level of confidence to satisfy the established release criteria. Consequently, survey units are classified by contamination potential. Contamination potential is determined by evaluating available information on the radiological characteristics of the area, the historical use of radioactive materials in the area, and by professional judgment. This evaluation includes review of initial and current characterization surveys, historical site assessments, and any other available radiological survey information.

To provide an overall planning basis for the final status survey (FSS), the site was divided into two categories, impacted and non-impacted. To enable a concerted survey effort in the potentially contaminated areas, the impacted areas were further subdivided into Class 1, Class 2, or Class 3 survey units.

The end state of the site includes open land areas, above-grade structures, below-grade structure basements (including any penetrations and embedded piping) and buried piping. A list of buried piping, embedded piping, and penetrations to remain, as well as initial classification of the piping and penetrations, is provided in calculations and position paper (CPP) FC-21-002, "Description of Embedded Piping, Penetrations, and Buried Pipe to Remain in Fort Calhoun End State" (Reference 2.2.2)

This procedure applies to all personnel performing site characterization, radiological assessment (RA), remedial action support survey (RASS), and FSS sample plan development or implementation.

2 REFERENCES

2.1 Regulatory Requirements

2.1.1 NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" Revision 1

2.2 Procedures, Plans, and Technical Documents

2.2.1 Fort Calhoun Station Decommissioning Project License Termination Plan

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2.2.2 FC-21-002, "Description of Embedded Piping, Penetrations, and Buried Pipe to Remain in Fort Calhoun End State"

2.2.3 EPND-RM-100, "Record Management Program"

2.2.4 EPND-RM-101, "Records Creation, Index, and Transmittal Process"

2.2.5 FC-SRRS, "SRRS Process"

2.2.6 FCSD-RA-LT-200, "Characterization Survey Plan"

2.2.7 RSCS TSD 20-01, "Historical Site Assessment for Fort Calhoun Station"

2.2.8 FCSD-RA-LT-303, "Final Status Survey Isolation and Control Measures"

3 GENERAL

3.1 Definitions

3.1.1 Class 1 Areas: Areas that have, or had prior to remediation, a potential for radioactive contamination (based on site operating history) or known contamination (based on previous radiation surveys) above the derived concentration guideline level (DCGL). Examples of Class 1 areas include site areas previously subjected to remedial actions, locations where leaks or spills are known to have occurred, former burial or disposal sites, waste storage sites, and areas with contaminants in discrete solid pieces of material and high specific activity. The suggested size limitation is ≤ 100 m^2 for above-ground buildings and $\leq 2{,}000$ m^2 for land and basement areas.

3.1.2 Class 2 Areas: Areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination, but are not expected to exceed the DCGL or FSS dose criterion. To justify changing the classification from Class 1 to Class 2, there should be measurement data that provides a high degree of confidence that no individual measurement would exceed the DCGL. Other justifications for reclassifying an area as Class 2 may be appropriate based on site-specific considerations. Examples of areas that might be designated as Class 2 for the FSS include locations where radioactive materials were present in an unsealed form, potentially contaminated transport routes, areas downwind from stack release points, upper walls and ceilings of buildings or rooms subjected to airborne radioactivity, areas handling low concentrations of radioactive materials, and areas on the perimeter of former contamination control areas. The suggested size limitation is $\leq 1{,}000$ m^2 for above-ground buildings and $\leq 10{,}000$ m^2 for land and basement areas.

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3.1.3 Class 3 Areas: Any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the DCGL, based on site operating history and previous radiation surveys. Examples of areas that might be designated as Class 3 include buffer zones around Class 1 or Class 2 areas, and areas with very low potential for residual contamination but insufficient information to justify a non-impacted classification. There are no restrictions on structure or land size for this classification.

3.1.4 Derived Concentration Guideline Level (DCGL): DCGLs are radionuclide-specific activity concentrations within a survey unit corresponding to the release criterion derived from activity and dose relationships through various exposure pathway scenarios. The DCGL is based on the spatial distribution of the contaminant and hence is derived differently for the nonparametric statistical test ($DCGL_W$) and the elevated measurement comparison ($DCGL_{EMC}$). The $DCGL_W$ (the DCGL that is used for the statistical tests) is based on an average concentration over a large area. The $DCGL_{EMC}$ (the DCGL that is used for the elevated measurement comparison) is derived separately for small areas of elevated activity.

3.1.5 Final Status Survey: Measurements and sampling to describe the radiological conditions of a site, following completion of decontamination activities (if any) in preparation for release.

3.1.6 Impacted Areas: Areas with a possibility of containing residual radioactivity from licensed radioactive materials in excess of natural background and fallout levels.

3.1.7 Non-Impacted (NI) Areas: Areas where there is no reasonable possibility of residual contamination from licensed activities.

3.1.8 Standard Deviation (Sigma): The standard deviation of the measurement results expresses the variability in the sample population. The standard deviation of measurements in a survey unit is used during FSS design to calculate the relative shift. The standard deviation is a survey unit-specific variable, typically estimated from preliminary survey data (e.g., characterization or post-remediation).

3.2 Abbreviations

AB	Auxiliary Building
BOP	balance of plant
CAD	Computer Aided Design
CB	Containment Building
CPP	calculations and position paper
DA	Deconstruction Area

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DCGL	derived concentration guideline level
EMC	elevated measurement comparison
FSS	final status survey
GIS	Geographic Information System
HSA	historical site assessment
LTP	license termination plan
LT/FSS	License Termination/Final Status Survey
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
NI	non-impacted
NRC	United States Nuclear Regulatory Commission
OpDCGL	Operational DCGL
QA	quality assurance
RA	radiological assessment
RASS	remedial action support survey
TB	Turbine Building

3.3 Responsibilities

3.3.1 License Termination/Final Status Survey (LT/FSS) Manager

- Provides FSS program direction and technical guidance and ensures the program adheres to all applicable regulatory and license requirements.
- Ensures proper implementation of this procedure.
- Reviews and approves revisions to survey unit classifications.

3.3.2 LT/FSS Specialist

- Evaluates and interprets survey data and verifies that the initial or current classification of a survey unit is correct.
- Notifies the LT/FSS Manager when survey unit classification requires modification from the initial or current classification as maintained in Attachment 5.1, Survey Unit Classifications.

3.3.3 Survey Mapping/CAD/GIS Specialist

- Preparation and revision of drawings and other graphics, as necessary, to support survey unit final classification or re-classification.

3.4 Precautions, Limitations, and Prerequisites

3.4.1 Precautions

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A. Documents and databases containing FSS data and survey records are quality assurance (QA) records when complete. Positive control of these records shall be maintained in accordance with EPND-RM-100, "Record Management Program" (Reference 2.2.3), EPND-RM-101, "Records Creation, Index, and Transmittal Process" (Reference 2.2.4), and FC-SRRS, "SRRS Process" (Reference 2.2.5).

B. A survey unit may not be reclassified to a lesser classification (i.e., from a Class 1 to a Class 2 or from a Class 2 to a Class 3) without LT/FSS Manager approval and NRC concurrence.

C. If possible, all Class 1 open land areas shall have a Class 2 or Class 3 "buffer zone" between the Class 1 area and any non-impacted area.

D. If an individual FSS measurement in a Class 2 survey unit exceeds the Operational DCGL (OpDCGL), then the survey unit, or portion of the survey unit will be investigated. If small areas of elevated activity exceeding the OpDCGL are confirmed by this investigation or , if the investigation suggests that there is a reasonable potential that contamination is present in excess of the OpDCGL, then all or part of the survey unit will be reclassified as Class 1 and the survey strategy for the survey unit will be redesigned.

E. If an individual survey measurement in a Class 3 survey unit exceeds 50 percent of the OpDCGL, then the survey unit, or a portion of a survey unit, will be investigated. If the investigation confirms residual radioactivity in excess of 50 percent of the OpDCGL, then the survey unit, or the impacted portion of the survey unit will be reclassified to a Class 1 or a Class 2 survey unit and the survey will be redesigned and reperformed as a Class 1 or Class 2 survey unit.

F. Reclassification of a survey unit from a less restrictive classification to a more restrictive classification may be done without prior NRC approval.

3.4.2 Limitations

A. A survey unit must be reclassified if at any time during the planning, design, or data evaluation phases it is determined that the criteria for the current classification are no longer satisfied.

B. Survey units will not be reclassified during the actual performance of the survey process. The survey shall be completed in accordance with the survey instructions. Once data evaluation is complete, the area will be investigated, remediated, and/or reclassified as appropriate.

C. Decreasing a survey unit classification (i.e., from a Class 1 to a Class 2 or a Class 2 to a Class 3) requires a notification to the NRC a minimum of 14 days prior to implementing the change in classification.

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D. Class 1 or Class 2 basement survey unit sizes can exceed the sizes provided in the definitions presented above, but the direct measurement frequency (i.e., samples per area) must be equal to or greater than that derived assuming survey unit sizes of 2,000 m^2 and 10,000 m^2 ; respectively.

E. All forms described in this procedure may be generated electronically. If electronic forms are used, the physical layout of the form may be modified provided the intent described in this procedure is not changed.

3.4.3 Prerequisites

A. The impacted open land survey areas at FCS have been subdivided into Class 1, Class 2, or Class 3 survey units. The initial classifications and survey unit boundaries for open land survey units and structures are specified in FCSD-RA-LT-200, "Characterization Survey Plan" (Reference 2.2.6). Actual open land survey unit boundaries may vary from the conceptual survey unit boundaries presented in Reference 2.2.6, based on actual conditions at the time of survey design. A list of buried piping, embedded piping, and penetrations to remain, as well as initial classification of the piping and penetrations, provided in Reference 2.2.2.

B. Each survey unit shall have only one classification.

C. Prior to performing FSS in a survey unit, the classification of the survey unit and the basis for the classification shall be verified based on any scoping, characterization, operational, and/or post-remediation surveys performed in that survey unit to date.

3.5 Records

3.5.1 Records generated by this procedure are listed below and shall be processed per References 2.2.3, 2.2.4, and 2.2.5.

A. FCSD-RA-LT-301-F-01, Survey Unit Classification Summary

B. FCSD-RA-LT-301-F-02, Survey Unit Classification Worksheet

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4 REQUIREMENTS AND GUIDANCE

i	**NOTE** Initial survey unit numbers and classifications from FCSD-RA-LT-200, "Characterization Survey Plan" are presented in Attachment 5.1. As changes are made to the physical boundaries of survey units, and as survey unit classifications change due to the results of characterization, RAs, RASSs, or FSS, Attachment 5.1 will be updated through revision to this procedure.	i

4.1 Survey Unit Classification Basis

4.1.1 Initiate FCSD-RA-LT-301-F-01, Survey Unit Classification Summary, for the survey unit.

i	**NOTE** Initial classification is performed only once, at the time of survey unit creation. Verification and change of classification can be performed at any time. Final classification is performed in conjunction with the preparation of the FSS sample plan. Only one box should be checked off on FCSD-RA-LT-301-F-01 to indicate the type of classification. However, re-classification of a survey unit requires either the "Verification" or "Final" boxes and the "Change" box to be checked off.	i

4.1.2 Denote the survey area number, survey unit number, the name of the survey unit, and the type of classification.

A. If the type of classification is "Initial," then describe the relationship between the new survey unit and the survey units described in the Reference 2.2.6 in the space denoted for "comments."

B. If the type of classification is "Verification," then describe the reason why the classification verification is being performed in the space denoted for "comments."

C. If the type of classification is "Change," then describe the reason why the classification change is being performed in the space denoted for "comments."

D. If the type of classification is "Final," then state in the space denoted for "comments" that the classification verification is being performed to support FSS design for the survey unit.

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4.1.3 Denote the current classification of the survey unit by checking the appropriate box and denote the basis for the classification as follows:

A. Summarize the function of the area of interest during facility operation.

B. Summarize any process events, spills, or radiological incidents that have been documented in Radiation Safety and Control Services technical support document 20-01, "Historical Site Assessment for Fort Calhoun Station" (HSA) (Reference 2.2.7) and are pertinent to the survey unit.

C. Summarize the historical radiological conditions of the survey unit using all pertinent radiological surveys (e.g., routine surveys, characterization, RA, RASS, Radiation Work Permit coverage surveys).

i	**NOTE** Visual inspection and walk-down is a good practice but is not always necessary to perform the classification process. This step of the procedure may be omitted if the responsible LT/FSS Specialist decides, with concurrence from the LT/FSS Manager, to make the classification without walking down the survey unit.	**i**

4.1.4 If validating final classification for FSS, then ensure that any pre-FSS walk-down requirements for the survey unit have been performed in accordance with FCSD-RA-LT-303, "Final Status Survey Isolation and Control Measures" (Reference 2.2.8).

A. Check the appropriate box on FCSD-RA-LT-301-F-01 signifying that a visual inspection and walk-down of the survey unit was or was not performed.

B. If the walk-down was performed, then record on FCSD-RA-LT-301-F-01 a brief summary of any observations and findings of the visual inspection and walk-down, including the date and time it was performed in the comment section provided. Use additional pages as necessary.

4.1.5 If the survey unit classification is being performed for verification, change, or final classification for FSS, then document the radiological survey data that is pertinent to the decision.

A. Review the results of any pertinent characterization, RASS, RA, or turnover survey data.

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B. Summarize the historical radiological conditions of the survey unit that the current classification was based on, using all pertinent radiological surveys.

4.1.6 Record a brief explanation of the review results in the comment section of FCSD-RA-LT-301-F-01, summarizing the information that was used as the basis for the classification or change in classification. Use additional pages as necessary.

4.1.7 Initiate and complete FCSD-RA-LT-301-F-02, Survey Unit Classification Worksheet, in accordance with Section 4.2 of this procedure.

4.1.8 Denote the derived classification of the survey unit by checking the appropriate box commensurate with the conclusion of FCSD-RA-LT-301-F-02.

4.2 Survey Unit Classification Worksheet

i	**NOTE** Classifying a survey unit correctly is critical to FSS design. The potential for making decision errors increases when a survey unit is classified incorrectly. This is the reason for beginning the classification process with the assumption that all survey units have residual radioactivity levels in excess of the DCGL, thereby resulting in a default Class 1 designation. Information (survey and historical) is then used to present evidence that the potential or known residual radioactivity in a survey unit is less than the DCGL, which is then used as a basis to support classification of a survey unit as Class 2, Class 3, or non-impacted. The formal screening tool, FCSD-RA-LT-301-F-02, is used to document the decision process for survey unit classification. Information obtained in previous steps of this procedure and recorded in FCSD-RA-LT-301-F-01 will be used to support the screening process described by FCSD-RA-LT-301-F-02.	**i**

4.2.1 Denote the survey area number and survey unit number.

4.2.2 Identify all applicable items by checking the appropriate boxes on FCSD-RA-LT-301-F-02 using FCSD-RA-LT-301-F-01 for input.

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i	**NOTE** A complete screening process with every question answered as positive is commensurate with a non-impacted classification.	i

4.2.3 Answer the question at the end of each classification section. If the response to the question is negative (or unknown), then the screening process is complete at that point. Otherwise, continue the screening process until a negative response is reached.

4.2.4 Record a brief summary of the basis in FCSD-RA-LT-301-F-02, using additional pages for comments as necessary.

4.3 Review and Approval

4.3.1 Review the classification package containing FCSD-RA-LT-301-F-01, FCSD-RA-LT-301-F-02, and any supplemental or supporting documents for completeness, legibility, and adequacy of classification.

4.3.2 Sign and date all forms.

4.3.3 Forward the classification package to a qualified peer reviewer.

4.3.4 Peer review the classification as follows:

A. Ensure the forms are complete and the basis for classification is adequately justified.

B. Review and resolve comments with the author.

C. Sign and date indicating approval when complete.

4.3.5 If the classification of the survey unit has changed from the initial classification, then the change must be approved by the LT/FSS Manager, who will indicate approval by signature in the provided space.

4.3.6 Place a copy of completed, reviewed, and signed classification documents in the appropriate survey package for the survey unit.

5 ATTACHMENTS

5.1 Survey Unit Classifications

6 FORMS

FCSD-RA-LT-301-F-01, Survey Unit Classification Summary

FCSD-RA-LT-301-F-02, Survey Unit Classification Worksheet

Docusign Envelope ID: BC327697-A2BF-8700-820E-501088DD8BCE

ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
1000	Unit 1 Containment Building (CB)		
1000	CB Basement	1	1,246
1001	CB 973' Elevation West Wall Concrete	1	43.7
1002	Stressing Gallery	1	1,142
1003	Containment Annulus and Shaft	1	303
1004	NW CB Footprint	1	1,837
1005	NE CB Footprint	1	1,572
1006	SW CB Footprint	1	1,645
1007	SE CB Footprint	1	2,036
1100[a]	CB 977' Elevation – Under Vessel Area	1	NA
1200[a]	CB 995'/996' Elevation G/A	1	NA
1201[a]	CB 995' Elevation – 'A' S/G Enclosure	1	NA
1202[a]	CB 995' Elevation – 'B' S/G Enclosure	1	NA
1203[a]	CB 996' Elevation – Reactor Cavity	1	NA
1204[a]	CB 996' Elevation – Fuel Transfer Canal	1	NA
1300	CB 1013' Elevation G/A	1	NA
1400	CB 1045' Elevation G/A	1	NA
1500	CB 1060' Elevation G/A	1	NA
1600	CB Exterior Surfaces	-	-
1601	CB Roof	2	NA
1602	CB Exterior Walls	3	NA
2000	Auxiliary Building (AB)		
2002	AB East Trenches	1	860
2003 #1	AB 989' Elevation Rooms 9, 10, and 11	1	134

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
2003 #2	AB 989' Elevation Spent Fuel Pool, Adjacent Floor/Walls, and Trenches 31, 32, and 33	1	495
2100	AB 971' Elevation G/A	1	NA
2101	AB 971' Elevation – Embedded Pipe	1	24.52
2102	AB 971' Elevation Ungrouted Walls	1	533.75
2103	AB 971' Elevation Grouted Walls	1	50.25
2104	AB 971' Elevation Grouted Floor	1	588
2200	AB 989' Elevation Floor and Lower Walls	1	2,368
2201	AB 989' Elevation – Embedded Pipe	1	34.4
2202	AB 989' Elevation – Upper Walls	1	736.89
2300	AB 1007' Elevation G/A	1	NA
2400	AB 1011' Elevation G/A	1	NA
2500	AB 1013' Elevation G/A	1	NA
2600	AB 1025' Elevation G/A	1	NA
2700	AB 1036' Elevation G/A	1	NA
2800	AB 1039' Elevation G/A	1	NA
2900	AB Exterior Surfaces	-	-
2901	AB Roof	2	NA
2902	AB Exterior Walls	3	NA
3000	Turbine Building (TB)		
3100	TB Basement	3	1,246
3102	TB 990' Elevation – Embedded Pipe	2	187
3103	TB – Circulating Water Discharge Tunnels West	2	1,550
3104	TB – Circulating Water Discharge Tunnels East	1	2,311

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
3200	TB 1000' Elevation G/A	3	NA
3300	TB 1011' Elevation G/A	3	NA
3400	TB 1036' Elevation G/A	3	NA
4000	Balance of Plant (BOP) Buildings Inside Deconstruction Area (DA)		
4100	Radwaste Processing Building	1	NA
4100	Radwaste Processing Building Excavation	1	1,233
4101	Radwaste Building Basement Wall	1	80.56
4200	Intake Building	3	3,789
4202	Intake Building – Embedded Pipes	2	11.24
4203	Intake Building – Warm Water Recirc. Tunnel	2	533
4204	Intake Building – Intake Tunnels	3	743
4300	Security Building	3	NA
4400	Security Access Facility (SAF)	3	NA
4500	Service Building	3	NA
4500	Service Building Caustic Storage Tank Pit	3	189
4501	Service Building Elevator Shaft	3	54
4600	Maintenance Shop	3	NA
4700	Technical Support Center (TSC)	3	NA
4800	Chemistry and Radiation Protection Facility	3	NA
4900	New Warehouse	3	NA
5000	BOP Buildings Outside DA		
5100	Administrative Office Building	3	34,478
5200	Training Center	3	59,144
5300	Mausoleum (Original Steam Generator Storage Facility)	2	NA
5400	FLEX Building	3	NA

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
5401	FLEX Building – Truck Bay	2	16,324
5402	FLEX Building – Admin Area	3	26,629
5500	New Maintenance Storage Shed	3	2,003
5600	Chemical Pump House	3	NA
5700	Storage Shed	3	2,689
5800	Sanitary Lift Stations	3	NA
5900	Chemical Storage Shed	3	NA
5901	3451 Old Building	3	674
5902	1251 Control and Switchgear Building	3	915
5903	3451 New Building	3	1,357
5904	Boat House	3	583.6
Buried Piping			
6200	Storm Drain	2	NA
6201		2	2,735
6202		2	33
7003	Fire Protection	3	663.8
9017	Sanitary Sewer	3	460.3
9020	Raw Water	2	462
9021	Condensate	2	12.2
9022	Vacuum Priming	3	5.8
9024	Auxiliary Steam	3	5
9027	Compressed Air	3	2.9
9028	Service Water	3	2.9
9029	Regen Drain	3	22
9033	Demineralized Water	3	231.6
7000	Land Areas Inside DA		
7100	Northwest Land Areas I/S DA Fence	-	9,064
7101		1	1,625

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
7102		1	1,995
7103		1	1,995
7104		1	1,571
7105		1	1,878
7200	Southwest Land Area I/S DA Fence	-	10,933
7201		1	1,657
7202		1	1,726
7203		1	1,632
7204		1	1,930
7205		1	1,934
7206		1	899
7207		1	1,155
7300	Southeast Land Area I/S DA Fence	-	8,406
7301		1	432
7302		1	2,033
7303		1	2,051
7304		1	2,054
7305		1	1,836
7400	Northeast Land Area I/S DA Fence	-	12,909
7401		1	1,673
7402		1	1,876
7403		1	1,996
7404		1	1,996
7405		1	1,996
7406		1	1,995
7407		1	1,376
7500	Primary Plant Land Area	-	14,212
7501		1	2,035
7502		1	2,033

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
7503		1	2,040
7504		1	2,034
7505		1	2,035
7506		1	2,035
7507		1	2,000
8000	Owner Controlled Area Outside the DA		
8100	North Owner Controlled Areas	-	839,265
8101		3	99,306
8102		3	74,736
8103		3	58,538
8104		3	100,040
8105		3	100,060
8106		3	98,127
8107		3	22,144
8108		3	77,801
8109		3	98,296
8110		3	105,682
8111		3	4,252
8112		2	281
8200	West Owner Controlled Area	-	472,587
8201		3	29,987
8202		3	54,987
8203		3	99,341
8204		3	86,497
8205		3	54,025
8206		3	74,774
8207		3	24,033
8208		3	1,18
8209		3	4,039

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
8210		3	17,218
8211		3	25,349
8212		2	451
8213		1	309
8214		2	462
8215		1	281
8216		2	313
8217		1	285
8300	South Owner Controlled Area	-	762,313
8301		3	37,283
8302		3	50,783
8303		3	47,259
8304		3	77,774
8305		3	98,126
8306		3	97,389
8307		3	90,194
8308		3	58,718
8309		3	73,436
8310		3	73,577
8311		1	1,819
8312		2	7,800
8313		1	1,878
8314		2	9,704
8315		1	1,598
8316		2	5,710
8317		1	154
8318		2	373
8319		1	1,737
8320		2	1,119

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
8321		1	1,879
8322		2	6,990
8323		1	1,969
8324		2	2,729
8325		1	1,130
8326		2	3,317
8327		1	1,736
8328		2	2,849
8329		1	1,396
8400	Waste Haul Path Buffer Zone	-	76,747
8401		2	8,270
8402		2	9,275
8403		2	8,530
8404		2	9,562
8405		2	10,840
8406		2	9,063
8407		2	3,606
8408		2	8,819
8409		2	6,085
8410		2	2,365
8411		1	331
8500	Waste Loadout Containment Structure	-	10,194
8501		1	1,781
8502		1	1,737
8503		1	1,750
8504		1	1,884
8505		1	1,554
8506		1	1,488

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
8600	Waste Haul Path	-	14,345
8601		1	2,030
8602		1	1,941
8603		1	1,372
8604		1	1,712
8605		1	1,625
8606		1	1,883
8607		1	1,978
8608		1	1,803
8700	Sewage Lagoon	-	54,188
8701		2	6,010
8702		2	6,265
8703		2	5,739
8704		2	6,080
8705		2	10,272
8706		1	730
8707		1	756
8708		2	6,260
8709		2	5,995
8710		2	6,081
Miscellaneous SSC			
9001	Blast and Ballistic Rated Enclosures	3	NA
9002	DW-68 & Pump House	3	NA
9003	Firing Range	3	NA
9004	Hazardous Materials Storage Building	3	NA
9005	Access Road Security Guardhouse (OCA Entrance Building)	3	NA
9006	Condensate Storage Tank	3	827
9007	Burn Pad	3	860

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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Survey Unit ID No.	Survey Unit Description	Classification	Survey Unit Area (m^2)
9008	Intake Structure and Vent Stack	1	NA
9009	Safety Injection Recirculation Lines	1	NA
9010	CARP & TSC East Footprint	1	1,556
9011	CARP & TSC West Footprint	1	1,814
9012	CARP & TSC Wall	1	39.24
9013	Old Warehouse Slab	3	2,300
9014	Chemical Pump House (Neutralization Basin)	3	150
9015	Fab Shop	1	NA
9016	Switch Gear	3	NA
9018	Northeast Land Area I/S PA – North Yard	1	4,344
9019	Off-Site Soil for Backfill	NI	NA
9023	Rad Waste Line	1	NA
9025	12-in Service Building Drain Discharge Acid Buried Pipe	3	NA
9026	Unused Survey Unit Number	N/A	NA
9030	Non-Sanitary Structures	3	NA
9031	Manhole 3	3	15.94
9032	Training Center Lift Station	3	14
9034	Rad-Waste Line Excavation	1	165
9035	Excavation 2-5 and 6-2	1	328
9036	Portion of the WPS Excavation	1	178
9037	Storm Drain 34 Excavation	1	158
9038	Jersey Barriers and King Tut Blocks	3	N/A
9039	Abandoned Well Water Pipe and Access Point	3	N/A

[a] Survey Units 1100, 1200, 1201, 1202, 1203, and 1204 replaced with Survey Unit 1000.

Bold survey unit numbers indicate that the survey unit will remain at end-state and be subject to FSS.

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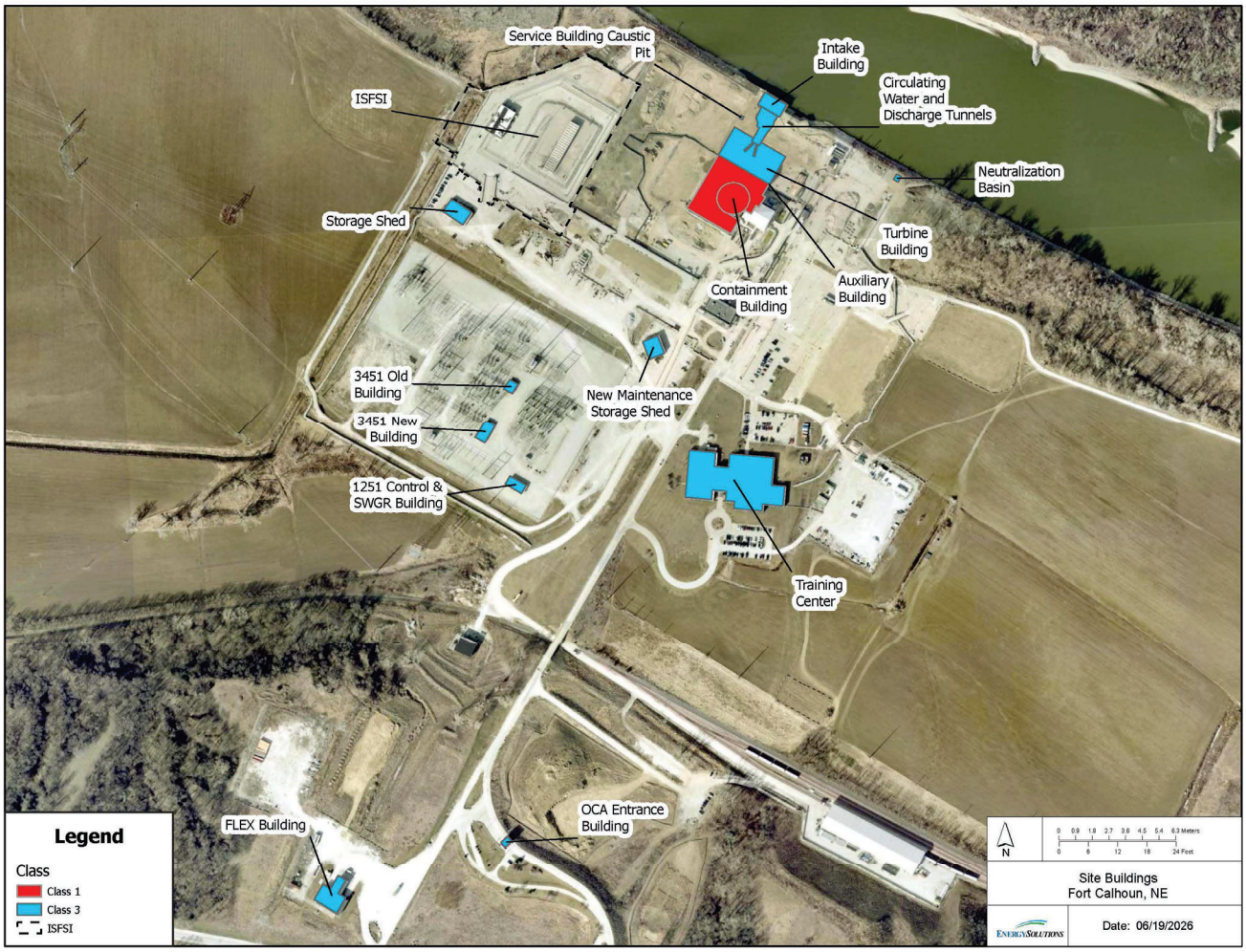
ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS

Structure Survey Units for FSS



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ATTACHMENT 5.1
SURVEY UNIT CLASSIFICATIONS
Open Land Survey Units

ATTACHMENT 3

Kd Sampling Report

109 Pages Follow

HALEY & ALDRICH, INC.
100 Corporate Place
Suite 105
Rocky Hill, CT 06067
860.282.9400

19 June 2024
File No. 0205251

Mr. Jason Spaide
Energy*Solutions*
9610 Power Lane
Blair, Nebraska 68008

Subject: Distribution Coefficient (Kd) Sampling Report
Fort Calhoun Station
9610 Power Lane
Blair, Nebraska

Dear Mr. Spaide:

Haley & Aldrich has published this Distribution Coefficient (Kd) Sampling Report (Report) for Fort Calhoun Station (FCS) to summarize the activities completed to evaluate Kd values for select isotopes. These values are intended to be used as input values into the RESRAD modeling program in support of the decommissioning project.

This work has been completed consistent with industry standards, Haley & Aldrich's operating procedures, and requirements under the Nebraska Department of Natural Resources (DNR) and the Nuclear Regulatory Commission (NRC). If you have any questions or would like to discuss our findings, please do not hesitate to call Nadia Glucksberg at 207.482.4623 or Miles van Noordennen at 860.817.3152 at your convenience.

Sincerely yours,
HALEY & ALDRICH, INC.

Miles van Noordennen
Senior Technical Specialist

Nadia Glucksberg
Program Manager

Enclosures

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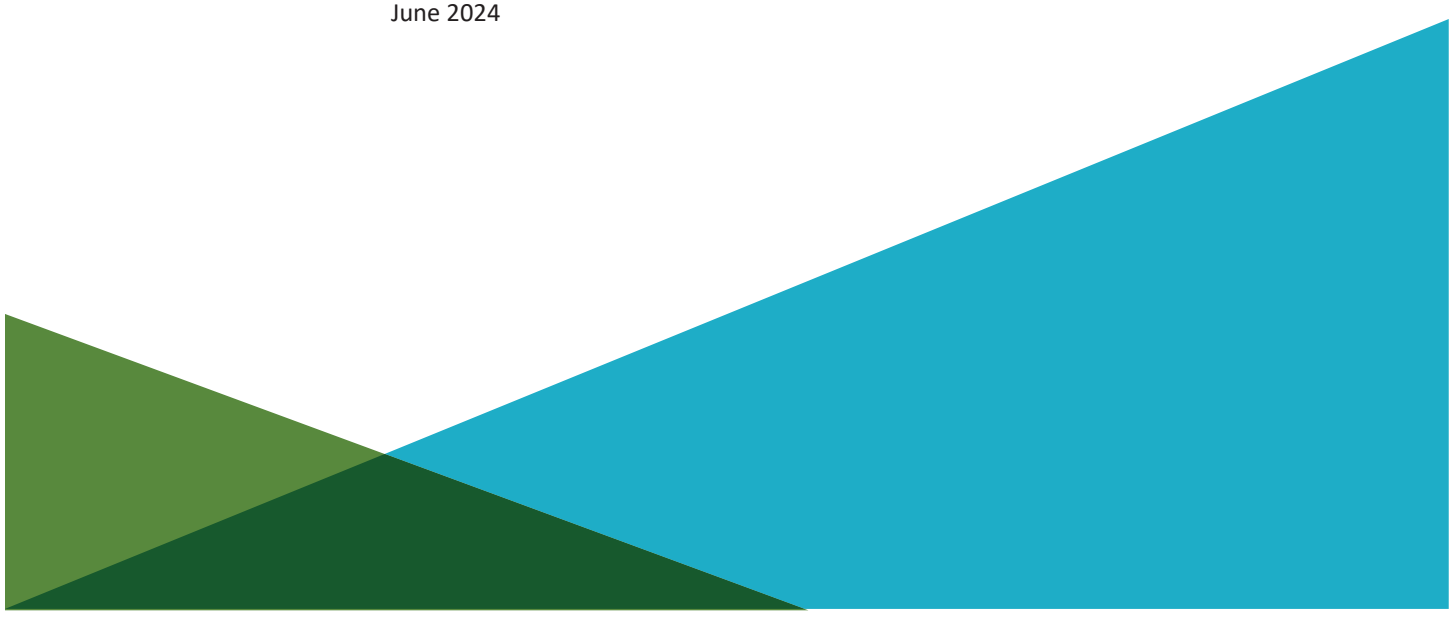
by
Haley & Aldrich, Inc.
Rocky Hill, Connecticut

for
Energy*Solutions*
Blair, Nebraska

File No. 0205251
June 2024



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SIGNATURE PAGE FOR

DISTRIBUTION COEFFICIENT (Kd) SAMPLING REPORT
FORT CALHOUN STATION
BLAIR, NEBRASKA

PREPARED FOR
ENERGY*SOLUTIONS*
BLAIR, NEBRASKA

PREPARED BY:

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1. Introduction

Haley & Aldrich, Inc. (Haley & Aldrich) has prepared this Distribution Coefficient (Kd) Sampling Report (Report) to support the continuing development of RESRAD input values for Fort Calhoun Station (FCS; See Figure 1). Specifically, this Report has been developed to summarize the activities completed to select appropriate Kd input values for the RESRAD program.

1.1 PURPOSE

The RESRAD modeling program was designed and developed by the Argonne National Laboratory (ANL) for the evaluation of radiologically contaminated sites to support development of License Termination Plans (LTPs) and predicting final site conditions after decommissioning activities are completed. More specifically, the software assists with modeling the impacts of radiological materials in soil and building materials and developing the Derived Concentration Guideline Levels (DCGLs) for each medium.

To select Kd input parameters for the RESRAD program, a site investigation was completed in August 2023. Kd is the ratio of the mass of solute species adsorbed or precipitated on the solids per unit of dry mass of the soil to the solute concentration in the liquids. Simply, the Kd value determines how much the ion (or isotope) sorbs to the soil, and each coefficient is compound-specific for the target soil type. This Report describes the sample collection and handling activities performed, provides a summary of the laboratory analysis results, and includes recommendations for selecting RESRAD input values. The sample collection, handling and laboratory analysis was completed following methods prescribed by ASTM C1733-21.

1.2 BACKGROUND

FCS Unit 1 was a Combustion Engineering two-loop pressurized water reactor (PWR) rated at 479-megawatts (MW) electrical. Plant construction began in 1966. The first fuel assembly was loaded into the reactor in May to June 1973. The United States Nuclear Regulatory Commission (NRC) issued an operating license on 9 August 1973. The plant officially went online on 1 September 1973, with commercial operation starting 25 days later.

FCS ceased operations on 24 October 2016, and the site is currently undergoing decommissioning activities. Spent fuel has been transferred into the Independent Spent Fuel Storage Installation (ISFSI), and site dismantlement and demolition (D&D) activities are ongoing. FCS has submitted their LTP to the NRC for review, and this field program was completed in response to Requests for Additional Information (RAIs) to obtain agency approval.

2. Field Activities

This section presents the activities performed onsite to complete the sampling required for the Kd analysis. All work was completed in accordance with the Distribution Coefficient (Kd) Sampling Work Plan (Haley & Aldrich, 2023), which included all pertinent Standard Operating Procedures (SOPs) and ASTM C1733-21 and followed all FCS safety requirements.

2.1 UTILITY CLEARANCE

Under federal and state law, Nebraska811 was notified more than 72 hours in advance of any subsurface work being conducted. Ticket number 232341715 was issued on 22 August 2023 and is included as Appendix A. In addition to this notification, Haley & Aldrich worked with FCS staff to better understand the potential for any underground utilities within the work area. Based on engineering drawing review and site knowledge, it was determined that the only underground utility in the vicinity of the work area was the fiber optic cable that services the waste processing site; however, no work activities were completed within 50 feet of the cable. No other utilities were within the area.

2.2 SOIL SAMPLING ACTIVITIES

To fully assess the Kd in soils for the RESRAD program, in-situ soil samples were collected from the unsaturated (above the water table) and saturated (below the water table) zones on 29 August 2023. Five locations were selected for soil collection (FCS-01a through FCS-01e), which were then composited into one analytical sample from each zone (FCS-01UNSAT and FCS-01SAT). Samples were collected using direct-push drilling methods, with drilling extending approximately 10 feet into the water table. Total drill depths at the five locations ranged from 40 to 49 feet. Drilling was conducted by Environmental Works, Inc. of Carter Lake, Iowa, a Nebraska-licensed drilling subcontractor. Boring logs for each of the five locations are provided in Appendix B.

In addition to the in-situ sampling, soil samples were also collected from stockpiled materials which will potentially be used as backfill within structure basements as the D&D activities progress on 29 August 2023. These samples were also five-part composite samples (FCS-02a through FCS-02e) but were collected using a shovel and hand auger to a depth of five feet at each of the five locations and composited into one analytical sample (FCS-02SP).

Analytical samples were collected in plastic bags and placed into a cooler with ice packs for shipping purposes. All excess drill cuttings were returned to the boring annulus. All sample locations are shown on Figure 2.

2.3 GROUNDWATER SAMPLING ACTIVITIES

Site groundwater is used by the laboratory to conduct the Kd analysis. FCS personnel selected MW-13A as the monitoring well to be used to provide the groundwater. On 29 August 2023, a centrifugal pump (i.e. whale pump) was used to purge three well volumes out of MW-13A. Following the purge, 20 gallons of groundwater was collected into 20 1-gallon plastic containers and placed into coolers with ice packs for shipping purposes.

2.4 SAMPLE CUSTODY AND SAMPLE MANAGEMENT

Sample custody was maintained under chain-of-custody protocols from the time samples were collected until the time they were delivered to the laboratory. As mentioned previously, soil and groundwater samples were immediately placed into coolers with ice packs upon collection. These coolers were always in the possession of site personnel with chain of custody documentation included inside the coolers. Once the coolers were filled, they were closed, sealed with tape for shipping, and had custody seals placed. All samples were shipped offsite on 30 August 2023 for delivery to the analytical laboratory, Southwest Research Institute of San Antonio, Texas.

2.5 GROUT SAMPLING

To assess the Kd in the grout materials that are proposed to fill underground voids, a composite sample was collected onsite, maintained under chain of custody, and shipped to the analytical laboratory (identified as Intake Structure Flyash). These activities were all completed by FCS personnel.

3. Analytical Results

The laboratory received the three soil samples and the groundwater sample on 31 August 2023. They received the grout sample on 19 October 2023. Analysis was completed on the four solid materials using the site groundwater as the transport medium, measuring the Kd of five radionuclides chosen by FCS personnel: carbon-14 (C-14), cesium-137 (Cs-137), cobalt-60 (Co-60), europium-152 (Eu-152), and strontium-90 (Sr-90). It should be noted that Sr-85 was used as a surrogate for Sr-90. All laboratory methodologies were completed in accordance with ASTM C1733-21.

Following the ASTM, soils were sieved through a #10 sieve to remove gravel-sized particles greater than 2 millimeters (mm) in diameter. The mass fraction of particles greater than 2 mm was calculated, and the moisture content of the sieved material was used to determine dry weight equivalent required per the ASTM. Soils were then prepped in quadruplicate, rinsed with site groundwater, and had tracer solution added to run the tests. Laboratory analysis was completed, and the final report was published on 28 March 2024, which is provided in Appendix C. The reported results are summarized and provided on Table 1.

Upon review of the laboratory report, it should be noted that two sets of Kd values were reported for each of the five isotopes tested, including:

- Kd is based on theoretical starting concentration of each isotope from the spike solution; and
- Kd* is based on starting concentration of each isotope measured in the control test (without soils).

The control tests showed that Eu-152 and Co-60 had low recoveries (<30%), meaning that their concentrations in the water, without contact soil, decreased significantly over the 21-day test period. As a result, there is a large difference between Kd and Kd* for Eu-152 and Co-60 (See tables 9 and 10 on Page 8 of the final laboratory report provided in Appendix C). We recommend reporting both sets of values, as suggested by the laboratory, noting the difference between the values, and using the average of the results for RESRAD inputs. These average values are also provided on Table 1.

4. Conclusions

Each of the five isotopes tested had two sets of Kd values reported by the laboratory per medium; a value based on the theoretical starting concentration of tracer in the groundwater solution (Kd), and a value based on the average concentration of the isotope in the tracer control solution without soil added (Kd*). Both sets of data were completed due to tracer soil interactions, such as adsorption, ion exchange, complex formation, redox reactions, precipitate formation, and precipitate filtration. These data can be considered bounding values.

Following review of the laboratory methodologies and analysis calculations, we have verified that all requirements of ASTM C1733-21 were met, and that the data is sound and defensible. As the Kd values listed in Table 1 included the soil and grout materials being used onsite, we recommend using the average value for each isotope as input parameters for the RESRAD program.

References

1. Haley & Aldrich, 2023. Distribution Coefficient (Kd) Sampling Plan, 24 August 2023.

\\haleyaldrich.com\share\CF\Projects\0205251\Kd Sampling\Completion Report\2024-0426 FCS Kd Sampling Report DF.docx

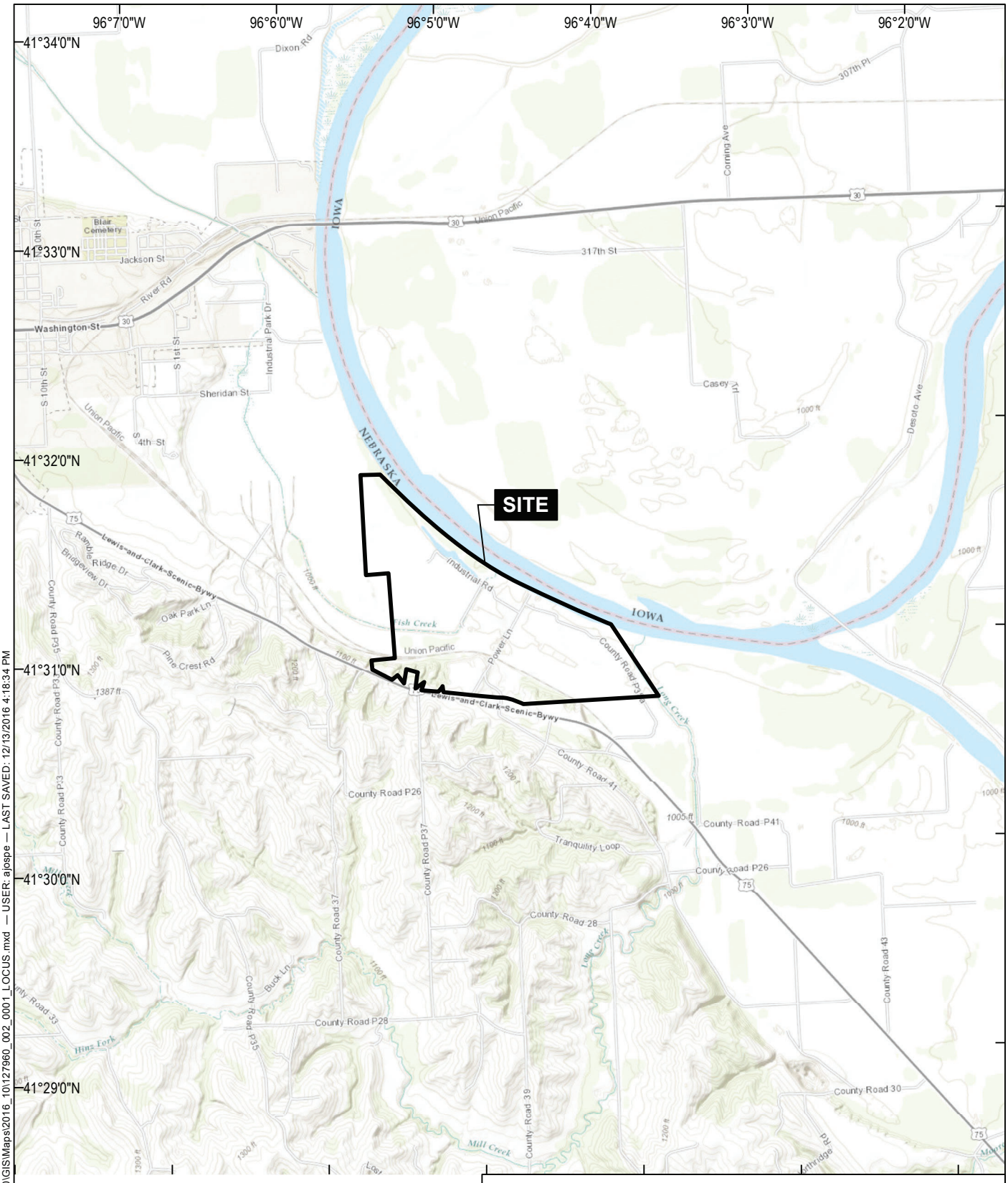
TABLES

Table 1
Summary of Analytical Results - Average Kd Values
Fort Calhoun Station
Blair, Nebraska

Sample ID	FCS-01UNSAT			FCS-01SAT			FCS-02SP			Intake Structure Flyash		
Isotope	Kd	Kd*	RESRAD	Kd	Kd*	RESRAD	Kd	Kd*	RESRAD	Kd	Kd*	RESRAD
Carbon-14	13.8	< 2	7.9	8.56	< 2	5.28	12.9	< 2	7.45	3840	2420	3130
Cesium-137	4520	4200	4360	3910	3630	3770	5060	4710	4885	7.70	5.41	6.56
Cobalt-60	2510	721	1616	4160	1200	2680	2910	839	1875	> 16800	> 4920	10860
Europium-152	> 6890	> 223	3557	> 7680	> 251	3966	> 6840	> 221	3531	> 6820	> 220	3520
Strontium-85	20.3	20.3	20.3	16.5	16.5	16.5	19.8	19.8	19.8	39.4	39.4	39.4

Notes:
- All results reported in milliliters per gram
Kd - results based on theoretical starting concentration of tracer in contact solution
Kd* - results based on average concentration of the isotope in the tracer control solution (no soil added)
RESRAD - recommended values to be used as RESRAD input values (average of Kd and Kd*)
Discrete numbers used for averaging the < and > values

FIGURES



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NE

MAP SOURCE: ESRI
SITE COORDINATES: 41°31'13"N, 96°4'33"

HALEY ALDRICH

FORT CALHOUN NUCLEAR PLANT
POWER LANE
BLAIR, NEBRASKA

PROJECT LOCUS

APPROXIMATE SCALE: 1 IN = 4000 FT
DECEMBER 2016

FIGURE 1

FIGURE 2
SAMPLING LOCATIONS

APPENDIX A
Nebraska811 Ticket

From: ne@occinc.com
To: Adam Kubat
Subject: Ticket: 232341715
Date: Tuesday, August 22, 2023 5:51:43 PM

You don't often get email from ne@occinc.com. Learn why this is important

NEBRASKA 811

You must ensure that both the ticket information and mapping location are correct, and that no work will take place outside the area indicated on the map, by clicking on the TicketLINK. Immediately call 800-331-5666, or 811, if you find any incorrect information.

The TicketLINK may also be used to view utility status, request a 'Relocate', report a 'No Response', 'Cancel' a request, keep notes, view and add attachments, and provide access to all your other requests.

TICKET SUMMARY

Ticket Number:	232341715	NORMAL	**Type:**	I-Tic
Requested By:	ADAM KUBAT			
Type of Work:	SOIL SAMPLING			
Work For:	HALEY & ALDRICH			
Address/Street:	POWER LN, BLAIR			
Intersecting:	S 13TH ST			
Location Info:	PLEASE MARK THE ENTIRE EMPTY LOT TO THE NORTH OF THE SECURITY CHECKPOINT, APPROXIMATELY 0.2 MILES NORTHWEST OF THE INTERSECTION OF POWER LN AND S 13TH ST. IN BLAIR, NE. FROM THE INTERSECTION OF N 13TH ST. AND POWER LN, DRIVE NORTHWEST APPROXIMATELY 0.2 MILES. THE EMPTY LOT WILL BE TO THE NORTH OF THE SECURITY CHECKPOINT. PAINT AND FLAG.			

MEMBERS NOTIFIED

The following utility(s) are required to respond by marking the approximate location of their underground facility in the appropriate color, by marking CLEAR or OK at the site, or by phone/fax/email that they are not affected. You must contact any other utilities directly.

Company Name	Utility Type	Marked	Clear
FASTWYRE BROADBAND - NEBRASKA	TEL,TV	_____	_____
CITY OF BLAIR	S,W	_____	_____
CITY OF FORT CALHOUN - SEWER	S	_____	_____
CITY OF FORT CALHOUN - WATER	W	_____	_____
GREAT PLAINS COMMUNICATIONS	FO,TEL,TV	_____	_____
OMAHA PUBLIC POWER DISTRICT	E	_____	_____

EXCAVATOR RESPONSIBILITIES

* It is the excavator's responsibility to determine which utilities have, or have not, responded prior to beginning excavation. If any utility has not responded by 8/28/23 7:00 AM call 800-331-5666 and request a 'NO RESPONSE' ticket or use the TicketLink at the top of this email.
* This ticket number serves as proof of your request and is valid until 9/14/23 as long as marking remain visible and usable. You are required to request a 'REFRESH' anytime markings become unusable due to work or weather AND/OR at least three working days before the ticket expires.
* Any damage or disturbance of any buried utility during excavation must be immediately reported, as required by law, by calling 800-331-5666 and filing a 'DAMAGE' ticket.

Please visit http://www.ne1call.com for the APWA color code, an explanation of markings, and other information on digging safely.

Follow us on Facebook at http://www.Facebook.com/ne1call

APPENDIX B
Boring Logs

HALEY ALDRICH

GEOPROBE REPORT

BORING NO. FCS-01a

Page 1 of 1

PROJECT	Fort Calhoun Station Kd Sampling	**H&A FILE NO.**	205251
LOCATION	Blair, Nebraska	**PROJECT MGR.**	Rick Volpi
CLIENT	Energy*Solutions*	**FIELD REP.**	Miles van Noordennen
CONTRACTOR	Environmental Works, Inc.	**DATE STARTED**	8/29/2023
DRILLER	Mike Gagnon	**DATE FINISHED**	8/29/2023

Elevation ft. **Datum** **Boring Location** FCS-01a **PID Make / Model:** N/A

Item	Casing	Sampler	Core Barrel
Type	N/A	SS	N/A
Inside Diameter (in.)	N/A	2	N/A
Hammer Weight (lb.)	N/A	N/A	
Hammer Fall (in.)	N/A	N/A	

Rig Make & Model

☐ Truck	☐ Tripod	☐ Cat-Head
☐ ATV	☑ Geoprobe	☐ Winch
☐ Track	☐ Air Track	☐ Roller Bit
☐ Skid	☐ _____	☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic

Drilling Mud: ☐ Bentonite ☐ Polymer ☑ None

Casing Advance — Type Method Depth: N/A

Drilling Notes:

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretatio	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
	N/A	N/A	N/A	N/A	N/A	N/A											
0							0 - 27 ft: Brown/reddish brown silt, trace sand, trace clay, dry										
10																	
20																	
30							27 - 30 ft: Grey and brown silt, some rust staining, damp										
40							30 - 40 ft: Grey and brown silt, wet										
50																	
60																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water
8/29/2023	0937	N/A	N/A	40	30

Sample ID

O	Open End Rod
T	Thin Wall Tube
U	Undisturbed Sample
S	Split Spoon Sample
G	Geoprobe

Well Diagram

Riser Pipe, Screen, Filter Sand, Cuttings, Grout, Concrete, Bentonite Seal

Summary

Overburden (Linear ft.)	40
Rock Cored (Linear ft.)	N/A
Number of Samples	2

BORING NO.

Field Tests

Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Meduim H - High V - Very High

***NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.**

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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HALEY ALDRICH

GEOPROBE REPORT

BORING NO. FCS-01b

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PROJECT	Fort Calhoun Station Kd Sampling	**H&A FILE NO.**	205251
LOCATION	Blair, Nebraska	**PROJECT MGR.**	Rick Volpi
CLIENT	Energy*Solutions*	**FIELD REP.**	Miles van Noordennen
CONTRACTOR	Environmental Works, Inc.	**DATE STARTED**	8/29/2023
DRILLER	Mike Gagnon	**DATE FINISHED**	8/29/2023

Elevation ft. **Datum** **Boring Location** FCS-01b **PID Make / Model:** N/A

Item	Casing	Sampler	Core Barrel
Type	N/A	SS	N/A
Inside Diameter (in.)	N/A	2	N/A
Hammer Weight (lb.)	N/A	N/A	
Hammer Fall (in.)	N/A	N/A	

Rig Make & Model

☐ Truck	☐ Tripod	☐ Cat-Head
☐ ATV	☑ Geoprobe	☐ Winch
☐ Track	☐ Air Track	☐ Roller Bit
☐ Skid	☐ _____	☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic

Drilling Mud: ☐ Bentonite ☐ Polymer ☑ None

Casing Advance: Type Method Depth — N/A

Drilling Notes:

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretatio	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
	N/A	N/A	N/A	N/A	N/A	N/A											
0							0 - 26 ft: Light brown to reddish brown silt, trace sand, trace clay, dry										
10																	
20																	
30							26 - 29 ft: Brown to reddish brown silt, trace sand, trace clay, damp										
							29 - 37 ft: Brown to reddish brown silt, trace sand, trace clay, wet										
							37 - 40 ft: Grey silt, wet										
40																	
50																	
60																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water
8/29/2023	1330	N/A	N/A	40	29

Sample ID

O	Open End Rod
T	Thin Wall Tube
U	Undisturbed Sample
S	Split Spoon Sample
G	Geoprobe

Well Diagram

Riser Pipe, Screen, Filter Sand, Cuttings, Grout, Concrete, Bentonite Seal

Summary

Overburden (Linear ft.)	40
Rock Cored (Linear ft.)	N/A
Number of Samples	2

BORING NO.

Field Tests

Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Meduim H - High V - Very High

***NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.**

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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GEOPROBE REPORT

BORING NO. FCS-01c

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PROJECT	Fort Calhoun Station Kd Sampling	**H&A FILE NO.**	205251
LOCATION	Blair, Nebraska	**PROJECT MGR.**	Rick Volpi
CLIENT	Energy*Solutions*	**FIELD REP.**	Miles van Noordennen
CONTRACTOR	Environmental Works, Inc.	**DATE STARTED**	8/29/2023
DRILLER	Mike Gagnon	**DATE FINISHED**	8/29/2023

Elevation ft. **Datum** **Boring Location** FCS-01c **PID Make / Model:** N/A

Item	Casing	Sampler	Core Barrel
Type	N/A	SS	N/A
Inside Diameter (in.)	N/A	2	N/A
Hammer Weight (lb.)	N/A	N/A	
Hammer Fall (in.)	N/A	N/A	

Rig Make & Model

☐ Truck	☐ Tripod	☐ Cat-Head
☐ ATV	☑ Geoprobe	☐ Winch
☐ Track	☐ Air Track	☐ Roller Bit
☐ Skid	☐ _____	☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic

Drilling Mud: ☐ Bentonite ☐ Polymer ☑ None

Casing Advance — Type Method Depth: N/A

Drilling Notes:

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretatio	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0	N/A	N/A	N/A	N/A	N/A	N/A	0 - 22 ft: Light brown to brown fine to medium silt, trace sand, trace clay, dry										
10																	
20							22 - 28 ft: Brown to reddish brown silt, damp										
30							28 - 40 ft: Grey silt, some sand, some clay, wet										
40																	
50																	
60																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water
8/29/2023	1230	N/A	N/A	40	28

Sample ID

O	Open End Rod
T	Thin Wall Tube
U	Undisturbed Sample
S	Split Spoon Sample
G	Geoprobe

Well Diagram

- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary

Overburden (Linear ft.)	40
Rock Cored (Linear ft.)	N/A
Number of Samples	2

BORING NO.

Field Tests

Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Meduim H - High V - Very High

***NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.**

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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GEOPROBE REPORT

BORING NO. FCS-01d

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PROJECT	Fort Calhoun Station Kd Sampling	**H&A FILE NO.**	205251
LOCATION	Blair, Nebraska	**PROJECT MGR.**	Rick Volpi
CLIENT	Energy*Solutions*	**FIELD REP.**	Miles van Noordennen
CONTRACTOR	Environmental Works, Inc.	**DATE STARTED**	8/29/2023
DRILLER	Mike Gagnon	**DATE FINISHED**	8/29/2023

Elevation ft. **Datum** **Boring Location** FCS-01d **PID Make / Model:** N/A

Item	Casing	Sampler	Core Barrel
Type	N/A	SS	N/A
Inside Diameter (in.)	N/A	2	N/A
Hammer Weight (lb.)	N/A	N/A	
Hammer Fall (in.)	N/A	N/A	

Rig Make & Model

☐ Truck	☐ Tripod	☐ Cat-Head
☐ ATV	☑ Geoprobe	☐ Winch
☐ Track	☐ Air Track	☐ Roller Bit
☐ Skid	☐ _____	☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic

Drilling Mud: ☐ Bentonite ☐ Polymer ☑ None

Casing Advance — Type Method Depth: N/A

Drilling Notes:

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretatio	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
	N/A	N/A	N/A	N/A	N/A	N/A											
0							0 - 5 ft: Light brown silt, some sand, dry										
							5 - 29 ft: Reddish brown silt, trace sand, trace clay, dry										
10																	
20																	
							29 - 36 ft: Reddish brown and grey silt, trace sand, trace clay, damp										
30																	
							36 - 44 ft: Reddish brown and grey silt, trace sand, trace clay, wet										
40																	
							44 - 49 ft: Grey silt, some sand, some clay, wet										
50																	
60																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water
8/29/2023	1030	N/A	N/A	49	36

Sample ID

O	Open End Rod
T	Thin Wall Tube
U	Undisturbed Sample
S	Split Spoon Sample
G	Geoprobe

Well Diagram

Riser Pipe, Screen, Filter Sand, Cuttings, Grout, Concrete, Bentonite Seal

Summary

Overburden (Linear ft.)	49
Rock Cored (Linear ft.)	N/A
Number of Samples	2

BORING NO.

Field Tests

Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Meduim H - High V - Very High

***NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.**

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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HALEY ALDRICH

GEOPROBE REPORT

BORING NO. FCS-01e

Page 1 of 1

PROJECT	Fort Calhoun Station Kd Sampling	**H&A FILE NO.**	205251
LOCATION	Blair, Nebraska	**PROJECT MGR.**	Rick Volpi
CLIENT	Energy*Solutions*	**FIELD REP.**	Miles van Noordennen
CONTRACTOR	Environmental Works, Inc.	**DATE STARTED**	8/29/2023
DRILLER	Mike Gagnon	**DATE FINISHED**	8/29/2023

Elevation ft. **Datum** **Boring Location** FCS-01e **PID Make / Model:** N/A

Item	Casing	Sampler	Core Barrel
Type	N/A	SS	N/A
Inside Diameter (in.)	N/A	2	N/A
Hammer Weight (lb.)	N/A	N/A	
Hammer Fall (in.)	N/A	N/A	

Rig Make & Model

☐ Truck	☐ Tripod	☐ Cat-Head
☐ ATV	☑ Geoprobe	☐ Winch
☐ Track	☐ Air Track	☐ Roller Bit
☐ Skid	☐ _____	☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic

Drilling Mud: ☐ Bentonite ☐ Polymer ☑ None

Casing Advance: Type Method Depth — N/A

Drilling Notes:

Depth (ft.)	Sampler Blows per 6 in.	Sample No. & Recovery (in.)	Sample Depth (ft.)	Well Diagram	Stratum Change (ft.)	USCS Symbol	Visual-Manual Identification & Description (color, GROUP NAME & SYMBOL, maximum particle size*, structure, odor, moisture, optional descriptions, geologic interpretatio	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0	N/A	N/A	N/A	N/A	N/A	N/A	0 - 28 ft: Brown/reddish brown silt, trace sand, trace clay, dry										
28							28 - 30 ft: Reddish brown silt and sand, moist										
30							30 - 37 ft: Brown silt, trace sand, trace clay, damp										
37							37 - 47 ft: Brown/greyish brown silt, trace sand, wet										
60																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth in feet to: Bottom of Casing	Bottom of Hole	Water
8/29/2023	1100	N/A	N/A	47	37

Sample ID

O	Open End Rod
T	Thin Wall Tube
U	Undisturbed Sample
S	Split Spoon Sample
G	Geoprobe

Well Diagram

- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary

Overburden (Linear ft.)	47
Rock Cored (Linear ft.)	N/A
Number of Samples	2

BORING NO.

Field Tests

Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Meduim H - High V - Very High

***NOTE: Maximum Particle Size is determined by direct observation within the limitations of sampler size.**

NOTE: Soil identifications based on visual-manual methods of the USCS system as practiced by Haley & Aldrich, Inc.

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APPENDIX C
Analytical Laboratory Report

March 28, 2024

Test Report

SwRI Project #:	28282.01.001
SwRI SDG:	708887
SwRI Task Order:	231109-2
SwRI Sample Receipt:	70069, 70289
Date Received:	08/31/2023, 10/19/2023

Prepared by:

Southwest Research Institute®
Department of Analytical and Environmental Chemistry
6220 Culebra Road
San Antonio, Texas 78238

Prepared for:

Energy Solutions, LLC.
9610 Power Lane
Blair, NE 68008
Attn: Jason Spaide

Authorized for Release
03/28/2024 5:00PM
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210-522-3242

Mike Dammann
Laboratory Director

"I certify that this data package is in compliance with the terms and conditions of the contract, both technically and for completeness, for other than the conditions detailed within this report. This report shall not be reproduced except in full without the written approval of SwRI."

Results relate only to the items tested and the samples/materials received by the laboratory.

SOUTHWEST RESEARCH INSTITUTE®
Chemistry and Chemical Engineering Division
Analytical and Environmental Chemistry Department

ANALYTICAL REPORT

Distribution Coefficient (K_d) of Radionuclides in Soil and Grout Samples using the Batch Method

SwRI Project #: 28282.01.001

Report Date: 3/27/2024

Prepared For:
Energy Solutions, LLC
9610 Power Lane
Blair, NE 68008

Prepared By:

Radonna Spies
Principal Scientist

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Appendices

Appendix A Certificates of Analysis/Datasheets for Radioisotope Stock Standards
Appendix B Preliminary and Final Test Sample IDs
Appendix C Preliminary Timepoint Concentrations in Solution
Appendix D Preliminary Equilibrium Graphs
Appendix E Final K_d Calculation Data Sheets

1. INTRODUCTION

Three soil samples and one groundwater sample were received on 08/31/23, and one grout sample was received on 10/19/23. The samples were logged into the Laboratory Information Management System (LIMS) under individual Sample Receipt Reports (SRR). Samples were assigned to Task Orders 231109-2 for distribution coefficient determination. Table 1 contains the sample login information. The chain of custody forms and login information are provided in a separate attachment.

Table 1. Sample Login Information

SwRI ID	**Customer ID**	Matrix	No. of Containers	SRR	Date Received
708887	FCS-01SAT	Soil	4	70069	08/31/23
708888	FCS-01UNSAT	Soil	2	70069	08/31/23
708889	FCS-02SP	Soil	1	70069	08/31/23
708890	MW-13A	Water	20	70069	08/31/23
711291	Intake Structure Flyash	Solid	2	70289	10/19/23

The purpose of this study was to measure the distribution coefficient (K_d) of five radionuclides in three soil samples and one grout sample in accordance with ASTM C1733-21 *Standard Test Method for Distribution Coefficients of Inorganic Species by Batch Method*. The experimentally determined K_d is used to assess the degree to which a chemical species will be removed from the groundwater (permanently or temporarily) as the fluid migrates through the geologic medium or contacts a solid material. The water listed in Table 1 is the representative groundwater from the test zone. The isotopes of interested were added to the groundwater and used as a tracer contact solution for the solid materials being tested.

Before completing the actual K_d determination, the time required for the tracer/solid system to attain equilibrium for each test species was ascertained; therefore, a preliminary K_d batch experiment was initially performed. The preliminary test samples were sampled over several time intervals to determine the time required to attain constant solution concentrations of the test species in the liquid. The preliminary test samples and the final K_d tests samples were started at the same time, but the preliminary test samples were evaluated first to assess the minimum contact time required prior to concluding the final K_d test samples.

2. ANALYTICAL

2.1. Radionuclides

The requested radionuclides for this K_d study were Carbon-14 (C-14), Cesium-137 (Cs-137) Cobalt-60 (Co-60), Europium-152 (Eu-152), and Strontium-90 (Sr-90). For the purposes of this study, Strontium-85 (Sr-85) was used as a surrogate for Sr-90. Additionally, sodium bicarbonate, [^{14}C] was utilized for the carbon tracer source. Appendix A contains the certificates of analysis or data sheets for the radionuclide stock standards.

2.2. Tracer Contact Solution Preparation

The groundwater sample was received in twenty 1-gallon containers. Since the groundwater contained some sediment, the groundwater was filtered through a 0.7 µm borosilicate glass fiber filter using vacuum filtration, and the filtrate was homogenized in a 20-gallon carboy prior to testing. The pH of the groundwater was determined to be 7.79.

Two separate tracer contact solutions were prepared based on the analytical technique used for analysis. Each tracer contact solution fraction was prepared by spiking the site groundwater with the designated radionuclides at the specified concentrations shown in Table 2. The gamma tracer contact solution required pH adjustment after the addition of the spikes due to the acidity of the standards added. The solution was adjusted to 7.75 using sodium hydroxide. The tracer solutions were allowed to equilibrate overnight prior to beginning the test.

Table 2. Tracer Contact Solutions

Tracer Contact Solution/ Fraction	Radionuclides	Tracer Concentration
LSC (Liquid Scintillation Counter)	C-14	500 pCi/mL
Gamma	Cs-137, Co-60, Eu-152, Sr-85	500 pCi/mL

2.3. Soil Preparation

Soils were sieved through a #10 sieve to remove gravel-sized grains larger than 2 mm in diameter per the ASTM method. The mass fraction of material greater than 2 mm in the sample aliquot was determined for correcting final K_d result as specified in the ASTM method. The moisture content of the sieved fraction was performed to determine the dry weight equivalent for the 25:1 liquid to soil mass ratio. The necessary amount of equivalent dry weight sample was weighed into each test container. Two soil sets were prepared for the preliminary and final test samples based on the analytical technique. One set was prepared for the C-14 determination by liquid scintillation (LSC) and another set for the gamma analysis. The preliminary sample sets were prepared in duplicate, and the final sample sets were prepared in quadruplicate. Table 3 contains the nominal sample weight and bottle type used for each fraction. The soil samples were pretreated by washing three times with the site groundwater. For the first two washes, the mixture was placed on a shaker for ~15 minutes, centrifuged for ~15-20 min and decanted. The third wash was allowed to leach for a minimum of overnight with occasional stirring prior to centrifuging and decanting.

2.4. K_d Test Sample Naming Schemes

The naming scheme for the K_d test samples were as follows:

- Soil/Tracer Contact Solution test sample IDs
  - "SwRI Soil System ID" - "Tracer Fraction"- "P for Prelim or F for Final" & Replicate#
  - Ex: 708887-LSC-P1, 711291-Gamma-F4
- Tracer Contact Solution test sample IDs
  - Tracer -"Tracer Fraction"- "P for Prelim or F for Final" & Replicate#
  - Ex. Tracer-LSC-P1, Tracer-Gamma-F4

Appendix B contains a list of the preliminary and final test sample IDs that were prepared and analyzed for each test fraction. When preliminary samples were aliquoted for analysis, a "day" identifier was added to the sample IDs. Ex. 708887-LCS-P1-D1 for Day 1. Preliminary sample aliquots and final K_d test sample aliquots were logged into the SwRI LIMs system and given a unique system IDs for reference in the laboratory.

2.5. Test Sample Preparation

On Day 0, the defined amount of prepared Tracer Contact Solution was added to the corresponding pretreated soils for both the preliminary and final K_d test samples. The volume added for test is presented in Table 3.

Two types of reference control solutions were also analyzed with each set of preliminary and final test samples. The control samples used the same bottles and sample volumes as the test samples. Controls were prepared for each test fraction set and consisted of the following:

- Tracer control solution (aka Tracer contact solution with no soil added)
- Laboratory control sample (LCS), which consisted of deionized water spiked at the same concentration as the Tracer Contact Solution

Procedure blanks, consisting of deionized water, were also prepared to assess potential contamination. The control samples were prepared in duplicate for the preliminary test batches and quadruplicate for the final test batch and are also shown in Appendix B. All sample bottles were shaken each workday throughout the test period.

Table 3. Nominal Soil Weight and Liquid Volumes, and Bottle Types for each K_d Fraction

	Preliminary Test Samples			Final Test Samples		
K_d Test Fraction	**Soil Dry Weight**	**Solution Vol/Wt**	**Bottle Type**	**Soil Dry Weight**	**Solution Weight**	**Bottle Type**
LSC	18 g	450 g	500 mL HDPE	4 g	100 g	100 mL HDPE
Gamma	18 g	450 g	500 mL HDPE	4 g	100 g	100 mL HDPE

2.6. Preliminary K_d Samples

At prescribed intervals, preliminary sample aliquots were taken for analysis. After samples were shaken and allowed to settle, 5.5 - 6 mL of each solution was removed and filtered through a 0.45 µm PES syringe filter. Preliminary test sample aliquots were pulled on Day 1, Day 3, Day 7, Day 14, and Day 21. All preliminary samples aliquots were logged into the LIMS system and given unique system IDs, which were references in the analytical testing.

Data for the preliminary analyses is presented in Appendix C for reference. Graphs of preliminary concentration versus time are located in Appendix D. The radiochemical analytical data packages for the preliminary test samples is provided as a separate attachment.

2.7. Final K_d Samples

It was determined the preliminary samples attained equilibrium by Day 21; therefore, the final K_d test sample were concluded and prepared for analysis. Table 4 lists the day the final test sample were concluded for each test fraction.

Table 4. Day the Final Test Samples were Finalized

Test Fraction	Final K_d Samples - Day Concluded Test
LSC	Day 21
Gamma	Day 22

The entire volume of the final test samples was filtered through a 0.45 µm PES membrane filter using a vacuum filtration unit. A small aliquot of each filtrate was reserved for pH measurement, and the remainder of the filtrate was submitted for radiochemical analysis.

2.8. Radiochemical Analysis

The Final K_d test samples were logged in under Sample Receipt Reports (SRR) 70851 and were assigned SwRI systems IDs that were referenced during the radiochemical analysis. The radiochemical analytical data package for the K_d final test samples, with detailed analytical narrative, is provided as a separate attachment.

2.8.1 Carbon-14 by Liquid Scintillation Counting

For the preliminary and final test samples, a 5-mL aliquot of each sample was added to 13 mL of Ultima Gold LLT scintillation cocktail in low potassium borosilicate scintillation vials for analysis. The sample vials were inspected prior to counting to ensure homogeneity of the scintillation fluid with the sample and each sample set was dark adapted for at least 1 hour prior to counting. The samples were counted on a liquid scintillation counter programmed to count only the ^{14}C region of interest. The liquid scintillation counter ^{14}C program was standardized using ^{14}C as the radioisotope to establish a specific efficiency quench curve. For all liquid scintillation analysis, the daily instrument performance checks were within the running statistical control limits. Preliminary test samples were counted for 10 minutes each, and the final samples were counted for 60 minutes each.

When the final K_d test samples were analyzed, the standard laboratory quality control samples were prepared and analyzed with each batch of samples. The quality control samples consisted of a preparation blank, laboratory control sample, and sample duplicate. Two separate sample batches were prepared and analyzed.

2.8.2 Cesium-137, Cobalt-60, Europium-152 and Strontium-85 by Gamma Spectroscopy

For the preliminary test samples, a 5-mL aliquot of each sample was counted in a 20-mL polyethylene vial using a geometry directly on the detector. The 5-mL volume was used in order to reduce dead time and maintain good sensitivity. The samples were counted for ten minutes each.

For the final test samples, a 50 mL aliquot of each sample was counted in a 250 mL Nalgene bottle using a geometry directly on the detector. The laboratory control sample and preparation blanks also consisted of 50 mL in a 250 mL Nalgene bottle. All samples were counted for one hour each. Two separate sample batches were analyzed.

The daily gamma calibration blanks and check standards were within control limits, and the gamma detector monthly backgrounds were within date for all analyses.

3. CALCULATIONS

ASTM C1733 gives two options for calculating K_d; therefore, SwRI provided K_d results based on each situation.

3.1. K_d based on Tracer Starting Concentration

The K_d calculation shown in Table 1 of the ASTM is based on the starting concentration of Tracer in the Contact Solution, (C_s).

$$K_d = \frac{\frac{(VxC_s) - (VxC_f)}{M}}{C_f}(1 - f)$$

Where:

K_d = Distribution coefficient, mL/g (equivalent to L/kg)

V = Total volume of tracer solution (mL)

C_s =Starting Concentration of tracer in contact solution (pCi/mL)

C_f = Final Concentration of tracer in contact solution after reacting with soil phase (pCi/mL)

M = Dry mass of Solid, g (wet sample Wt x % solids)

f = decimal mass fraction of gravel >2mm in total sample

3.2. K_d based on Tracer Concentration in Reference Solution (K_d *)

Section 7.13 of the ASTM states the concentration found in the reference solution (C_{rs}) may be used as the starting concentration when calculating the quantity of tracer sorbed on the solid by difference. In this study, the soils corresponding groundwater spiked with tracer (aka Tracer Contact Solution) was used as the reference solution.

$$K_d{}^* = \frac{\frac{(VxC_{tcs}) - (VxC_f)}{M}}{C_f}(1-f)$$

Where:

$K_d{}^*$ = Distribution coefficient, mL/g (equivalent to L/kg) based tracer solution

V = Total volume of tracer solution (mL)

C_{tcs} = Final Concentration $_{(avg)}$ of tracer in tracer control solution (no soil) sample (pCi/mL)

C_f = Final Concentration of tracer in contact solution after reacting with soil phase (pCi/mL)

M = Dry mass of Solid, g (wet sample Wt x % solids)

f = decimal mass fraction of gravel >2mm in total sample

4. RESULTS

The pH of the final contact solution aliquots for each fraction, along with the starting pH of the contact solutions, are presented in Tables 5 and 6.

Table 5. Gamma Final Test Samples - Summary of Starting and Final pHs of Contact Solutions

Test Sample ID	Client ID	Starting pH of Contact Solution	Final pH of Filtered Contact Solution			
			Rep 1	Rep 2	Rep 3	Rep 4
708887-Gamma	FCS-01SAT	7.79	8.44	8.43	8.41	8.45
708888-Gamma	FCS-01UNSAT		8.48	8.50	8.48	8.48
708889-Gamma	FCS-02SP		8.44	8.45	8.42	8.46
711291-Gamma	Intake Structure Flyash		8.79	8.66	8.69	8.88
Tracer-Gamma	-	7.75	8.58	8.56	8.59	8.54
LCS-Gamma-F1	-	-	2.18	2.12	2.08	2.06
PB-Gamma-F1	-	-	6.42	5.73	6.01	5.28

Table 6. LSC (C-14) Final Test Samples - Summary of Starting and Final pHs of Contact Solutions

Test Sample ID	Client ID	Starting pH of Contact Solution	Final pH of Filtered Contact Solution			
			Rep 1	Rep 2	Rep 3	Rep 4
708887-LSC	FCS-01SAT	7.79	8.50	8.45	8.52	8.52
708888-LSC	FCS-01UNSAT		8.55	8.50	8.49	8.50
708889-LSC	FCS-02SP		8.53	8.52	8.53	8.54
711291-LSC	Intake Structure Flyash		11.13	11.20	11.04	11.19
Tracer-LSC	-	7.77	8.70	8.68	8.68	8.67
LCS-LSC	-	-	9.44	9.48	9.45	9.76
PB-LSC	-	-	5.81	5.62	5.65	5.72

The mean K_d results for each isotope are presented in Tables 7 – 11. The "**K_d**" results are based on the theoretical starting concentration of tracer in the contact solution, and the "**K_d***" results are based on the average concentration of the isotope in the tracer contol solution (tracer contact solution with no soil added), at the conclusion of the study.

The K_d data sheets for each isotope are in Appendix E and present all data used in the calculation of each replicate's K_d result. The average and relative standard deviation of the quadruplicate K_d results are also presented in the data sheets.

Table 7. C-14 Average K_d Results

Client Soil ID	K_d mL/g	K_d* mL/g	Flag
FCS-01SAT	8.56	<2	
FCS-01UNSAT	13.8	<2	
FCS-02SP	12.9	<2	
Intake Structure Flyash	3840	2420	

Table 8. Cs-137 Average K_d Results

Client Soil ID	K_d mL/g	K_d* mL/g	Flag
FCS-01SAT	3910	3630	
FCS-01UNSAT	4520	4200	
FCS-02SP	5060	4710	
Intake Structure Flyash	7.70	5.41	

Table 9. Co-60 Average K_d Results

Client Soil ID	K_d mL/g	K_d* mL/g	Flag
FCS-01SAT	4160	1200	L
FCS-01UNSAT	2510	721	L
FCS-02SP	2910	839	L
Intake Structure Flyash	>16800	>4920	L

Table 10. Eu-152 Average K_d Results

Client Soil ID	K_d mL/g	K_d* mL/g	Flag
FCS-01SAT	>7680	>251	L
FCS-01UNSAT	>6890	>223	L
FCS-02SP	>6840	>221	L
Intake Structure Flyash	>6820	>220	L

Table 11. Sr-85 Average K_d Results

Client Soil ID	K_d mL/g	K_d* mL/g	Flag
FCS-01SAT	16.5	16.5	
FCS-01UNSAT	20.3	20.3	
FCS-02SP	19.8	19.8	
Intake Structure Flyash	39.4	39.4	

Flag definitions:
L = Significantly low Tracer Control Sample recovery <30%

5. DISCUSSION

5.1. Less Than (>) Results

In this study, it was determined that two K_d values would be reported for the project to evaluate since the ASTM gives the option of calculating the K_d value based on the known starting concentration of the isotope in the contact solution (500 pCi/ml) or based on the average concentration of isotope in the tracer control solution at the conclusion of the test, which is referred to as K_d * in this study. The two K_d values can be considered bounding values for each soil based on the test conditions of this method.

The final K_d values presented in Tables 7-11 are the average of the quadruplicate K_d results. When the solution replicate's concentration was below the sample specific MDA, the K_d result was reported as a greater than (>) K_d value, which was calculated using the MDA as final concentration (Cf).

If any one of the sample replicates resulted in (>) K_d value, the numerical K_d values of all four replicates were averaged and reported as greater than (>) the average result. An example of this occurred in the Co-60 K_d determination of the "Intake Structure Flyash". The results are shown below.

Replicate	K_d mL/g	Average K_d mL/g
1	>16570	>16800
2	>18940	
3	>14220	
4	17420	

5.2. K_d Control Samples

Laboratory Control Samples (LCS) were used to check the possible sorption of tracers onto the bottle, filter, and other material. Tracer Control Solutions (tracer added to soils corresponding groundwater) were also used as a reference solution to assess the stability of the tracer in the site groundwater, as well as possible sorption onto bottle, filter, and other material.

The LCS recoveries in the final K_d test samples are presented in Table 12. The LCS recoveries were within satisfactory recovery limits of 75-125%.

Table 12. Laboratory Control Samples (Tracer in deionized water) Final Recoveries

Isotope	Mean Conc pCi/mL	%TV
C-14	441	88.2%
Co-60	517	103%
Cs-137	462	92.4%
Eu-152	427	85.4%
Sr-85	486	97.2%

The Tracer Control Solution consisted of tracer spiked into the site-specific groundwater was used to assess the isotope behavior in the groundwater. The recoveries in the final tracer K_d test samples are presented in Table 13.

Table 13. Tracer Control Solution (isotope in groundwater) Final Recoveries

Isotope	Mean Conc pCi/mL	%TV
C-14	316	63.2%
Co-60	147	29.4%
Cs-137	465	93.0%
Eu-152	17.9	3.58%
Sr-85	500	100%

The Cs-137 and Sr-85 tracers were stable in the site groundwater with average tracer recoveries of 93.0% and 100%, respectively. The remaining isotopes indicated possible instability in the site-specific groundwater.

- The average C-14 tracer recovery in the groundwater control samples was 63.2%, which was moderately lower than the LCS recovery of 88.2%.
- The average Co-60 tracer recovery in the tracer control sample was slightly less than 30% recovery, which was significantly lower than the LCS recovery of 88.2%.
- The average Eu-152 tracer recovery in the groundwater control samples was only 3.58% of the original spike value, which was significantly lower than the LCS recovery of 85.4%.
- Eu-152 and Co-60 K_d values in Table 8 and 10, respectively, are flagged with an "L" for significantly low (<30%) tracer recoveries in the tracer control solution.

5.3. Low Tracer Recovery – Possible Explanations

5.3.1 Carbon-14

The behavior of C-14 in the environmental can be influenced by many factors. pH and the presence of certain cationic species can significantly affect the chemical behavior and equilibrium of inorganic carbon in geochemical systems. Thus, inorganic carbon may exist as dissolved gaseous carbon dioxide, carbonic acid (H_2CO_3), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) in waters, and as insoluble carbonates and sorbed species in the solid phase.

The instability of the C-14 in the site groundwater, where the concentration of the ^{14}C decreased over time (Figure 1), is likely due to isotopic exchange with atmospheric CO_2. In the 2017 study conducted by Boylan et al., they found that water containing ^{14}C in contact with the atmosphere rapidly lost ^{14}C from the solution as opposed to closed system when the pH of the water was less than 9.3, which they deduced as a loss through $^{14}CO_2$.[2]

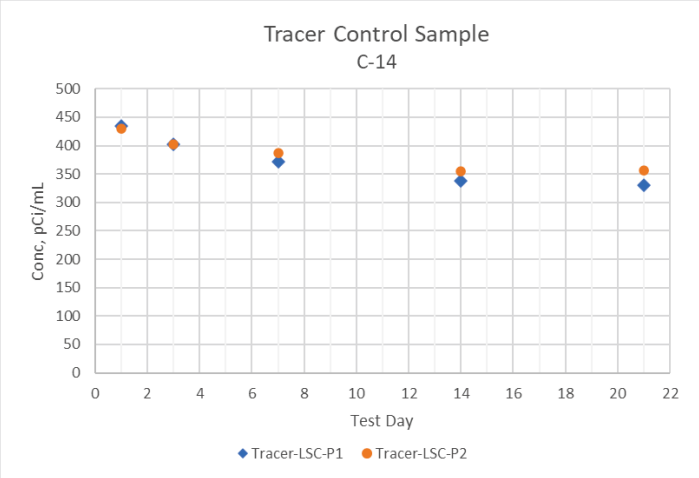


Figure 1. Carbon-14 loss in tracer control sample during preliminary test.

For the solid samples in this study, there appeared to be no C-14 tracer uptake in the three soil samples when compared to the final concentration of C-14 in the tracer contact solution control samples. The final concentrations of in the tracer contact solution control samples (C_{trs}) were similar to the concentration in the soil test samples. The K_d^* values calculated to negative values but were reported as <2 mL/g, which is the nominal reporting limit determined by SwRI based on statistical analysis.

5.3.2 Cobalt-60

Although Co^{2+} has been reported as stable in water under most geochemical conditions[3], Yuzer et al. experimentally determined cobalt hydroxide can start to precipitate at a pH of 8.2 and Zhang et al. reported cobalt carbonate precipitation in the range of in the range of 6.5-8 in an aqueous process. Therefore, the instability of the Co-60 in the site groundwater is likely due to chemical composition of water.

5.3.3 Europium-152

Europium (III) is described as unstable in geochemical systems due to the insoluble complexes it may form, which is dependent pH and redox potential of the system. When carbonate is a predominant species, europium carbonate hydrate ($Eu_2(CO_3)_3 \cdot 2H_2O$) has the potential to form and may precipitate in the pH 5 to 8 range under certain conditions.[3] Therefore, the instability of the Eu-152 in the site groundwater is likely due to chemical composition of water as well.

6. CONCLUSION

Per the ASTM method, distribution coefficient (K_d) is defined as the mass of solute on the solid phase per unit mass of solid phase divided by the mass of solute in solution per unit volume of liquid phase. As an aqueous fluid migrates through geologic media, certain reactions occur that are dependent upon the chemistry of the fluid and the chemistry of the solid phase it encounters. Certain processes can retard the chemical species contained in the migrating fluid such as: adsorption, ion exchange, complex formation, redox reactions, precipitate formation, and precipitate filtration. Due to these tracer soil interactions, SwRI reported two sets of K_d results, which can be considered bounding values.

Distribution coefficient, K_d, is affected by many variables, some of which may not be controlled or measured in a laboratory batch method test. The K_d results presented in this report are laboratory determined K_d values based on the test conditions outlined in the ASTM C1733 batch method, which may not correlate in natural situations due to time-dependence or kinetics of the specific reactions involved. The scope of this study did not include understanding sorption mechanisms responsible for increasing or decreasing sorption.

7. REFERENCES

1. ASTM Standard C1733, 2021 Standard Test Method for Distribution Coefficients of Inorganic Species by Batch Method. ASTM International, West Conshohocken, PA, 2003, www.astm.org.

2. Boylan, Aislinn; Stewart, Douglas; Graham, James; Trivedi, Divyesh; Burke, Ian. Mechanisms of Inorganic Carbon-14 Attenuation in Contaminated Groundwater: Effect of Solution pH on Isotopic Exchange and Carbonate Precipitation Reactions. Applied Geochemistry, 2017, 85, 137-147.

3. Krupka, Kenneth M.; Serne, R Jeffrey. Geochemical Factors Affecting the Behavior of Antimony, Cobalt, Europium, Technetium, and Uranium in Vadose Zone Sediments (PNNL--14126), 2002.

4. Yüzer, Hayrettin; Kara, Mustafa; Sabah, Eyup; Çelik, Mehmet. Contribution of Cobalt Ion Precipitation to Adsorption in Ion Exchange Dominant Systems. Journal of Hazardous Materials, 2008, 151, 33-7.

5. Zhang, Jianxin; Mani, Rajaboopathi; Louhi-Kultanen, Marjatta. Process Monitoring of Cobalt Carbonate Precipitation by Reactions between Cobalt Sulfate and Sodium Carbonate solutions to Control Product Morphology and Purity, Hydrometallurgy, 2024, 224.

Appendix A

Certificates of Analysis/Datasheets

for Radioisotope Stock Standards

Sodium Bicarbonate, [^{14}C]-

Product Number:

NEC086H

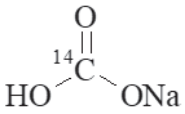
LOT SPECIFIC INFORMATION

Lot Number: 3240472

Specific Activity: 58 mCi/mmol

2146 MBq/mmol

Production Date: 01-DEC-2023



M.W. 84.0
$CHNaO_3$

PACKAGING: 1.0 mCi/ml (37 MBq/ml) steri-packaged in glass ampoules containing aqueous solution, pH 9.5.

STABILITY AND STORAGE: Dilute solutions of sodium bicarbonate, [^{14}C]- in sterile water have been found to be extremely stable when stored at 5°C (not frozen).

SPECIFIC ACTIVITY RANGE: 40-60 mCi/mmol (1480-2220 MBq/mmol)

IMPORTANT: Since the sodium bicarbonate, [^{14}C]- solutions are thermally sensitive, the following procedure for using the product is recommended:

1) Shake ampoule just prior to opening.
2) Gently tap ampoule to remove any solution remaining in the head.
3) Open ampoule while still cold.

FAILURE TO FOLLOW THE ABOVE DIRECTIONS MAY RESULT IN THE INCOMPLETE RECOVERY OF SODIUM BICARBONATE, [^{14}C]-

NOTE: Ensure dilution solvent is basic, and previously degassed with an inert gas. If solution needs to be diluted, the bulk must be stored in an air-tight closed vial under inert gas. Aliquoting the solution into an acidic solvent will result in significant radioactivity loss as gaseous carbon dioxide [^{14}C]-.

HAZARD INFORMATION: WARNING: This product contains a chemical known to the state of California to cause cancer.

Eckert & Ziegler
Isotope Products

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661 309 1010
Fax 661 257 8303

CERTIFICATE OF CALIBRATION
GAMMA STANDARD SOLUTION

Radionuclide:	Cs-137	**Customer:**	SOUTHWEST RESEARCH INSTITUTE
Half-life:	30.17 ± 0.16 years	**P.O. No.:**	R39915MM
Catalog No.:	7137	**Reference Date:**	1-Sep-23 12:00 PST
Source No.:	2389-91-1	**Contained Radioactivity:**	97.30 µCi 3600 kBq

Physical Description:

A. Mass of solution:	5.00054 g in 5 mL flame-sealed ampoule
B. Chemical form:	CsCl in 0.1M HCl
C. Carrier content:	10 µg Cs/mL of solution
D. Density:	0.9996 g/mL @ 20°C

Radioimpurities:

None detected

Radionuclide Concentration: 19.46 µCi/g, 720.0 kBq/g

Method of Calibration:

This source was assayed using a pressurized well type ionization chamber.

Uncertainty of Measurement:

A. Type A (random) uncertainty:	± 0.2 %
B. Type B (systematic) uncertainty:	± 3.0 %
C. Uncertainty in aliquot weighing:	± 0.0 %
D. Total uncertainty at the 99% confidence level:	± 3.0 %

Notes:

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- This solution has a recommended working life of 5 years.

Daniel James Van Dalsen — **Quality Control**

17-Aug-23 — **Date**

EZIP Ref. No.: 2389-91

Eckert & Ziegler
Isotope Products

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CERTIFICATE OF CALIBRATION
GAMMA STANDARD SOLUTION

Radionuclide:	Co-60	**Customer:**	SOUTHWEST RESEARCH INSTITUTE
Half-life:	5.272 ± 0.001 years	**P.O. No.:**	S39322SS
Catalog No.:	7060	**Reference Date:**	1-Jan-24 12:00 PST
Source No.:	2427-24	**Contained Radioactivity:**	99.72 **µCi** 3.690 **MBq**

Physical Description:

A. Mass of solution:	5.01980 g in 5 mL flame-sealed ampoule
B. Chemical form:	$CoCl_2$ in 0.1M HCl
C. Carrier content:	10 µg Co/mL of solution
D. Density:	0.9996 g/mL @ 20°C

Radioimpurities:

None detected

Radionuclide Concentration: 19.87 µCi/g, 0.7352 MBq/g

Method of Calibration:

This source was assayed using a pressurized well type ionization chamber.

Uncertainty of Measurement:

A. Type A (random) uncertainty:	± 0.2 %
B. Type B (systematic) uncertainty:	± 3.0 %
C. Uncertainty in aliquot weighing:	± 0.0 %
D. Total uncertainty at the 99% confidence level:	± 3.0 %

Notes:

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- This solution has a recommended working life of 5 years.

David James Van Dalsem
Quality Control

16-Dec-23
Date

EZIP Ref. No.: 2427-24

Eckert & Ziegler
Isotope Products

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Valencia, California 91355

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CERTIFICATE OF CALIBRATION
GAMMA STANDARD SOLUTION

Radionuclide:	Eu-152	**Customer:**	SOUTHWEST RESEARCH INSTITUTE
Half-life:	4933 ± 11 days	**P.O. No.:**	S39323SS
Catalog No.:	7152	**Reference Date:**	1-Jan-24 12:00 PST
Source No.:	2427-25	**Contained Radioactivity:**	103.1 **µCi** 3.815 **MBq**

Physical Description:

A. Mass of solution:	5.02733 g in 5 mL flame-sealed ampoule
B. Chemical form:	$EuCl_3$ in 0.5M HCl
C. Carrier content:	10 µg Eu/mL of solution
D. Density:	1.0077 g/mL @ 20°C

Radioimpurities:

Eu-154 = 0.547%; Gd-153 = 0.462% on 1-Jan-24

Radionuclide Concentration: 20.51 µCi/g, 0.7589 MBq/g

Method of Calibration:

This source was prepared from a weighed aliquot of solution whose activity in µCi/g was determined using gamma ray spectrometry.

Peak energy used for integration:	344.3 keV
Branching ratio used:	0.266 gammas per decay

Uncertainty of Measurement:

A. Type A (random) uncertainty:	± 0.3 %
B. Type B (systematic) uncertainty:	± 3.0 %
C. Uncertainty in aliquot weighing:	± 0.2 %
D. Total uncertainty at the 99% confidence level:	± 3.0 %

Notes:

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- This solution has a recommended working life of 5 years.

Daniel James Van Dalsem — Quality Control

16-Dec-23 — Date

EZIP Ref. No.: 2427-25

Isotope Production and Application Program
P.O. Box 1663, Mailstop J975
Los Alamos, NM 87545

Certificate of Analysis

Strontium-85

Batch ID: 22-7-1-Sr82 (Sr-85)
Release Date: Friday, August 25, 2023
Retest Date: Monday, October 23, 2023

**All values are calculated to 0800 MST.*

Property	Specification		On Assay Date: 6/15/2023		Decayed to Calibration Date: 8/16/2023	
Chemical Form	Strontium (II) in 0.1 N HCl		Strontium (II) in 0.1 N HCl			
Activity Concentration of Primary Isotope	[^{85}Sr] > 0.05 mCi/mL		1.64	mCi/mL	0.85	mCi/mL
Specific Activity	> 10 mCi/mg		165.2	mCi/mg	85.1	mCi/mg
Radionuclidic Purity	> 99%		98.38	%	99.22	%
Activity concentration of minor isotopes		^{82}Sr	0.023	mCi/mL	0.004	mCi/mL
		^{83}Rb	0.004	mCi/mL	0.002	mCi/mL
		Other Isotopes	ND			

Stable Element Concentrations (µg/mL)						
Sr =	9.93	Al =	ND	Ba =	ND
Ca =	10.42	Cd =	ND	Co =	ND
Cr =	ND	Cu =	ND	Fe =	ND
Mg =	ND	Mn =	ND	Mo =	ND
Na =	0.81	Ni =	ND	Pb =	ND
Rb =	2.44				

Comments: In order to reduce evaportion, the product was diluted to a total volume of approximately 100 µL. The numbers on this certificate reflect the numbers of the product as it is in the shipping vial. Dilution factor = 4.02

Quality Unit Signatory: X Christopher Henning Digitally signed by Christopher Henning Date: 2023.08.09 12:05:04 -06'00'

Verifier: X Guy Dutech Digitally signed by Guy Dutech Date: 2023.08.09 12:47:15 -06'00'

Appendix B

Preliminary and Final Test Sample IDs

Table 1B. Liquid Scintillation Counter (LSC) Fraction Test Sample IDs – Preliminary and Final

Preliminary Test		
Sample IDs	Nominal Sample Dry Wt g	Final Vol, mL
708887-LSC-P1	18	450
708887-LSC-P2	18	450
708888-LSC-P1	18	450
708888-LSC-P2	18	450
708889-LSC-P1	18	450
708889-LSC-P2	18	450
711291-LSC-P1	18	450
711291-LSC-P2	18	450
Tracer-LSC-P1	-	450
Tracer-LSC-P2	-	450
LCS-LSC-P1	-	450
LCS-LSC-P2	-	450
PB-LSC-P1	-	450
PB-LSC-P2	-	450

Final Test		
Sample IDs	Nominal Sample Dry Wt g	Final Vol, mL
708887-LSC-F1	4	100
708887-LSC-F2	4	100
708887-LSC-F3	4	100
708887-LSC-F4	4	100
708888-LSC-F1	4	100
708888-LSC-F2	4	100
708888-LSC-F3	4	100
708888-LSC-F4	4	100
708889-LSC-F1	4	100
708889-LSC-F2	4	100
708889-LSC-F3	4	100
708889-LSC-F4	4	100
711291-LSC-F1	4	100
711291-LSC-F2	4	100
711291-LSC-F3	4	100
711291-LSC-F4	4	100
Tracer-LSC-F1	-	100
Tracer-LSC-F2	-	100
Tracer-LSC-F3	-	100
Tracer-LSC-F4	-	100
LCS-LSC-F1	-	100
LCS-LSC-F2	-	100
LCS-LSC-F3	-	100
LCS-LSC-F4	-	100
PB-LSC-F1	-	100
PB-LSC-F2	-	100
PB-LSC-F3	-	100
PB-LSC-F4	-	100

Table 2B. Gamma Fraction Test Sample IDs – Preliminary and Final

Preliminary Test		
Sample IDs	Nominal Sample Dry Wt g	Final Vol, mL
708887-Gamma-P1	18	450
708887-Gamma-P2	18	450
708888-Gamma-P1	18	450
708888-Gamma-P2	18	450
708889-Gamma-P1	18	450
708889-Gamma-P2	18	450
711291-Gamma-P1	18	450
711291-Gamma-P2	18	450
Tracer-Gamma-P1	-	450
Tracer-Gamma-P2	-	450
LCS-Gamma-P1	-	450
LCS-Gamma-P2	-	450
PB-Gamma-P1	-	450
PB-Gamma-P2	-	450

Final Test		
Sample IDs	Nominal Sample Dry Wt g	Final Vol, mL
708887-Gamma-F1	4	100
708887-Gamma-F2	4	100
708887-Gamma-F3	4	100
708887-Gamma-F4	4	100
708888-Gamma-F1	4	100
708888-Gamma-F2	4	100
708888-Gamma-F3	4	100
708888-Gamma-F4	4	100
708889-Gamma-F1	4	100
708889-Gamma-F2	4	100
708889-Gamma-F3	4	100
708889-Gamma-F4	4	100
711291-Gamma-F1	4	100
711291-Gamma-F2	4	100
711291-Gamma-F3	4	100
711291-Gamma-F4	4	100
Tracer-Gamma-F1	-	100
Tracer-Gamma-F2	-	100
Tracer-Gamma-F3	-	100
Tracer-Gamma-F4	-	100
LCS-Gamma-F1	-	100
LCS-Gamma-F2	-	100
LCS-Gamma-F3	-	100
LCS-Gamma-F4	-	100
PB-Gamma-F1	-	100
PB-Gamma-F2	-	100
PB-Gamma-F3	-	100
PB-Gamma-F4	-	100

Appendix C

Preliminary Timepoint Concentrations in Solution

Table 1C. Preliminary C-14 Concentration in Tracer Contact Solution exposed to Soil

		C-14 Concentration, pCi/mL					
Test Sample ID	**Client Sample ID or Control Sample ID**	**Spike Conc**	**Day 1**	**Day 3**	**Day 7**	**Day 14**	**Day 21**
708887-LSC-P1	FCS-01SAT	500	415	388	385	359	401
708887-LSC-P2		500	415	397	393	379	388
708888-LSC-P1	FCS-01UNSAT	500	397	375	355	344	353
708888-LSC-P2		500	397	380	359	338	358
708889-LSC-P1	FCS-02SP	500	399	378	361	346	354
708889-LSC-P2		500	413	379	365	349	357
711291-LSC-P1	Intake Structure Flyash	500	214	90.5	2.33	2.26	2.28
711291-LSC-P2		500	213	97.3	2.83	2.27	2.25
Tracer-LSC-P1	Tracer Control Solution	500	434	402	371	338	330
Tracer-LSC-P2		500	430	402	387	355	357
LCS-LSC-P1	Laboratory Control Solution	500	479	465	454	457	481
LCS-LSC-P2		500	472	462	452	455	475
PB-LSC-P1	Procedure Blank	500	<0.517	<0.531	<0.499	<0.519	<0.536
PB-LSC-P2		500	<0.521	<0.525	<0.493	<0.526	<0.533

Table 2C. Preliminary Cs-137 Concentration in Tracer Contact Solution exposed to Soil

		Cs-137 Concentration, pCi/mL					
Test Sample ID	**Client Sample ID or Control Sample ID**	**Spike Conc**	**Day 1**	**Day 3**	**Day 7**	**Day 14**	**Day 21**
708887-Gamma-P1	FCS-01SAT	500	<15.2	<9.64	<8.92	<9.64	<7.54
708887-Gamma-P2		500	<14.8	<9.40	<7.25	<6.59	<7.54
708888-Gamma-P1	FCS-01UNSAT	500	<12.8	<8.14	<7.84	<6.23	<5.82
708888-Gamma-P2		500	<11.9	<10.1	<7.25	<9.64	<7.25
708889-Gamma-P1	FCS-02SP	500	<11.9	<8.14	<7.54	<5.82	<8.14
708889-Gamma-P2		500	<12.2	<9.16	<8.68	<6.23	<6.95
711291-Gamma-P1	Intake Structure Flyash	500	453	431	432	414	441
711291-Gamma-P2		500	448	455	423	432	438
Tracer-Gamma-P1	Tracer Control Solution	500	484	498	468	519	510
Tracer-Gamma-P2		500	487	493	487	504	478
LCS-Gamma-P1	Laboratory Control Solution	500	489	471	506	481	476
LCS-Gamma-P2		500	492	481	504	463	519
PB-Gamma-P1	Procedure Blank	500	<3.74	<4.38	<2.92	<2.92	<4.38
PB-Gamma-P2		500	<3.74	<4.38	<4.38	<3.75	<3.75

Table 3C. Preliminary Co-60 Concentration in Tracer Contact Solution exposed to Soil

		Co-60 Concentration, pCi/mL					
Test Sample ID	**Client Sample ID or Control Sample ID**	**Spike Conc**	**Day 1**	**Day 3**	**Day 7**	**Day 14**	**Day 21**
708887-Gamma-P1	FCS-01SAT	500	40.8	<15.1	<10.8	<11.5	<11.5
708887-Gamma-P2		500	63.2	<15.1	<8.62	<9.45	<8.62
708888-Gamma-P1	FCS-01UNSAT	500	<21.7	<13.7	<11.5	<10.9	<11.5
708888-Gamma-P2		500	<22.0	<15.6	<12.1	<8.62	<10.9
708889-Gamma-P1	FCS-02SP	500	<23.2	<11.5	<9.45	<9.45	<12.7
708889-Gamma-P2		500	<18.0	<10.2	<12.7	<10.2	<13.3
711291-Gamma-P1	Intake Structure Flyash	500	38.9	<18.0	<14.2	<9.45	<7.68
711291-Gamma-P2		500	53.9	<20.7	<10.8	<11.5	<9.45
Tracer-Gamma-P1	Tracer Control Solution	500	433	446	354	169	62.7
Tracer-Gamma-P2		500	463	449	370	115	38.7
LCS-Gamma-P1	Laboratory Control Solution	500	484	470	490	465	477
LCS-Gamma-P2		500	480	494	455	483	463
PB-Gamma-P1	Procedure Blank	500	<7.63	<1.6	<1.6	<5.11	<1.6
PB-Gamma-P2		500	<1.59	<5.09	<6.52	<1.6	<5.12

Table 4C. Preliminary Eu-152 Concentration in Tracer Contact Solution exposed to Soil

		Eu-152 Concentration, pCi/mL					
Test Sample ID	**Client Sample ID or Control Sample ID**	**Spike Conc**	**Day 1**	**Day 3**	**Day 7**	**Day 14**	**Day 21**
708887-Gamma-P1	FCS-01SAT	500	<15.3	<12.6	<14.3	<12.5	<12.9
708887-Gamma-P2		500	<16.5	<13.3	<8.68	<12.3	<10.6
708888-Gamma-P1	FCS-01UNSAT	500	<13.1	<12.2	<12.8	<11.3	<11.4
708888-Gamma-P2		500	<14.8	<13.1	<8.68	<11.9	<10.8
708889-Gamma-P1	FCS-02SP	500	<14.2	<13.5	<11.9	<10.4	<11.4
708889-Gamma-P2		500	<14.0	<14.7	<8.68	<10.6	<8.38
711291-Gamma-P1	Intake Structure Flyash	500	<17.7	<17.0	<7.25	<15.7	<8.68
711291-Gamma-P2		500	<18.4	<17.3	<8.68	<17.9	<16.6
Tracer-Gamma-P1	Tracer Control Solution	500	328	319	282	150	<22.0
Tracer-Gamma-P2		500	351	329	272	<23.7	<20.7
LCS-Gamma-P1	Laboratory Control Solution	500	456	438	456	441	457
LCS-Gamma-P2		500	448	462	462	452	449
PB-Gamma-P1	Procedure Blank	500	<4.48	<7.01	<4.49	<4.49	<5.17
PB-Gamma-P2		500	<6.05	<4.48	<3.64	<3.60	<5.48

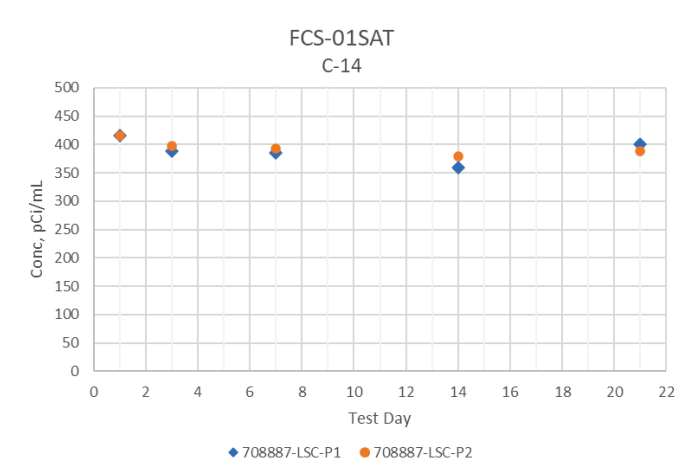
Table 5C. Preliminary Sr-85 Concentration in Tracer Contact Solution exposed to Soil

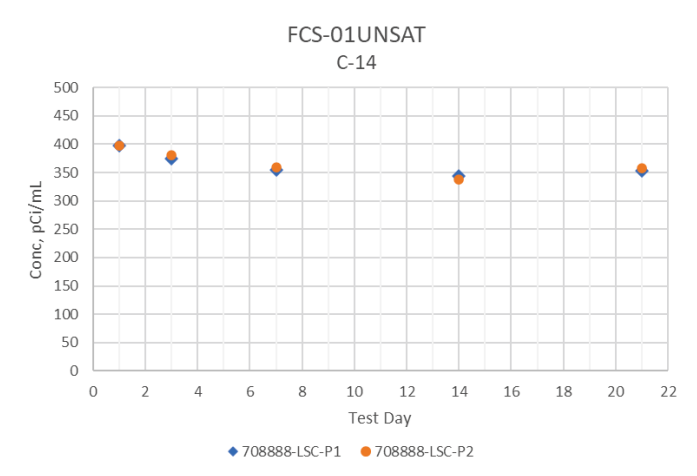
		Sr-85 Concentration, pCi/mL					
Test Sample ID	**Client Sample ID or Control Sample ID**	**Spike Conc**	**Day 1**	**Day 3**	**Day 7**	**Day 14**	**Day 21**
708887-Gamma-P1	FCS-01SAT	500	324	292	294	300	287
708887-Gamma-P2		500	329	315	307	293	289
708888-Gamma-P1	FCS-01UNSAT	500	278	275	263	272	266
708888-Gamma-P2		500	287	272	267	260	250
708889-Gamma-P1	FCS-02SP	500	277	272	271	281	263
708889-Gamma-P2		500	284	293	266	263	285
711291-Gamma-P1	Intake Structure Flyash	500	323	268	245	216	209
711291-Gamma-P2		500	326	266	230	210	216
Tracer-Gamma-P1	Tracer Control Solution	500	501	482	498	498	482
Tracer-Gamma-P2		500	479	490	481	475	463
LCS-Gamma-P1	Laboratory Control Solution	500	487	478	459	483	487
LCS-Gamma-P2		500	481	462	495	474	458
PB-Gamma-P1	Procedure Blank	500	<3.82	<4.82	<5.01	<6.46	<5.30
PB-Gamma-P2		500	<4.55	<3.59	<3.73	<4.91	<6.96

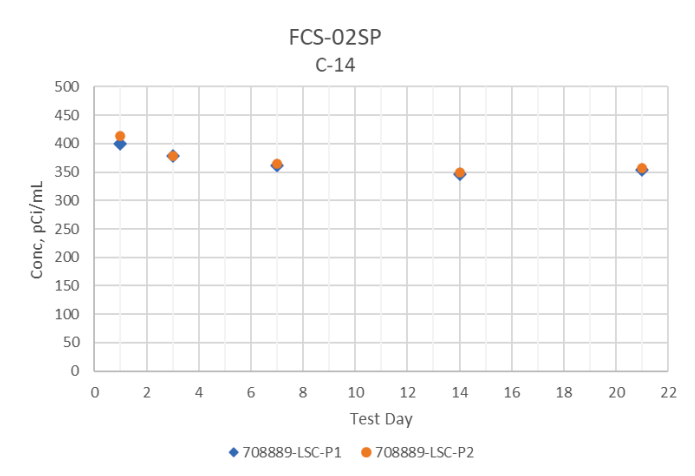
Appendix D

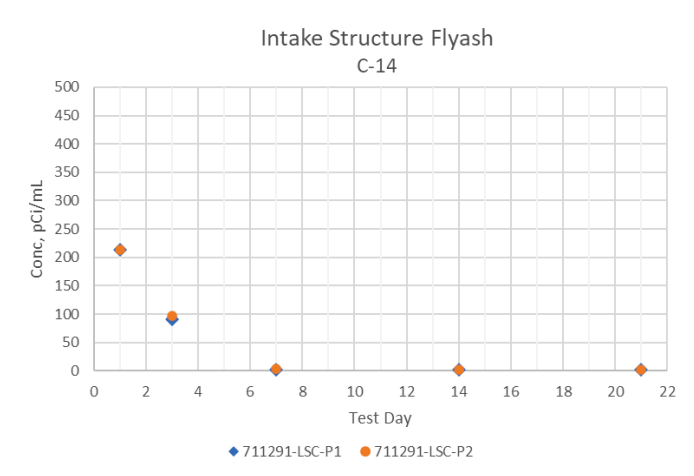
Preliminary Equilibrium Graphs

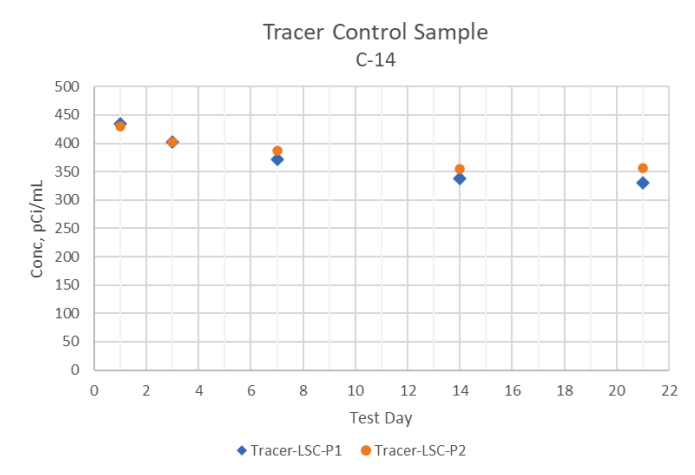
Carbon-14: Preliminary Equilibrium Graphs for Samples and Controls

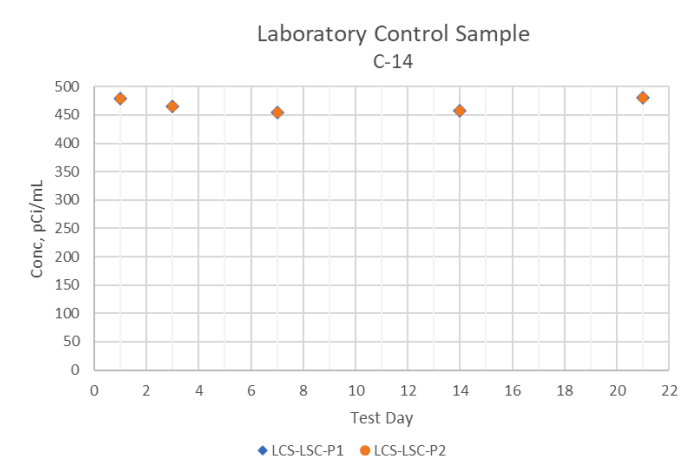




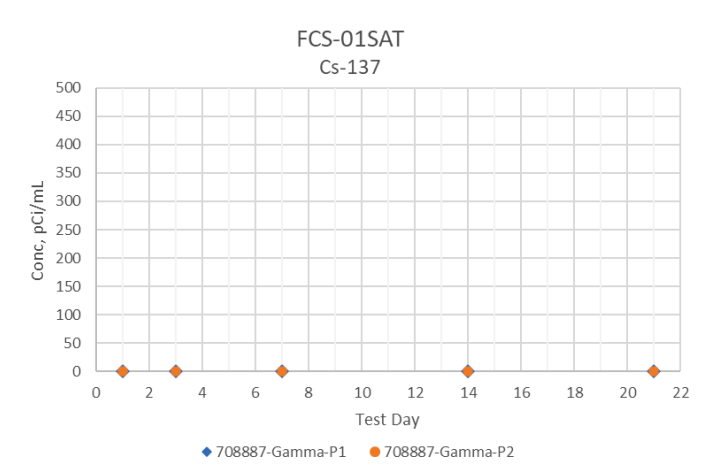


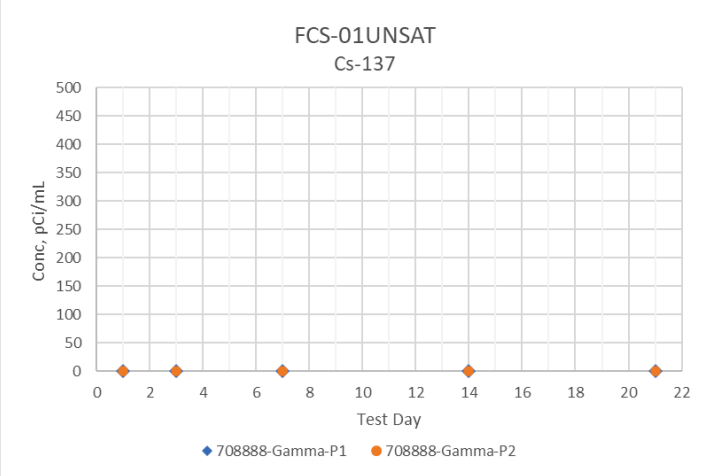


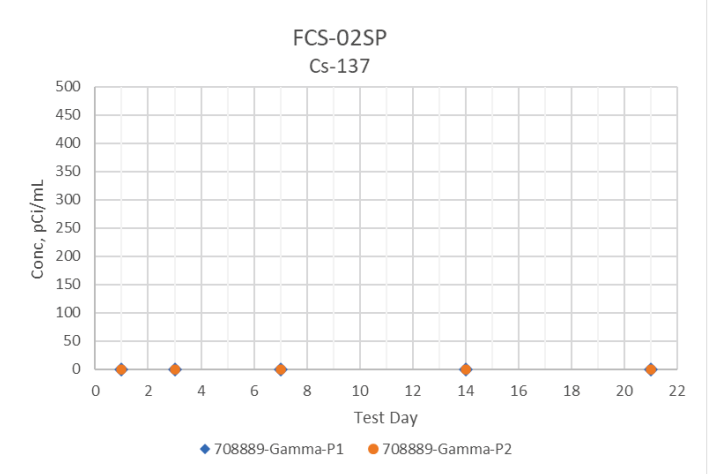


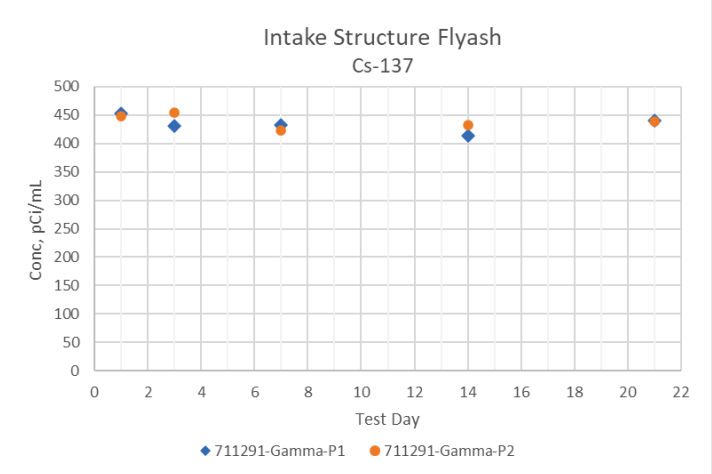


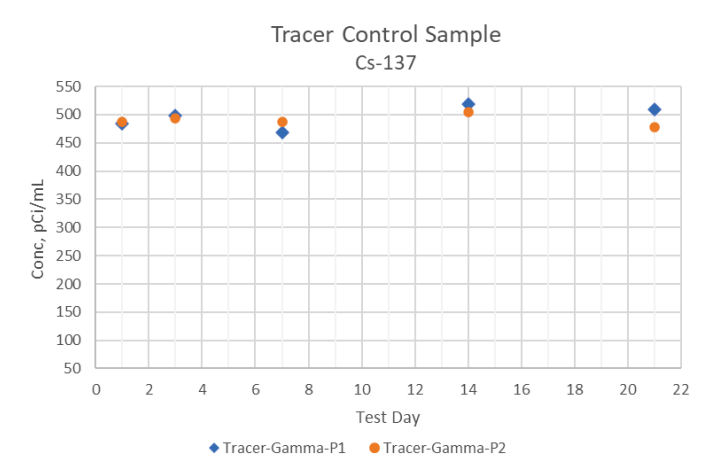
Cesium-137: Preliminary Equilibrium Graphs for Samples and Controls

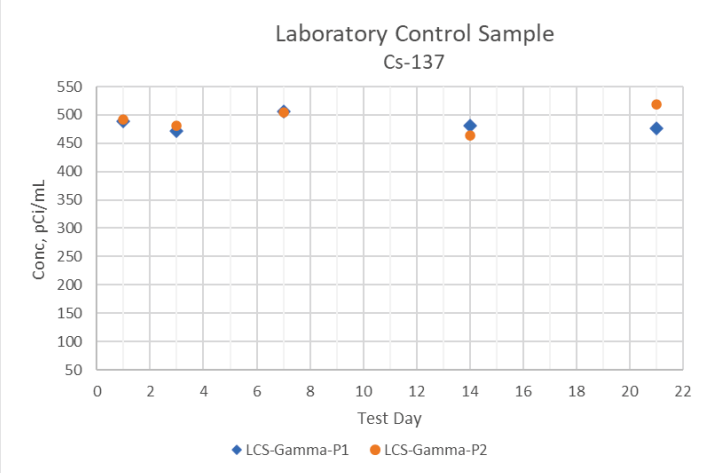




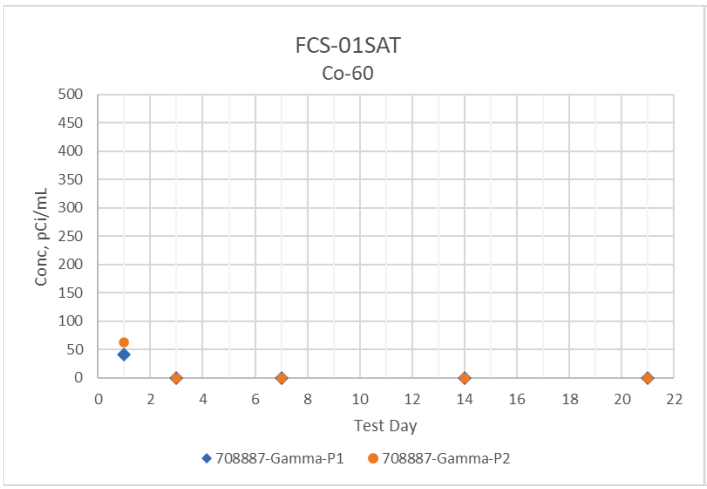


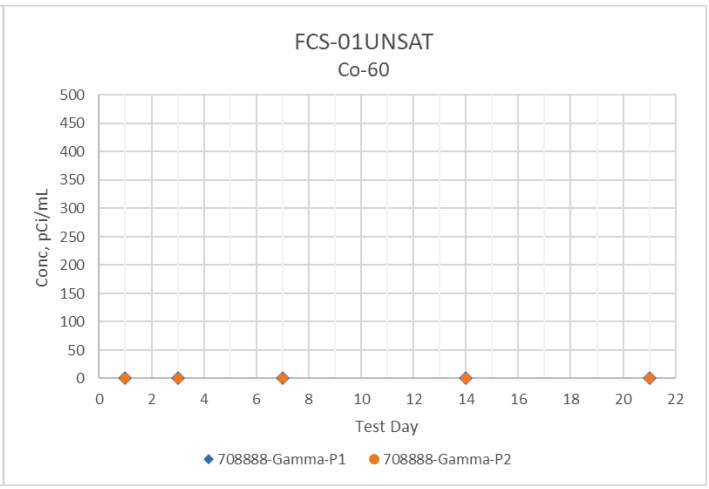


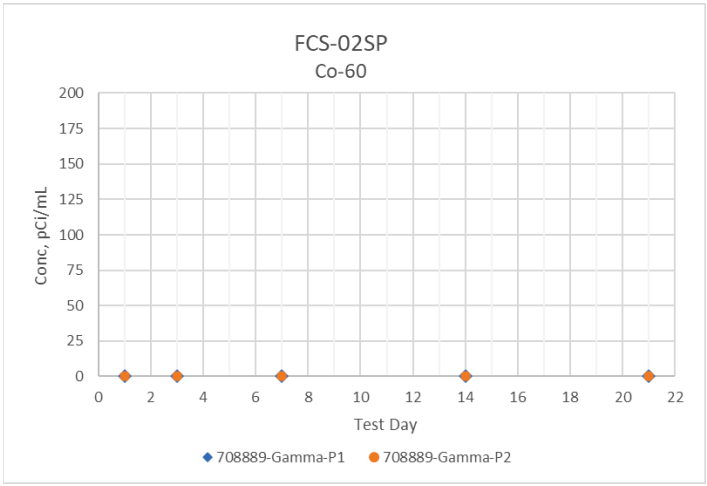


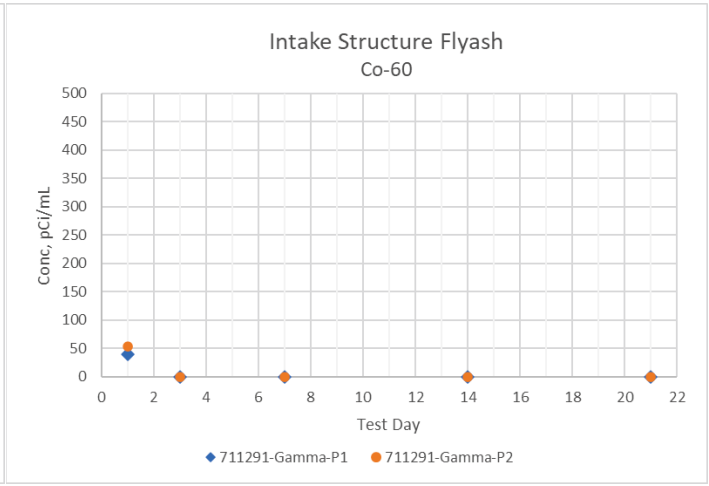


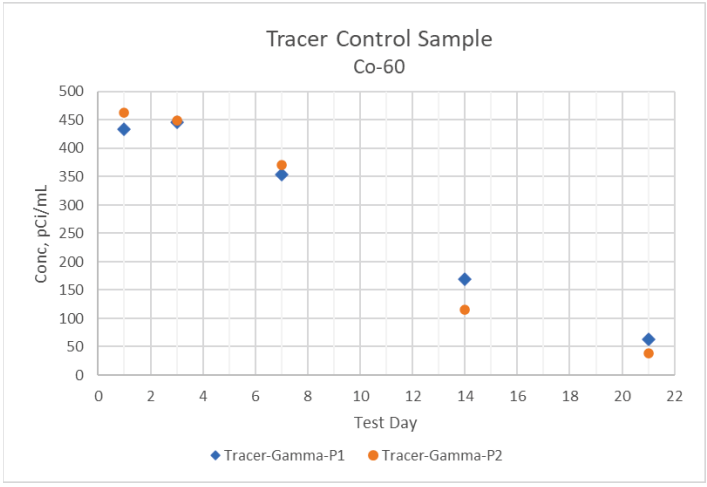
Cobalt 60: Preliminary Equilibrium Graphs for Samples and Controls

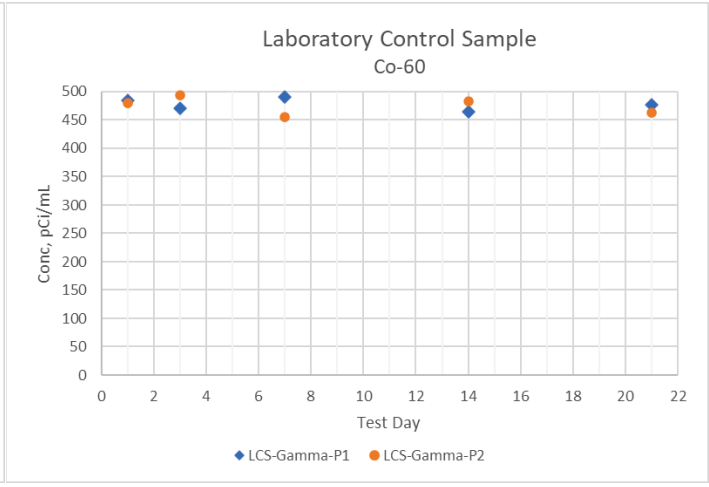




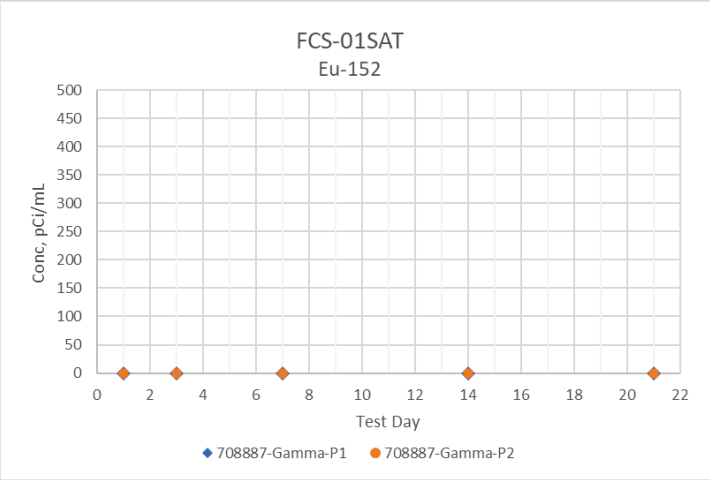


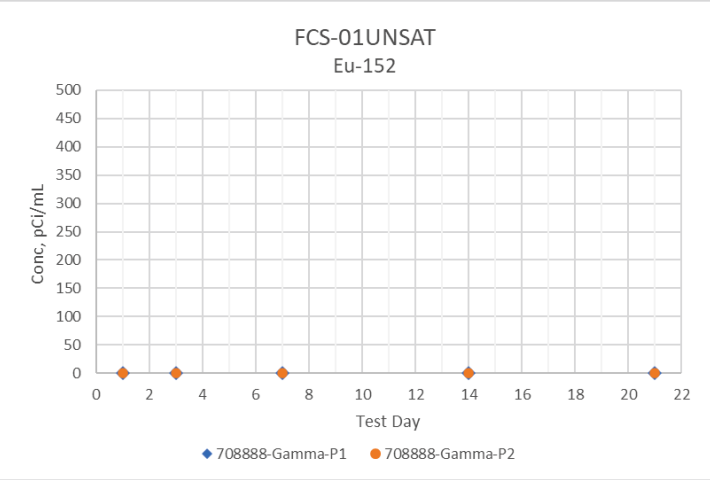


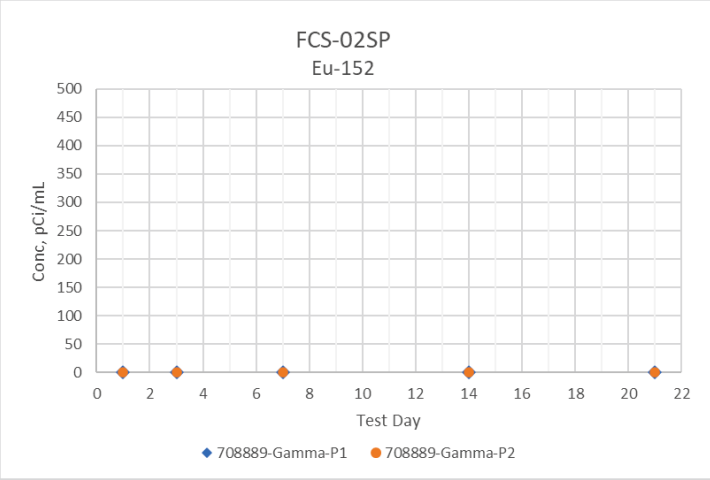


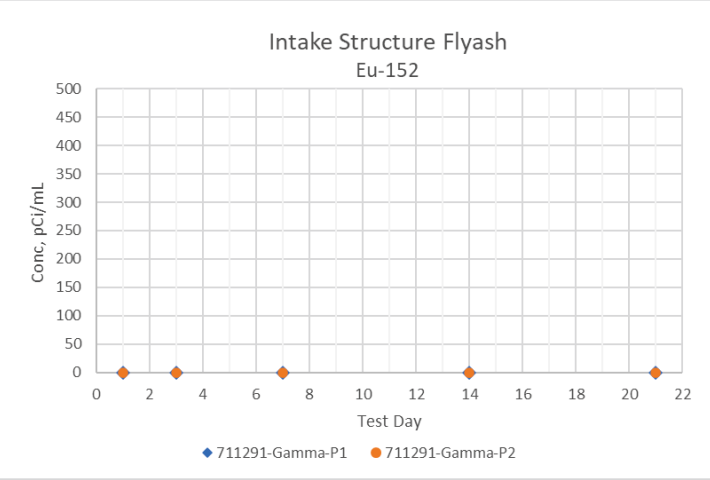


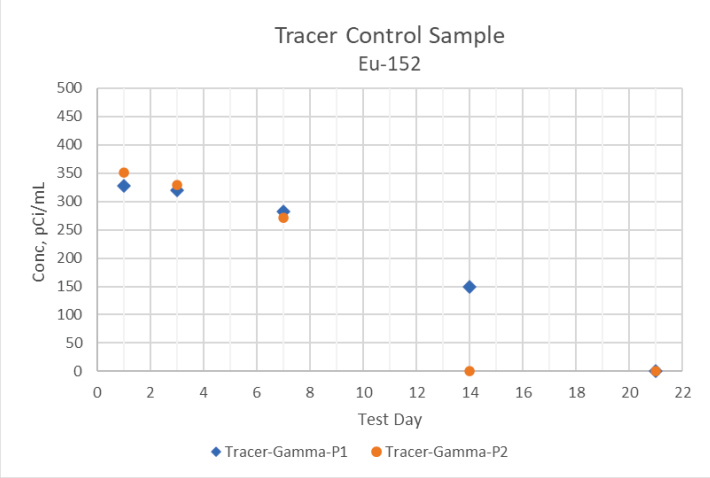
Europium-152: Preliminary Equilibrium Graphs for Samples and Controls

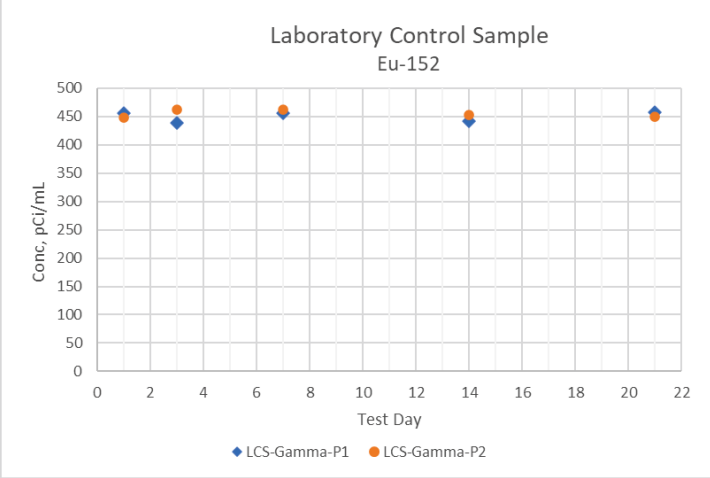




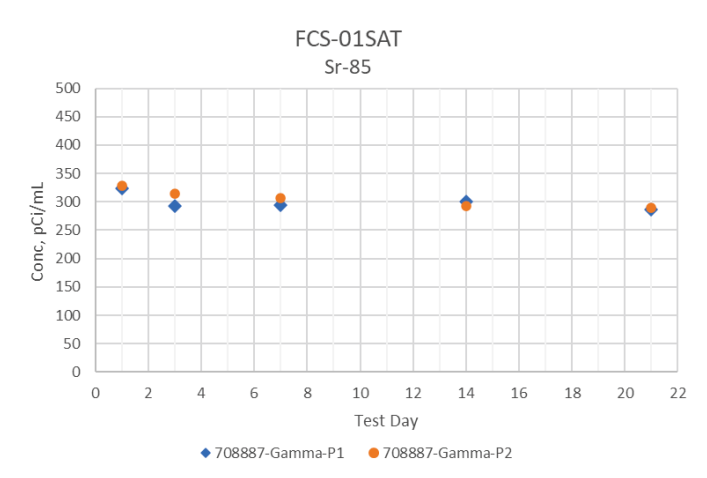


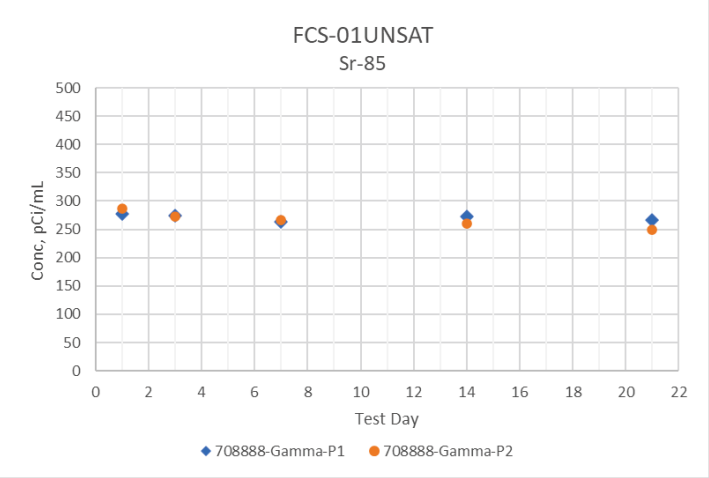


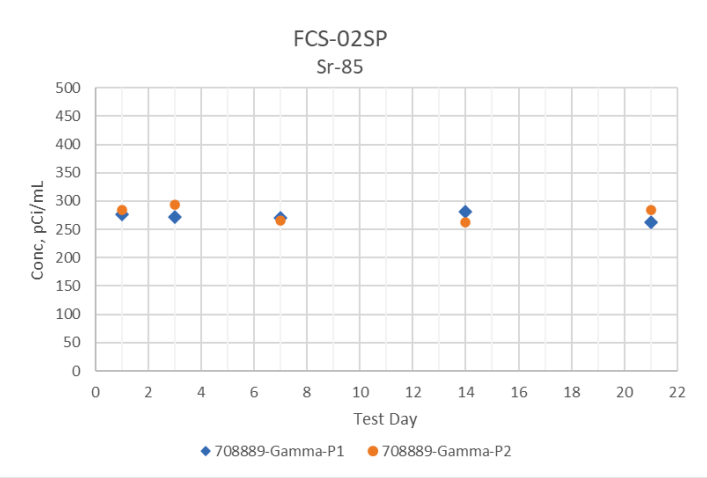


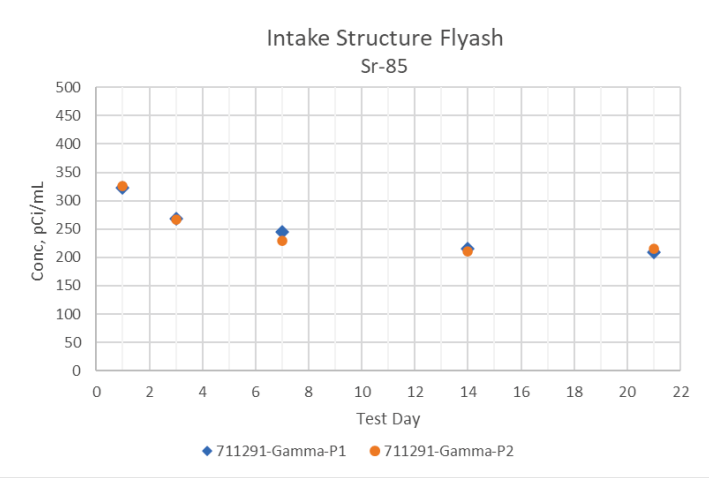


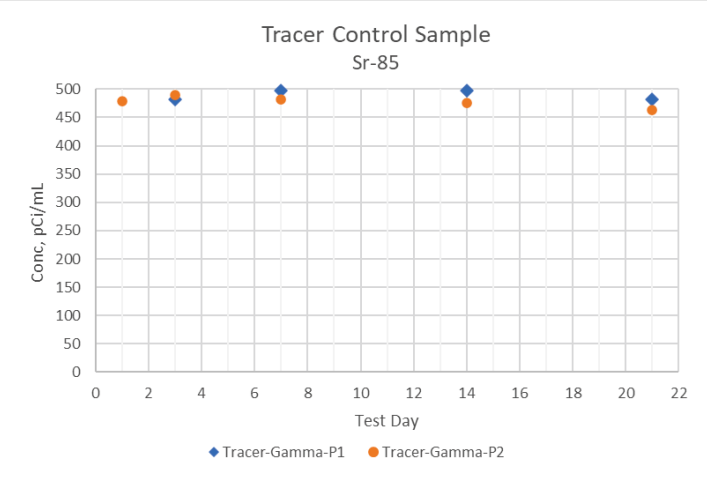
Strontium-85: Preliminary Equilibrium Graphs for Samples and Controls

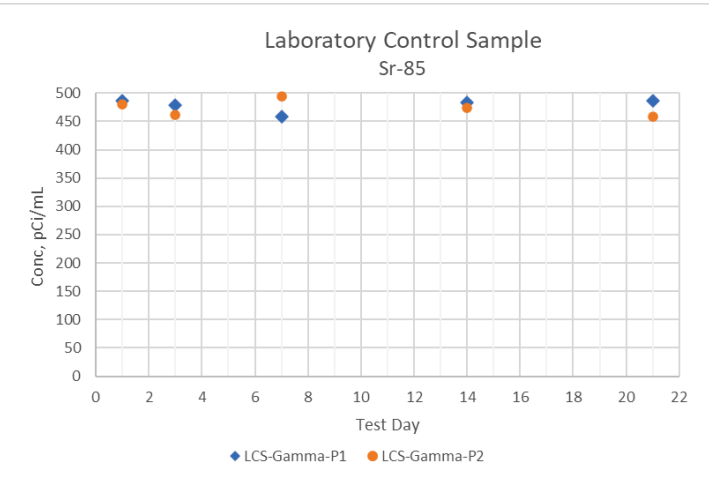












Appendix E

Final K_d Calculation Data Sheets

Southwest Research Institute

C14

Client EnergySolution

TO# 240229-6

Tracer C14

Starting Contact Solution Conc 500 pCi/mL (C_s)

Kd - based the Starting Concentration of tracer in contact solution

Kd* - based the Final Concentration in Tracer Contact Solution

		(C_f)		(M_w)		(V)	(f)	(S)	Kd	Avg Kd			(S)	Kd*	Avg Kd*		
SwRI ID	Soil + Tracer Contact Solution ID	Tracer Conc in Solution pCi/mL	MDC pCi/mL	Sample Wt g	% Solids	Vol. Contact Soln, mL	Fraction > 2mm	Tracer Conc sorbed in Soil (based on spiked value) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag	Tracer Conc sorbed in Soil (based on tracer conc @ final) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag
717467	708887-LSC-F1	375	0.191	5.1058	78.5%	100		3118.7	8.317				-1472.0	-3.93			
717468	708887-LSC-F2	374	0.194	5.1059	78.5%	100		3143.6	8.405				-1447.1	-3.87			
717469	708887-LSC-F3	370	0.192	5.1025	78.5%	100		3245.6	8.772				-1348.2	-3.64			
717470	708887-LSC-F4	370	0.191	5.1077	78.5%	100		3242.3	8.763	8.56	2.40%		-1346.8	-3.64	< 2	-	
717475	708888-LSC-F1	334	0.190	4.6673	85.9%	100		4140.5	12.40				-449.0	-1.34			
717476	708888-LSC-F2	310	0.193	4.6669	85.9%	100		4739.5	15.29				149.7	0.48			
717477	708888-LSC-F3	321	0.190	4.6634	85.9%	100		4468.5	13.92				-124.8	-0.39			
717478	708888-LSC-F4	323	0.191	4.6604	85.9%	100		4421.4	13.69	13.8	7.43%		-174.9	-0.54	< 2	-	
717483	708889-LSC-F1	329	0.191	4.6309	86.4%	100	2.33%	4174.4	12.69				-317.4	-0.96			
717484	708889-LSC-F2	322	0.192	4.6304	86.4%	100	2.33%	4345.7	13.50				-146.5	-0.45			
717485	708889-LSC-F3	336	0.192	4.6396	86.4%	100	2.33%	3996.0	11.89				-487.3	-1.45			
717486	708889-LSC-F4	321	0.191	4.6325	86.4%	100	2.33%	4368.1	13.61	12.9	5.38%		-122.0	-0.38	< 2	-	
717491	711291-LSC-F1	3.10	0.192	4.0037	100%	100		12411	4004				7815.3	2521			
717492	711291-LSC-F2	2.97	0.192	4.0034	100%	100		12415	4180				7819.1	2633			
717493	711291-LSC-F3	3.94	0.192	4.0023	100%	100		12394	3146				7797.0	1979			
717494	711291-LSC-F4	3.07	0.192	4.0049	100%	100		12408	4042	3840	10.62%		7813.7	2545	2420	10.65%	
717515	Tracer-LSC-F1	256	0.195														
717516	Tracer-LSC-F2	343	0.195														
717517	Tracer-LSC-F3	335	0.195	Avg (C_{tcs})	TV	Rec											
717518	Tracer-LSC-F4	330	0.196	316	500	63.2%											
717499	LCS-LSC-F1	442	0.191														
717500	LCS-LSC-F2	439	0.191														
717501	LCS-LSC-F3	446	0.193	Avg	TV	Rec											
717502	LCS-LSC-F4	438	0.190	441	500	88.2%											
717507	PB-LSC-F1	1.17	0.195														
717508	PB-LSC-F2	-0.349	0.196														
717509	PB-LSC-F3	-0.268	0.195														
717510	PB-LSC-F4	-0.275	0.193	<0.195													

$$K_d = \frac{\frac{(VxC_s) - (VxC_f)}{M}}{C_f}(1-f) \qquad K_d^* = \frac{\frac{(VxC_{tcs}) - (VxC_f)}{M}}{C_f}(1-f)$$

where M = Mw x %solids

Southwest Research Institute

Cs-137

Client EnergySolution

TO# 240229-6

Tracer Cs-137

Starting Contact Solution Conc 500 pCi/mL (C_s)

Kd - based the Starting Concentration of tracer in contact solution

Kd* - based the Final Concentration in Tracer Contact Solution

		(C_f)		(M_w)		(V)	(f)	(S)	Kd	Avg Kd			(S)	Kd*	Avg Kd*		
SwRI ID	Soil + Tracer Contact Solution ID	Tracer Conc in Solution pCi/mL	MDC pCi/mL	Sample Wt g	% Solids	Vol. Contact Soln, mL	Fraction > 2mm	Tracer Conc sorbed in Soil (based on spiked value) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag	Tracer Conc sorbed in Soil (based on tracer conc @ final) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag
717463	708887-Gamma-F1	3.04	0.294	5.1095	78.5%	100		12390	4076				11517	3789			
717464	708887-Gamma-F2	3.38	0.276	5.1054	78.5%	100		12392	3666				11518	3408			
717465	708887-Gamma-F3	3.12	0.287	5.1046	78.5%	100		12400	3974				11527	3694			
717466	708887-Gamma-F4	3.16	0.309	5.1044	78.5%	100		12399	3924	3910	3.87%		11526	3647	3630	3.87%	
717471	708888-Gamma-F1	2.53	0.293	4.6691	85.9%	100		12403	4903				11531	4558			
717472	708888-Gamma-F2	2.72	0.322	4.6624	85.9%	100		12416	4565				11543	4244			
717473	708888-Gamma-F3	2.94	0.325	4.6651	85.9%	100		12404	4219				11530	3922			
717474	708888-Gamma-F4	2.83	0.346	4.6620	85.9%	100		12415	4387	4520	5.61%		11541	4078	4200	5.61%	
717479	708889-Gamma-F1	2.41	0.252	4.6372	86.4%	100	2.33%	12130	5033				11277	4679			
717480	708889-Gamma-F2	2.44	0.297	4.6330	86.4%	100	2.33%	12141	4976				11287	4626			
717481	708889-Gamma-F3	2.34	0.241	4.6395	86.4%	100	2.33%	12126	5182				11273	4818			
717482	708889-Gamma-F4	2.40	0.303	4.6322	86.4%	100	2.33%	12144	5060	5060	1.49%		11290	4704	4710	1.49%	
717487	711291-Gamma-F1	379	0.851	4.0055	100%	100		3020.8	7.971				2147	5.665			
717488	711291-Gamma-F2	378	0.993	4.0078	100%	100		3044.1	8.053				2170.8	5.743			
717489	711291-Gamma-F3	382	0.931	4.0021	100%	100		2948.5	7.718				2073.9	5.429			
717490	711291-Gamma-F4	390	0.814	4.0036	100%	100		2747.5	7.045	7.70	5.14%		1873.3	4.803	5.41	6.82%	
717511	Tracer-Gamma-F1	467	2.23														
717512	Tracer-Gamma-F2	459	1.96														
717513	Tracer-Gamma-F3	468	1.760	Avg (C_{tcs})	TV	Rec											
717514	Tracer-Gamma-F4	466	1.85	465	500	93.0%											
717495	LCS-Gamma-F1	458	3.29														
717496	LCS-Gamma-F2	462	3.27														
717497	LCS-Gamma-F3	466	3.00	Avg	TV	Rec											
717498	LCS-Gamma-F4	462	3.52	462	500	92.4%											
717503	PB-Gamma-F1	-0.00806	0.242														
717504	PB-Gamma-F2	0.00	0.234														
717505	PB-Gamma-F3	0.0204	0.234														
717506	PB-Gamma-F4	-0.025	0.227	<0.234													

$$K_d = \frac{\frac{(VxC_s) - (VxC_f)}{M}}{C_f}(1-f) \qquad K_d{}^* = \frac{\frac{(VxC_{tcs}) - (VxC_f)}{M}}{C_f}(1-f)$$

where M = Mw x %solids

Southwest Research Institute

Co-60

Client EnergySolution

TO# 240229-6

Tracer Co-60

Starting Contact Solution Conc 500 pCi/mL (C_s)

Kd - based the Starting Concentration of tracer in contact solution

Kd* - based the Final Concentration in Tracer Contact Solution

		(C_f)		(M_w)		(V)	(f)	(S)	Kd	Avg Kd			(S)	Kd*	Avg Kd*		
SwRI ID	Soil + Tracer Contact Solution ID	Tracer Conc in Solution pCi/mL	MDC pCi/mL	Sample Wt g	% Solids	Vol. Contact Soln, mL	Fraction > 2mm	Tracer Conc sorbed in Soil (based on spiked value) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag	Tracer Conc sorbed in Soil (based on tracer conc @ final) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag
717463	708887-Gamma-F1	2.94	0.259	5.1095	78.5%	100		12393	4215			L	3591.7	1222			L
717464	708887-Gamma-F2	2.92	0.280	5.1054	78.5%	100		12403	4248			L	3595.0	1231			L
717465	708887-Gamma-F3	2.75	0.270	5.1046	78.5%	100		12409	4512			L	3599.9	1309			L
717466	708887-Gamma-F4	3.39	0.315	5.1044	78.5%	100		12394	3656	4160	7.49%	L	3584.0	1057	1200	7.65%	L
717471	708888-Gamma-F1	4.57	0.250	4.6691	85.9%	100		12353	2703			L	3551.2	777.1			L
717472	708888-Gamma-F2	5.13	0.226	4.6624	85.9%	100		12356	2409			L	3542.3	690.5			L
717473	708888-Gamma-F3	5.03	0.278	4.6651	85.9%	100		12352	2456			L	3542.8	704.3			L
717474	708888-Gamma-F4	4.97	0.319	4.6620	85.9%	100		12361	2487	2510	4.49%	L	3546.6	713.6	721	4.61%	L
717479	708889-Gamma-F1	4.30	0.309	4.6372	86.4%	100	2.33%	12084	2810			L	3478.8	809.0			L
717480	708889-Gamma-F2	4.00	0.245	4.6330	86.4%	100	2.33%	12103	3026			L	3489.3	872.3			L
717481	708889-Gamma-F3	4.24	0.331	4.6395	86.4%	100	2.33%	12080	2849			L	3478.5	820.4			L
717482	708889-Gamma-F4	4.08	0.269	4.6322	86.4%	100	2.33%	12103	2966	2910	2.99%	L	3487.9	854.9	839	3.04%	L
717487	711291-Gamma-F1	0.733	0.752	4.0055	100%	100		>12464	>16570			>, L	>3651.2	>4855			>, L
717488	711291-Gamma-F2	0.503	0.658	4.0078	100%	100		>12459	>18940			>, L	>3651.4	>5549			>, L
717489	711291-Gamma-F3	0.830	0.877	4.0021	100%	100		>12472	>14220			>, L	>3651.2	>4163			>, L
717490	711291-Gamma-F4	0.716	0.686	4.0036	100%	100		12471	17420	>16800	-	>, L	3653.8	5103	>4920	-	>, L
717511	Tracer-Gamma-F1	205	1.51														
717512	Tracer-Gamma-F2	151	1.35														
717513	Tracer-Gamma-F3	76.5	1.12	Avg (C_{tcs})	TV	Rec											
717514	Tracer-Gamma-F4	156	1.27	147	500	29.4%											
717495	LCS-Gamma-F1	514	2.62														
717496	LCS-Gamma-F2	517	2.62														
717497	LCS-Gamma-F3	519	2.58	Avg	TV	Rec											
717498	LCS-Gamma-F4	517	2.50	517	500	103.4%											
717503	PB-Gamma-F1	-0.0291	0.253														
717504	PB-Gamma-F2	-0.0607	0.309														
717505	PB-Gamma-F3	0.0340	0.291														
717506	PB-Gamma-F4	0.0818	0.308	<0.290													

$$K_d = \frac{\frac{(VxC_s) - (VxC_f)}{M}}{C_f}(1-f) \qquad K_d{}^* = \frac{\frac{(VxC_{tcs}) - (VxC_f)}{M}}{C_f}(1-f)$$

where M = Mw x %solids

Flag definition:

> = The Kd value for the sample was calculated based using the MDA concentration.

L = Tracer Control Sample recovery was less than 30% of the spike TV

Southwest Research Institute

Eu-152

Client EnergySolution

TO# 240229-6

Tracer Eu-152

Starting Contact Solution Conc 500 pCi/mL (C_s)

Kd - based the Starting Concentration of tracer in contact solution

Kd* - based the Final Concentration in Tracer Contact Solution

		(C_f)		(M_w)		(V)	(f)	(S)	Kd	Avg Kd			(S)	Kd*	Avg Kd*		
SwRI ID	Soil + Tracer Contact Solution ID	Tracer Conc in Solution pCi/mL	MDC pCi/mL	Sample Wt g	% Solids	Vol. Contact Soln, mL	Fraction > 2mm	Tracer Conc sorbed in Soil (based on spiked value) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag	Tracer Conc sorbed in Soil (based on tracer conc @ final) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag
717463	708887-Gamma-F1	1.40	1.54	5.1095	78.5%	100		>12427	>8070			>, L	>407.88	>264.9			>, L
717464	708887-Gamma-F2	1.45	0.953	5.1054	78.5%	100		12440	8579			L	410.46	283.1			L
717465	708887-Gamma-F3	1.25	1.67	5.1046	78.5%	100		>12436	>7447			>, L	>405.03	>242.5			>
717466	708887-Gamma-F4	0.597	1.88	5.1044	78.5%	100		>12431	>6612	>7680	-	>, L	>399.8	>212.7	>251	-	>, L
717471	708888-Gamma-F1	0.0195	1.77	4.6691	85.9%	100		>12422	>7018			>, L	>402.17	>227.2			>, L
717472	708888-Gamma-F2	-1.05	1.80	4.6624	85.9%	100		>12439	>6911			>, L	>402	>223.3			>, L
717473	708888-Gamma-F3	0.744	1.83	4.6651	85.9%	100		>12431	>6793			>, L	>401.02	>219.1			>, L
717474	708888-Gamma-F4	1.08	1.82	4.6620	85.9%	100		>12440	>6835	>6890	-	>, L	>401.53	>220.6	>223	-	>, L
717479	708889-Gamma-F1	-0.0841	1.81	4.6372	86.4%	100	2.33%	>12145	>6710			>, L	>392.25	>216.7			>, L
717480	708889-Gamma-F2	-1.19	1.79	4.6330	86.4%	100	2.33%	>12157	>6791			>, L	>393.09	>219.6			>, L
717481	708889-Gamma-F3	-0.788	1.79	4.6395	86.4%	100	2.33%	>12140	>6782			>, L	>392.54	>219.3			>, L
717482	708889-Gamma-F4	0.613	1.72	4.6322	86.4%	100	2.33%	>12160	>7070	>6840	-	>, L	>394.87	>229.6	>221	-	>, L
717487	711291-Gamma-F1	0.516	2.15	4.0055	100%	100		>12429	>5781			>, L	>393.21	>182.9			>, L
717488	711291-Gamma-F2	0.174	1.83	4.0078	100%	100		>12430	>6792			>, L	>400.97	>219.1			>, L
717489	711291-Gamma-F3	0.112	2.08	4.0021	100%	100		>12441	>5981			>, L	>395.29	>190			>, L
717490	711291-Gamma-F4	-0.0646	1.43	4.0036	100%	100		>12453	>8708	>6820	-	>, L	>411.38	>287.7	>220	-	>, L
717511	Tracer-Gamma-F1	11.6	2.77														
717512	Tracer-Gamma-F2	11.1	3.31														
717513	Tracer-Gamma-F3	31.7	3.94	Avg (C_{tcs})	TV	Rec											
717514	Tracer-Gamma-F4	17.1	3.16	17.9	500	3.58%											
717495	LCS-Gamma-F1	428	5.45														
717496	LCS-Gamma-F2	427	5.20														
717497	LCS-Gamma-F3	430	5.61	Avg	TV	Rec											
717498	LCS-Gamma-F4	424	5.41	427	500	85.4%											
717503	PB-Gamma-F1	-0.0804	0.304														
717504	PB-Gamma-F2	0.0120	0.337														
717505	PB-Gamma-F3	0.226	0.315														
717506	PB-Gamma-F4	-0.125	0.353	<0.327													

$$K_d = \frac{\frac{(VxC_s) - (VxC_f)}{M}}{C_f}(1-f) \qquad K_d{}^* = \frac{\frac{(VxC_{tcs}) - (VxC_f)}{M}}{C_f}(1-f)$$

where M = Mw x %solids

Flag definition:

> = The Kd value for the sample was calculated based using the MDA concentration.

L = Tracer Control Sample recovery was less than 30% of the spike TV

Southwest Research Institute

Sr-85

Client EnergySolution

TO# 240229-6

Tracer Sr-85

Starting Contact Solution Conc 500 pCi/mL (C_s)

Kd - based the Starting Concentration of tracer in contact solution

Kd* - based the Final Concentration in Tracer Contact Solution

		(C_f)		(M_w)		(V)	(f)	(S)	Kd	Avg Kd			(S)	Kd*	Avg Kd*		
SwRI ID	Soil + Tracer Contact Solution ID	Tracer Conc in Solution pCi/mL	MDC pCi/mL	Sample Wt g	% Solids	Vol. Contact Soln, mL	Fraction > 2mm	Tracer Conc sorbed in Soil (based on spiked value) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag	Tracer Conc sorbed in Soil (based on tracer conc @ final) pCi/g	Distribution Coeff ml/g	Average Distribution Coeff, mL/g	RSD	Flag
717463	708887-Gamma-F1	308	1.05	5.1095	78.5%	100		4786.9	15.54				4786.9	15.54			
717464	708887-Gamma-F2	296	0.969	5.1054	78.5%	100		5090.2	17.20				5090.2	17.20			
717465	708887-Gamma-F3	301	0.816	5.1046	78.5%	100		4966.2	16.50				4966.2	16.50			
717466	708887-Gamma-F4	299	1.01	5.1044	78.5%	100		5016.3	16.78	16.5	3.70%		5016.3	16.78	16.5	3.70%	
717471	708888-Gamma-F1	270	0.956	4.6691	85.9%	100		5734.6	21.24				5734.6	21.24			
717472	708888-Gamma-F2	276	0.965	4.6624	85.9%	100		5593.0	20.26				5593.0	20.26			
717473	708888-Gamma-F3	280	0.981	4.6651	85.9%	100		5490.0	19.61				5490.0	19.61			
717474	708888-Gamma-F4	276	0.868	4.6620	85.9%	100		5593.5	20.27	20.3	2.87%		5593.5	20.27	20.3	2.87%	
717479	708889-Gamma-F1	277	0.926	4.6372	86.4%	100	2.33%	5436.4	19.63				5436.4	19.63			
717480	708889-Gamma-F2	282	0.960	4.6330	86.4%	100	2.33%	5319.3	18.86				5319.3	18.86			
717481	708889-Gamma-F3	270	0.927	4.6395	86.4%	100	2.33%	5604.2	20.76				5604.2	20.76			
717482	708889-Gamma-F4	274	0.840	4.6322	86.4%	100	2.33%	5515.4	20.13	19.8	3.51%		5515.4	20.13	19.8	3.51%	
717487	711291-Gamma-F1	195	2.17	4.0055	100%	100		7614.5	39.05				7614.5	39.05			
717488	711291-Gamma-F2	190	1.91	4.0078	100%	100		7734.9	40.71				7734.9	40.71			
717489	711291-Gamma-F3	194	2.22	4.0021	100%	100		7646	39.41				7646	39.41			
717490	711291-Gamma-F4	197	2.16	4.0036	100%	100		7568.2	38.42	39.4	2.12%		7568.2	38.42	39.4	2.12%	
717511	Tracer-Gamma-F1	498	2.70														
717512	Tracer-Gamma-F2	494	3.25														
717513	Tracer-Gamma-F3	502	2.98	Avg (C_{tcs})	TV	Rec											
717514	Tracer-Gamma-F4	504	2.29	500	500	100.0%											
717495	LCS-Gamma-F1	481	4.52														
717496	LCS-Gamma-F2	485	4.74														
717497	LCS-Gamma-F3	489	4.16	Avg	TV	Rec											
717498	LCS-Gamma-F4	487	4.60	486	500	97.2%											
717503	PB-Gamma-F1	0.368	0.435														
717504	PB-Gamma-F2	0.295	0.421														
717505	PB-Gamma-F3	0.383	0.463														
717506	PB-Gamma-F4	0.383	0.463	<0.446													

$$K_d = \frac{\frac{(VxC_s) - (VxC_f)}{M}}{C_f}(1-f) \qquad K_d^* = \frac{\frac{(VxC_{tcs}) - (VxC_f)}{M}}{C_f}(1-f)$$

where M = Mw x %solids

SOUTHWEST RESEARCH INSTITUTE
CLIENT: Energy Solutions, LLC
SwRI PROJECT#: 28282.01.001

Sample Receipt Paperwork

Southwest Research Institute

Laboratory Task Order

TO #: 231109-2 Revision: 1

Project(s): 28282.01.001
Manager(s): Spies, Radonna
To Client: 01/12/24

SDG: 708887

SRR #'s: 70069, 70289
Client(s): EnergySolutions, LLC

Instructions

Distribution coefficient (Kd) analysis of soils and grout from the Fort Calhoun Nuclear Generating Station:
?? Three (3) soil samples
?? One (1) sample of the grout. o Grout will be pulverized by the lab to the required size limits.
?? Isotopes:
o Carbon-14
o Cobalt-60
o Strontium-90 (Strontium-85 will be utilized in testing)
o Cesium-137
o Europium-152
?? Preliminary (Equilibrium) will be performed in Duplicate and Final Kd Testing will be performed in Quadruplicate.
?? Test Plan will be prepared prior to testing.
?? Testing and Final report in compliance with EnergySolutions Q-Code 20.

Documents Related to this task order: 379249[COC for SRR 70069], 379250[Paperwork for SRR 70069], 380824[COC for SRR 70289], 380825[Paperwork for SRR 70289], 374386[], 377449[], 377450[], 377709[], 378032[], 386969[]

Deliverables --> Hard Copy: no EDD: no PDF: -YES-

Test: ASTM_C1733
Section: WETCHEM

Holding: 180 days from CED

ASTM C1733-(most current version) Method for Distribution Coefficients of Inorganic Species by the Batch Method

Cnt: 5

System ID	Type	Cont	Matrix	Customer ID	CED	Method Date
708887		1	Soil	FCS-01SAT	29 Aug 23	25 Feb 24
708887		2	Soil	FCS-01SAT	29 Aug 23	25 Feb 24
708887		3	Soil	FCS-01SAT	29 Aug 23	25 Feb 24
708887		4	Soil	FCS-01SAT	29 Aug 23	25 Feb 24
708888		1	Soil	FCS-01UNSAT	29 Aug 23	25 Feb 24
708888		2	Soil	FCS-01UNSAT	29 Aug 23	25 Feb 24
708889		1	Soil	FCS-02SP	29 Aug 23	25 Feb 24
708890		1	Water	MW-13A	29 Aug 23	25 Feb 24
708890		2	Water	MW-13A	29 Aug 23	25 Feb 24
708890		3	Water	MW-13A	29 Aug 23	25 Feb 24
708890		4	Water	MW-13A	29 Aug 23	25 Feb 24
708890		5	Water	MW-13A	29 Aug 23	25 Feb 24
708890		6	Water	MW-13A	29 Aug 23	25 Feb 24
708890		7	Water	MW-13A	29 Aug 23	25 Feb 24
708890		8	Water	MW-13A	29 Aug 23	25 Feb 24
708890		9	Water	MW-13A	29 Aug 23	25 Feb 24
708890		10	Water	MW-13A	29 Aug 23	25 Feb 24
708890		11	Water	MW-13A	29 Aug 23	25 Feb 24
708890		12	Water	MW-13A	29 Aug 23	25 Feb 24
708890		13	Water	MW-13A	29 Aug 23	25 Feb 24
708890		14	Water	MW-13A	29 Aug 23	25 Feb 24
708890		15	Water	MW-13A	29 Aug 23	25 Feb 24
708890		16	Water	MW-13A	29 Aug 23	25 Feb 24
708890		17	Water	MW-13A	29 Aug 23	25 Feb 24
708890		18	Water	MW-13A	29 Aug 23	25 Feb 24
708890		19	Water	MW-13A	29 Aug 23	25 Feb 24
708890		20	Water	MW-13A	29 Aug 23	25 Feb 24

Southwest Research Institute

Laboratory Task Order

TO #: 231109-2 Revision: 1

SDG: 708887

SRR #'s: 70069, 70289
Client(s): EnergySolutions, LLC

Project(s): 28282.01.001
Manager(s): Spies, Radonna
To Client: 01/12/24

System ID	Type	Cont	Matrix	Customer ID	CED	Method Date
711291		1	Solid	Intake Structure Flyash	17 Oct 23	14 Apr 24

Sample Receipt

Southwest Research Institute

Sample Receipt Number: 70069
Revision: 1

VTSR: 08/31/23

Time: 10:30:00

Project: 28282.01.001
Case #: Energy
Client: EnergySolutions, LLC

This Receipt was Revised 09/27/2023

Manager: Spies, Radonna
Logged in by: DXGARCIA
Creation Date: 08/31/23

Notes

4 coolers were delivered to SwRI's Shipping & Receiving Warehouse. Division 01 AEC LOGIN staff picked up the coolers from Receiving and took custody. Samples were received intact.

UPS TRACKING #:
1Z 21W 30R 15 0225 4589 _ 6.7°C (melted ice).
1Z 21W 30R 15 0225 8156 _ 7.4°C (melted ice).
1Z 21W 30R 15 6892 2439 _ 6.7°C (melted ice).
1Z 21W 30R 15 6892 3625 _ 7.2°C (melted ice).

See chain of custody for more information.

Test requirements located on applicable Task Order.

NOTE: Project # was issued on 09/27/23.

TEMP NOTE _ All 4 coolers arrived with slightly elevated temps (melted ice). Due to the size of the cubitainers, limited amount of room was available to add ice to the coolers, hence the higher temps.

REVISION 1, DRamirez 09/27/23: Sample Receipt revised to clarify the NOTES.

System ID	Customer ID	CED	Matrix	Containers	Special Reqs.
708887	FCS-01SAT	08/29/23	Soil	4	
708888	FCS-01UNSAT	08/29/23	Soil	2	
708889	FCS-02SP	08/29/23	Soil	1	
708890	MW-13A	08/29/23	Water	20	

Containers: 27 **Samples: 4**

These documents are associated with this receipt: 379249[COC for SRR 70069], 379250[Paperwork for SRR 70069], 374386[], 377449[], 377450[], 377709[], 378032[], 386969[]

Thermometer: 029926
Temperature: NOTE

70069 EnergySolutions, LLC

Cooler 1 of 4

SAMPLE LIST/CHAIN OF CUSTODY

Southwest Research Institute
Chemistry and Chemical Engineering Division
6220 Culebra Road
San Antonio, Texas 78238-5166

Requested Turnaround:
- 2 Weeks
- 3 Weeks
- Other: ↙

Shipper Name/ Address: Jason Spaide
Fort Calhoun Station
Power Lane
Blair, NE 68008

Client: EnergySolutions

Client Purchase Order/Other ID:

Site/Zone ID: Fort Calhoun Station

SwRI Contact: Radonna Spies

Analyses Requested

Sample ID	Sample Collection Date (mm/dd/yy)	Sample Collection Time	Matrix Type	Sample Type	# of Containers	Kd Analysis										REMARKS
FCS-01UNSAT	8/29/23	1400	S	ES	2	X										2 ziplock bags
FCS-01SAT	8/29/23	1410	S	ES	2	X										2 ziplock bags
FCS-02SP	8/29/23	1430	S	ES	1	X										1 poly bag
MW-13A	8/29/23	1500	W	ES	20	X										20 1-gallon poly bottles

Preservation
a = HCl to pH <2
b = HNO_3 to pH <2
c = H_2SO_4 to pH <2
d = NaOH to pH >12
e = Cool (4°C±2°C)
f = Other (specify)

Matrix Types:
A – Air
B – Biota
D - Dust
E – Emission/Stack
L - Liquid
P – Product
Sd - Solid
S – Soil
SED – Sediment
T - Tissue
W - Water
WP - Wipe

Sample Types:
D - Duplicate
ER – Equipment Rinsate
ES – Environmental Sample
FB – Field Blank
FD – Field Duplicate
MS – Matrix Spike
MSD – Matrix Spike Dup
TB – Trip Blank

Temp:

Therm #:

Comments:

	Date	Time
Relinquished by (Print/Signature): Miles van Noordennen	8/30/23	1100
Received by (Print/Signature):		
Relinquished by (Print/Signature):		
Received by (Print/Signature):		
Relinquished by (Print/Signature):		

SwRI Project#:

Received by SwRI Lab: (Signature)

Date: 8.31.23 Time: 10:30

Samples Disposed: Date / Time

Samples Disposed by:

Client: EnergySolutions
SRR # 70069
Project # 28282.01.001
Case: Energy
VTSR: 08/31/23
Sample(s) Received: Intact
Temperature: NOTES SN # 029926

UPS#: 8156

Cooler 2 of 4

SAMPLE LIST/CHAIN OF CUSTODY

Southwest Research Institute
Chemistry and Chemical Engineering Division
6220 Culebra Road
San Antonio, Texas 78238-5166

Shipper Name/ Address: Jason Spaide
Fort Calhoun Station
Power Lane
Blair, NE 68008

Client: EnergySolutions

Client Purchase Order/Other ID:

Site/Zone ID: Fort Calhoun Station

Requested Turnaround:
- [ ] 2 Weeks
- [ ] 3 Weeks
- [ ] Other:

SwRI Contact: Radonna Spies

Analyses Requested

Sample ID	Sample Collection Date (mm/dd/yy)	Sample Collection Time	Matrix Type	Sample Type	# of Containers	Kd Analysis										REMARKS
FCS-01UNSAT	8/29/23	1400	S	ES	2	X										2 ziplock bags
FCS-01SAT	8/29/23	1410	S	ES	2	X										2 ziplock bags
FCS-02SP	8/29/23	1430	S	ES	1	X										1 poly bag
MW-13A	8/29/23	1500	W	ES	20	X										20 1-gallon poly bottles

Preservation
a = HCl to pH <2
b = HNO_3 to pH <2
c = H_2SO_4 to pH <2
d = NaOH to pH >12
e = Cool (4°C±2°C)
f = Other (specify)

Matrix Types:
A – Air
B – Biota
D - Dust
E – Emission/Stack
L - Liquid
P – Product
Sd - Solid
S – Soil
SED – Sediment
T - Tissue
W - Water
WP - Wipe

Sample Types:
D - Duplicate
ER – Equipment Rinsate
ES – Environmental Sample
FB – Field Blank
FD – Field Duplicate
MS – Matrix Spike
MSD – Matrix Spike Dup
TB – Trip Blank

Temp:

Therm #:

Comments:

Relinquished by (Print/Signature)	Date	Time
Miles van Noordennen	8/30/23	1100
Received by (Print/Signature)	Date	Time
Relinquished by (Print/Signature)	Date	Time
Received by (Print/Signature)	Date	Time
Relinquished by (Print/Signature)	Date	Time

SwRI Project#:

Received by SwRI Lab: (Signature)

Date: 8.31.23 Time: 10:30

Samples Disposed: Date / Time

Samples Disposed by:

Client: EnergySolutions
SRR # 70069
Project # 28282.01.001
Case: Energy
VTSR: 08/31/23
Sample(s) Received: Intact
Temperature: NOTES SN # 029926

UPS#: 4589

Cooler 3 of 4

SAMPLE LIST/CHAIN OF CUSTODY

Southwest Research Institute
Chemistry and Chemical Engineering Division
6220 Culebra Road
San Antonio, Texas 78238-5166

Requested Turnaround:
- 2 Weeks
- 3 Weeks
- Other:

Shipper Name/ Address: Jason Spaide
Fort Calhoun Station
Power Lane
Blair, NE 68008

Client: EnergySolutions

Client Purchase Order/Other ID:

Site/Zone ID: Fort Calhoun Station

SwRI Contact: Radonna Spies

Analyses Requested

Sample ID	Sample Collection Date (mm/dd/yy)	Sample Collection Time	Matrix Type	Sample Type	# of Containers	Kd Analysis										REMARKS
FCS-01UNSAT	8/29/23	1400	S	ES	2	X										2 ziplock bags
FCS-01SAT	8/29/23	1410	S	ES	2	X										2 ziplock bags
FCS-02SP	8/29/23	1430	S	ES	1	X										1 poly bag
MW-13A	8/29/23	1500	W	ES	20	X										20 1-gallon poly bottles

Preservation
a = HCl to pH <2
b = HNO_3 to pH <2
c = H_2SO_4 to pH <2
d = NaOH to pH >12
e = Cool (4°C±2°C)
f = Other (specify)

Matrix Types:
A – Air
B – Biota
D - Dust
E – Emission/Stack
L - Liquid
P – Product
Sd - Solid
S – Soil
SED – Sediment
T - Tissue
W - Water
WP - Wipe

Sample Types:
D - Duplicate
ER – Equipment Rinsate
ES – Environmental Sample
FB – Field Blank
FD – Field Duplicate
MS – Matrix Spike
MSD – Matrix Spike Dup
TB – Trip Blank

Temp: Therm #:

Comments:

Relinquished by (Print/Signature)	Date	Time
Miles van Noordennen	8/30/23	1100
Received by (Print/Signature)	Date	Time
Relinquished by (Print/Signature)	Date	Time
Received by (Print/Signature)	Date	Time
Relinquished by (Print/Signature)	Date	Time

SwRI Project#:

Received by SwRI Lab: (Signature)

Date: 08.31.23 Time: 10:30

Samples Disposed: Date / Time

Samples Disposed by:

Client: EnergySolutions
SRR # 70069
Project # 28282.01.001
Case: Energy
VTSR: 08/31/23
Sample(s) Received: Intact
Temperature: NOTES SN # 029926

UPS#: 2439

Div 01 COC FRM-010 (Rev 1/Nov 05)

Cooler 4 of 4

SAMPLE LIST/CHAIN OF CUSTODY

Southwest Research Institute
Chemistry and Chemical Engineering Division
6220 Culebra Road
San Antonio, Texas 78238-5166

Requested Turnaround:
- [ ] 2 Weeks
- [ ] 3 Weeks
- [ ] Other: ↙

Shipper Name/ Address: Jason Spaide
Fort Calhoun Station
Power Lane
Blair, NE 68008

Client: EnergySolutions

Client Purchase Order/Other ID:

Site/Zone ID: Fort Calhoun Station

SwRI Contact: Radonna Spies

Analyses Requested

Sample ID	Sample Collection Date (mm/dd/yy)	Sample Collection Time	Matrix Type	Sample Type	# of Containers	Kd Analysis										REMARKS
FCS-01UNSAT	8/29/23	1400	S	ES	2	X										2 ziplock bags
FCS-01SAT	8/29/23	1410	S	ES	2	X										2 ziplock bags
FCS-02SP	8/29/23	1430	S	ES	1	X										1 poly bag
MW-13A	8/29/23	1500	W	ES	20	X										20 1-gallon poly bottles

Preservation
a = HCl to pH <2
b = HNO_3 to pH <2
c = H_2SO_4 to pH <2
d = NaOH to pH >12
e = Cool (4°C±2°C)
f = Other (specify)

Matrix Types:
A – Air
B – Biota
D - Dust
E – Emission/Stack
L - Liquid
P – Product
Sd - Solid
S – Soil
SED – Sediment
T - Tissue
W - Water
WP - Wipe

Sample Types:
D - Duplicate
ER – Equipment Rinsate
ES – Environmental Sample
FB – Field Blank
FD – Field Duplicate
MS – Matrix Spike
MSD – Matrix Spike Dup
TB – Trip Blank

Temp:

Therm #:

Comments:

	Date	Time
Relinquished by (Print/Signature) Miles van Noordennen	8/30/23	1100
Received by (Print/Signature)		
Relinquished by (Print/Signature)		
Received by (Print/Signature)		
Relinquished by (Print/Signature)		

SwRI Project#:

Received by SwRI Lab: (Signature)

Date: 8.31.23 Time: 10:30

Samples Disposed: Date / Time

Samples Disposed by:

Client: EnergySolutions
SRR # 70069
Project # 28282.01.001
Case: Energy
VTSR: 08/31/23
Sample(s) Received: Intact
Temperature: NOTES SN # 029926

UPS #: 3625

Div 01 COC FRM-010 (Rev 1/Nov 05)

Page 1 of 1

Sample Receipt

Southwest Research Institute

Sample Receipt Number: 70289
Revision: 1

VTSR: 10/19/23

Time: 09:20:00

Project: **28282.01.001**
Case #: **717991**
Client: **EnergySolutions, LLC**

This Receipt was Revised 03/15/2024

Manager: Spies, Radonna
Logged in by: DXGARCIA
Creation Date: 10/19/23

Notes

1 cooler was delivered to SwRI's Shipping & Receiving Warehouse. Division 01 AEC LOGIN staff picked up the cooler from Receiving and took custody. Samples were received intact.

FedEx TRACKING #:
7737 8199 1198 _ 5.6°C (blue ice pack).

See chain of custody for more information.

Test requirements located on applicable Task Order.

REVISION 1, DRamirez 03-15-24: Sample Receipt revised to indicate that only one sample was received, with 2 containers. To revise the Sample Receipt to reflect that, Lab ID 711292 (for "sample 2"), will be deleted. All custody history pertaining to that sample / container will be removed also because of it being deleted. Sample will be re-named to Intake Structure Flyash with two containers. Per email from Project Manager. Lab ID 711291 Container 2 won't have any custody history because of it was under deleted 711292.

System ID	Customer ID	CED	Matrix	Containers	Special Reqs.
711291	Intake Structure Flyash	10/17/23	Solid	2	

Containers: 2 **Samples: 1**

These documents are associated with this receipt: 380824[COC for SRR 70289], 380825[Paperwork for SRR 70289], 374386[], 377449[], 377450[], 377709[], 378032[], 386969[]

Thermometer: 029926
Temperature: 5.6

Page Printed: 03/28/2024 16:54
ver: (4/10/2017)

70289 EnergySolutions, LLC

SAMPLE LIST/CHAIN OF CUSTODY

Southwest Research Institute
Chemistry and Chemical Engineering Division
6220 Culebra Road
San Antonio, Texas 78238-5166

Requested Turnaround:
- ☐ 2 Weeks
- ☐ 3 Weeks
- ☐ Other:

Shipper Name/ Address: Anton Kodra
Fort Calhoun Station
Power Lane
Blair, NE 68008

Client: EnergySolutions
Anton Kodra(513) 496-9245

Client Purchase Order/Other ID: PO # 717991

Site/Zone ID: Fort Calhoun Station

SwRI Contact: Radonna Spies

Analyses Requested

Sample ID	Sample Collection Date (mm/dd/yy)	Sample Collection Time	Matrix Type	Sample Type	# of Containers	Kd Analysis										REMARKS Preservation
Intake Structure Flyash -1	10/17/23	1430	S	ES	1	X										1 500ml container
Intake Structure Flyash -2	10/17/23	1430	S	ES	1	X										1 500ml container

a = HCl to pH <2
b = HNO_3 to pH <2
c = H_2SO_4 to pH <2
d = NaOH to pH >12
e = Cool (4°C±2°C)
f = Other (specify)

Matrix Types:
A – Air
B – Biota
D - Dust
E – Emission/Stack
L - Liquid
P – Product
Sd - Solid
S – Soil
SED – Sediment
T - Tissue
W - Water
WP - Wipe

Sample Types:
D - Duplicate
ER – Equipment Rinsate
ES – Environmental Sample
FB – Field Blank
FD – Field Duplicate
MS – Matrix Spike
MSD – Matrix Spike Dup
TB – Trip Blank

Temp:

Therm #:

Comments:

	Date	Time
Relinquished by (Print/Signature): Kevin L Murray	10/18/23	0745
Received by (Print/Signature):		
Relinquished by (Print/Signature):		
Received by (Print/Signature):		
Relinquished by (Print/Signat		

SwRI Project#:

Received by SwRI Lab: (Signature)

Date: 10.19.23 Time: 05:20

Samples Disposed: Date / Time

Samples Disposed by:

Client: EnergySolutions, LLC
SRR # 70289
Project # 28282.01.001
Case: 717991
VTSR: 10/19/23
Sample(s) Received: Intact
Temperature: 5.6°C SN # 029926

Div 01 COC FRM-010 (Rev 1/Nov 05)

Page _____ of _____

Sample Preparation Info and Logbook Copies

Work continued from Page

RDyess 1/30/24

Southwest Research Institute

EnergySolutions
Project #28282.01.01

Balance # 135 Weighed By: RN Dates Weighted: 1/18/2024

Gamma

Sample ID	Sample Wt g	Replicate Sample ID	Sample Wt g	Replicate Sample ID	Sample Wt g	Replicate Sample ID	Sample Wt g	NOMINAL	Bottle
708887-Gamma-P1	22.9172	708887-Gamma-P2	22.9027					22.9	500mL Nalgene (450 mL FV)
708888-Gamma-P1	21.0001	708888-Gamma-P2	21.0324					21.0	
708889-Gamma-P1	20.8136	708889-Gamma-P2	20.8429					20.8	
711291-Gamma-P1	18.0471	711291-Gamma-P2	18.0068					18.0	
708887-Gamma-F1	5.1095	708887-Gamma-F2	5.1054	708887-Gamma-F3	5.1046	708887-Gamma-F4	5.1044	5.10	125 mL Nalgene (100 mL FV)
708888-Gamma-F1	4.6691	708888-Gamma-F2	4.6624	708888-Gamma-F3	4.6651	708888-Gamma-F4	4.6620	4.66	
708889-Gamma-F1	4.6372	708889-Gamma-F2	4.6330	708889-Gamma-F3	4.6395	708889-Gamma-F4	4.6322	4.63	
711291-Gamma-F1	4.0055	711291-Gamma-F2	4.0078	711291-Gamma-F3	4.0021	711291-Gamma-F4	4.0036	4.00	

4 RSS 3/28/24

RDyess 1/30/24

Southwest Research Institute

EnergySolutions
Project #28282.01.01

Balance # 135 Weighed By: RN Dates Weighted: 1/18/2024

LSC

Sample ID	Sample Wt g	Replicate Sample ID	Sample Wt g	Replicate Sample ID	Sample Wt g	Replicate Sample ID	Sample Wt g	NOMINAL	Bottle
708887-LSC-P1	22.9303	708887-LSC-P2	22.9126					22.9	500mL Nalgene (450 mL FV)
708888-LSC-P1	21.0542	708888-LSC-P2	21.0088					21.0	
708889-LSC-P1	20.8231	708889-LSC-P2	20.8946					20.8	
711291-LSC-P1	18.0171	711291-LSC-P2	18.0075					18.0	
708887-LSC-F1	5.1058	708887-LSC-F2	5.1059	708887-LSC-F3	5.1025	708887-LSC-F4	5.1077	5.10	125 mL Nalgene (100 mL FV)
708888-LSC-F1	4.6673	708888-LSC-F2	4.6669	708888-LSC-F3	4.6634	708888-LSC-F4	4.6604	4.66	
708889-LSC-F1	4.6309	708889-LSC-F2	4.6304	708889-LSC-F3	4.6396	708889-LSC-F4	4.6325	4.63	
711291-LSC-F1	4.0037	711291-LSC-F2	4.0034	711291-LSC-F3	4.0023	711291-LSC-F4	4.0049	4.00	

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RSS 3/28/24

1/30/24

Work continued to Page

SIGNATURE RDyess

Typed in book DM DATE 1/30/24

DISCLOSED TO AND UNDERSTOOD BY Jaime Neal DATE 2/28/24

Work continued from Page

SWRI

D Jpris 1/30/24

EnergySolutions
Project #28282.01.01

Weighed By: R. Nava
Balance # #009610 Dates Weighted: 12/29/23 & 1/2/24

Sample ID	#10 Sieve Wt Passed g	#10 Sieve Wt Retained g	% > #10
708887	1266.67	0	
708888	815.65	0	
708889	1417.28	33.77	2.33%
711291	630.61	0	

① RSS 1/30/24
The 20 - ~1 Gallon containers of water sample 708890 (MW-13A) were filtered through a ~~0.45~~ 0.7um glass fiber filters using vacuum filtration. All volume combined into 20 gallon container. The water to be used for tracer solutions.
Filtering conducted by ramiro. nava on 12/28/23 and 12/29/23.

late entry RSS 1/30/24.

RSS 1/30/24

Work continued to Page

SIGNATURE D Jpris / recorded - tape in book on DATE 1/30/24

DISCLOSED TO AND UNDERSTOOD BY DATE 2/28/24

2/5/2024 5:30pm

LSC - Tracer Contact Water							
Isotope	Rad ID	CIMS ID	Stock Conc uCi/mL	Volume Spiked mL	Target Conc pCi/mL	Stock Added mL	Matrix
C14 ✓	130RadSol4	252627	15.6938	10000 ✓	500	0.319 ✓	sample water

LSC -LCS							
Isotope	Rad ID	CIMS ID	Stock Conc uCi/mL	Volume Spiked mL	Target Conc pCi/mL	Stock Added mL	Matrix
C14 ✓	130RadSol4	252627	15.6938	1500 ✓	500	0.0478 ✓	DI Water

+ 80uL 10N NaOH

Gamma Tracer Contact Water							
Isotope	Rad ID	CIMS ID	Stock Conc uCi/mL	Volume Spiked mL	Target Conc pCi/mL	Stock Added mL	Matrix
Sr85 ✓	116RadSol4	243501	0.1237	10000 ✓	500	✓40.420✓	sample water
Cs137 ✓	114RadSol4	243497	0.9634	10000 ✓	500	✓5.190✓	
Co60 ✓	128RadSol4	252625	0.9849	10000 ✓	500	✓5.077✓	
Eu152 ✓	126RadSol4	252624	1.0261	10000 ✓	500	✓4.873	

+ 5mL 10N NaOH

Gamma LCS							
Isotope	Rad ID	CIMS ID	Stock Conc uCi/mL	Volume Spiked mL	Target Conc pCi/mL	Stock Added mL	Matrix
Sr85 ✓	116RadSol4	243501	0.1237	1300✓	500	✓5.255✓	DI Water
Cs137 ✓	114RadSol4	243497	0.9634	1300✓	500	0.675✓	
Co60 ✓	128RadSol4	252625	0.9849	1300✓	500	0.660✓	
Eu152 ✓	126RadSol4	252624	1.0261	1300✓	500	0.633 ✓	

Eppendorfs: 5000-11
1000-3
200-M

Sample water: System ID: 708890

RSS 2/5/24

Work continued to Page

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DISCLOSED TO AND UNDERSTOOD BY Jan Mad
DATE 2/5/2024
DATE RSS 2/6/24 2/28/24

Work continued from Page

pH meter calibration

pH Buffer	pH Reading	Temp °C
4 (CIMS 226575)	4.02	21.2
7 (CIMS 236208)	7.02	21.2
10 (CIMS 237526)	10.01	21.3

ICV (CIMS 227601)	7.30	21.2
LSC Tracer Contact Soln (p.34)	7.77	21.3
Gamma Tracer Contact Soln (p.34)	5.73	21.2
+ 0.5mL 10N NaOH	5.91	21.3
+ 2.0mL 10N NaOH	6.48	
+ 1.0mL 10N NaOH	7.06	
0.75mL 10N NaOH	7.26	
0.75mL 10N NaOH	7.75	
RSS 2/5/24 CCV (CIMS 227601)	7.33	

RSS 2/5/24

Work continued to Page

SIGNATURE

DISCLOSED TO AND UNDERSTOOD BY

DATE 2/5/24

DATE RSS 2/6/24

2/28/24

SWRI

Work continued from Page

(1) Aliquoted LSC Tracer Contact Solution to each sample + Tracer Bottles
(2) ALiquoted LSC - LCS Solution to LCS bottles.
(3) Aliquoted DI to All PB samples bottles.

Class A Graduated Cylinders.

DJ pris 2/6/24

LSC SAMPLES

Preliminary Test Sample IDs	Nominal Sample Dry Wt g	Aliquoted Final Vol, mL
(0) 708887-LSC-P1	18	450
(0) 708887-LSC-P2	18	450
(0) 708888-LSC-P1	18	450
(0) 708888-LSC-P2	18	450
(0) 708889-LSC-P1	18	450
(0) 708889-LSC-P2	18	450
(0) 711291-LSC-P1	18	450
(0) 711291-LSC-P2	18	450
(0) Tracer-LSC-P1		450
(0) Tracer-LSC-P2		450
(2) LCS-LSC-P1		450
(2) LCS-LSC-P2		450
(3) PB-LSC-P1		450
(3) PB-LSC-P2		450

Final Test Sample IDs	Nominal Sample Dry Wt g	Aliquoted Final Vol, mL
(0) 708887-LSC-F1	4	100
(0) 708887-LSC-F2	4	100
(0) 708887-LSC-F3	4	100
(0) 708887-LSC-F4	4	100
(0) 708888-LSC-F1	4	100
(0) 708888-LSC-F2	4	100
(0) 708888-LSC-F3	4	100
(0) 708888-LSC-F4	4	100
(0) 708889-LSC-F1	4	100
(0) 708889-LSC-F2	4	100
(0) 708889-LSC-F3	4	100
(0) 708889-LSC-F4	4	100
(0) 711291-LSC-F1	4	100
(0) 711291-LSC-F2	4	100
(0) 711291-LSC-F3	4	100
(0) 711291-LSC-F4	4	100
(0) Tracer-LSC-F1		100
(0) Tracer-LSC-F2		100
(0) Tracer-LSC-F3		100
(0) Tracer-LSC-F4		100
(2) LCS-LSC-F1		100
(2) LCS-LSC-F2		100
(2) LCS-LSC-F3		100
(2) LCS-LSC-F4		100
(3) PB-LSC-F1		100
(3) PB-LSC-F2		100
(3) PB-LSC-F3		100
(3) PB-LSC-F4		100

Aliquoted.

Work continued to Page

SIGNATURE DJ pris
DATE 2/6/24

DISCLOSED TO AND UNDERSTOOD BY
DATE 2/8/24

RSS 2/6/24

Work continued from Page

(1) Aliquoted Gammer Contact Solution to all sample + tracer sample bottles.
(2) Aliquoted Gamma LCS solution to LCS bottles
(3) Aliquoted DI water solutions to PB bottles.

Class A graduated cylinders

DJ 2/6/24

GAMMA SAMPLES

Preliminary Test Sample IDs	Nominal Sample Dry Wt g	Aliquoted Final Vol, mL
(1) 708887-Gamma-P1	18	450
(1) 708887-Gamma-P2	18	450
(1) 708888-Gamma-P1	18	450
(1) 708888-Gamma-P2	18	450
(1) 708889-Gamma-P1	18	450
(1) 708889-Gamma-P2	18	450
(1) 711291-Gamma-P1	18	450
(1) 711291-Gamma-P2	18	450
(1) Tracer-Gamma-P1	-	450
(1) Tracer-Gamma-P2	-	450
(2) LCS-Gamma-P1	-	450
(2) LCS-Gamma-P2	-	450
(3) PB-Gamma-P1	-	450
(3) PB-Gamma-P2	-	450

Final Test Sample IDs	Nominal Sample Dry Wt g	Aliquoted Final Vol, mL
(1) 708887-Gamma-F1	4	100
(1) 708887-Gamma-F2	4	100
(1) 708887-Gamma-F3	4	100
(1) 708887-Gamma-F4	4	100
(1) 708888-Gamma-F1	4	100
(1) 708888-Gamma-F2	4	100
(1) 708888-Gamma-F3	4	100
(1) 708888-Gamma-F4 RSS 3/28/24	4	100
(1) 708888-Gamma-F1	4	100
(1) 708889-Gamma-F2	4	100
(1) 708889-Gamma-F3	4	100
(1) 708889-Gamma-F4	4	100
(1) 711291-Gamma-F1	4	100
(1) 711291-Gamma-F2	4	100
(1) 711291-Gamma-F3	4	100
(1) 711291-Gamma-F4	4	100
(1) Tracer-Gamma-F1		100
(1) Tracer-Gamma-F2		100
(1) Tracer-Gamma-F3		100
(1) Tracer-Gamma-F4		100
(2) LCS-Gamma-F1		100
(2) LCS-Gamma-F2		100
(2) LCS-Gamma-F3		100
(2) LCS-Gamma-F4		100
(3) PB-Gamma-F1		100
(3) PB-Gamma-F2		100
(3) PB-Gamma-F3		100
(3) PB-Gamma-F4		100

Work continued to Page

SIGNATURE DJ DATE 2/6/24

DISCLOSED TO AND UNDERSTOOD BY DATE 2/28/24

Work continued from Page

Day 1

Samples are shaken each business day. Prior to sampling, all samples were shaken and allowed to settle several hours prior to sampling. Samples were filtered using a 0.45 um syringe filter.

Preliminary Gamma Sampling

Filtered 5.5-6 mL of each preliminary Gamma sample. Transferred 5 mL into 20 mL plastic vial for direct gamma analysis. Submitted to Radchem.

Preliminary LSC Sampling

Filtered 5.5-6 mL of each preliminary LSC sample into a 15-mL conical tube. Submitted to Radchem.

Filter Type Ic acrodisk 0.45um

Eppendorf: 5000-11

2/7/24

SAM

Work continued to Page

Work continued from Page

Day 3

Samples are shaken each business day. Prior to sampling, all samples were shaken and allowed to settle several hours prior to sampling. Samples were filtered using a 0.45 um syringe filter.

Preliminary Gamma Sampling

Filtered 5.5-6 mL of each preliminary Gamma sample. Transferred 5 mL into 20 mL plastic vial for direct gamma analysis. Submitted to Radchem.

Preliminary LSC Sampling

Filtered 5.5-6 mL of each preliminary LSC sample into a 15-mL conical tube. Submitted to Radchem.

Filter Type IC acrodisk 0.45um

Eppendorf: 5000-11

2/9/24

SAM 2/9/24

Work continued to Page

SIGNATURE

DATE 2/9/24

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DATE 3/1/24

Work continued from Page

Day 7

Samples are shaken each business day. Prior to sampling, all samples were shaken and allowed to settle several hours prior to sampling. Samples were filtered using a 0.45 um syringe filter.

Preliminary Gamma Sampling

Filtered 5.5-6 mL of each preliminary Gamma sample. Transferred 5 mL into 20 mL plastic vial for direct gamma analysis. Submitted to Radchem.

Preliminary LSC Sampling

Filtered 5.5-6 mL of each preliminary LSC sample into a 15-mL conical tube. Submitted to Radchem.

Filter Type IC acrodisk 0.45um

Eppendorf: 5000-11

James Moss 2/13/24

SAM 2/13/24

Work continued to Page

SIGNATURE James Moss DATE 2/13/24

DISCLOSED TO AND UNDERSTOOD BY R Staples DATE 3/1/24

Work continued from Page

Day 14

Samples are shaken each business day. Prior to sampling, all samples were shaken and allowed to settle several hours prior to sampling. Samples were filtered using a 0.45 um syringe filter.

Preliminary Gamma Sampling

Filtered 5.5-6 mL of each preliminary Gamma sample. Transferred 5 mL into 20 mL plastic vial for direct gamma analysis. Submitted to Radchem.

Preliminary LSC Sampling

Filtered 5.5-6 mL of each preliminary LSC sample into a 15-mL conical tube. Submitted to Radchem.

Filter Type IC acrodisk 0.45um

Eppendorf: 5000-11

2/20/24

SAM 2/20/24

Work continued to Page

SIGNATURE

DATE 2/20/24

DISCLOSED TO AND UNDERSTOOD BY

DATE 3/1/24

Work continued from Page

SWRI

Day 21

Samples are shaken each business day. Prior to sampling, all samples were shaken and allowed to settle several hours prior to sampling. Samples were filtered using a 0.45 um syringe filter.

Preliminary Gamma Sampling

Filtered 5.5-6 mL of each preliminary Gamma sample. Transferred 5 mL into 20 mL plastic vial for direct gamma analysis. Submitted to Radchem.

Preliminary LSC Sampling

Filtered 5.5-6 mL of each preliminary LSC sample into a 15-mL conical tube. Submitted to Radchem.

Filter Type Ic acrodisk 0.45um

Eppendorf: 5000-11

JAM 2/27/24

JAM 2/27/24

Work continued to Page

SIGNATURE JAM

DATE 2/27/24

DISCLOSED TO AND UNDERSTOOD BY RSpies

DATE 3/1/24

Work continued from Page

DRM 2/27/24

Final gamma Samples Sacrifice for Analysis:

All samples are shaken each business day. Prior to the day of sacrificing, all samples were shaken and allowed to settle several hours prior to filtering. Samples were filtered through 0.45 um filter using vacuum filtration. Approximately 5 mL of filtrate was reserved for pH analysis. Remaining filtrate volume was placed in a 100 mL Nalgene bottle and submitted for analysis.

Filter Type/SN Millipose Express Plus 0.45um PES
lot # 0000211023

RSS 2/29/24

Work continued to Page

SIGNATURE

DATE 2/27/24

DISCLOSED TO AND UNDERSTOOD BY

DATE 2/1/24

SWRI

Work continued from Page

DJ pms 2/27/24

Final LSC Samples Sacrifice for Analysis:

All samples are shaken each business day. Prior to the day of sacrificing, all samples were shaken and allowed to settle several hours prior to filtering. Samples were filtered through 0.45 um filter using vacuum filtration. Approximately 5 mL of filtrate was reserved for pH analysis. Remaining filtrate volume was placed in a 100 mL Nalgene bottle and submitted for analysis.

Filter Type/SN Millipore Express PLUSS 0.45µm PES
Lot # 000021102 3

RSS 2/29/24

Work continued to Page

SIGNATURE

DATE 2/28/24

DISCLOSED TO AND UNDERSTOOD BY DJ pms

DATE 3/1/24

pH Solids
Raw Data

Preparation Log

WetChem

A36209

A36209

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20240102-P001 (Ver. 1)
Status: APPROVED

Client(s): EnergySolutions, LLC
Task Order(s): 231109-2
SDG(s): 708887
Case(s): Energy, 717991
Project(s): 28282.01.001
Matrix(s): Soil, Solid, Water
Balance(s): Bal #135 (AN:020014)
Heating Device: Oven #31 (ID:024013)
Time In: 01/02/2024 10:42:31
Oven Time In: 01/02/2024 10:56:37 Oven Time Out: 01/03/2024 10:16:04

Sample Identification	Client Identification	Tare Wt (g)	WetSample +TareWt (g)	Wet Weight (g)	DriedSample +TareWt (g)	Dry Weight (g)	%Solids (%)
PB24A02RN1	NA	1.0014	1.0014	0	1.0015	0.0001	< 0.00
708887	FCS-01SAT	0.9963	2.5923	1.596	2.2493	1.253	78.5
708888	FCS-01UNSAT	1.0020	2.6884	1.6864	2.4506	1.4486	85.9
708889	FCS-02SP	0.9874	2.5436	1.5562	2.3318	1.3444	86.4
708889D	FCS-02SP	0.9704	2.5623	1.5919	2.3454	1.375	86.4
711291	Intake Structure Flyash	0.9685	2.5774	1.6089	2.5769	1.6084	100
711292	NA	0.9628	2.5510	1.5882	2.5508	1.588	100

Comments: NA

CGL - 03/28/2024

Prepared by: NAVA, RAMIRO Date: 01/02/2024

Reviewed by: SPIES, RADONNA Date: 03/04/2024

Disposal Int/Date/Loc:

Program version(8/11/2011)

pH 9040C

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20240126-A004 (Ver. 1)
Status: CONSUMED

Customer: EnergySolutions, LLC
Project: 28282.01.001
SDG: 708887
Task Order: 231109-2
Instrument: Accumet 50
Analyte Test: pH 9040C
Analysis Method: pH 9040C (TAP: TAP 01-0406-100)
Reagent: (pH) Buffer 4.0 (226575; exp 08/16/24), (pH) buffer 7.0 (236208; exp 01/04/25), (pH) buffer 10.0 (237526; exp 0302/25)
Start Time: 01/26/2024 10:46:32
Equipment: ATC (029067)
Batch Note: pH result compensated to 25°C, Curve Status Pass/Fail?
Matrix: Water
Limit: pH 9040

		pH at 25°C			
Sample Identification	Client Identification	1st pH reading (s.u.)	2nd pH reading (s.u.)	pH (s.u.)	Temp (s.u.)
4.00	NA	4.02	4.01	4.01	22.1
7.00	NA	7.02	7.01	7.01	21.7
10.00	NA	9.99	10.00	10.00	22.2
ICV ①	NA	7.35	7.33	7.33	21.8
708890	MW-13A	7.76	7.79	7.79	23.0
708890D	MW-13A	7.79	7.83	7.83	22.9
CCV 1 ①	NA	7.33	7.33	7.33	21.8 (C)

① spiked 10 mL of pH Reference Material - #227601 (Lot# UNDEFINED, Source: UNDEFINED, Exp: 02/25/2025) with pH at 25°C at 7.33 s.u.

Comments:

Buffer:	Slope:
4.00-7.00	101%
7.00-10.00	96.7%

Procedure:
See TAP 01-0406-100 for details.

CGL - 03/18/2024

U - Result is less than the SwRI Reporting Limit (RL)

Prepared by: NAVA, RAMIRO Date: 01/26/2024

Reviewed by: SPIES, RADONNA Date: 02/05/2024

Program version(8/11/2011)

pH 9040C

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20240229-A008 (Ver. 1)
Status: CONSUMED

Customer: EnergySolutions, LLC
Project: 28282.01.001
SDG: 717463 Final
Task Order: 240229-6
Instrument: Accumet 50 pH
Start Time: 02/28/2024 13:30:00
Analyte Test: pH 9040C
Analysis Method: pH 9040C (TAP: TAP 01-0406-100)
Reagent: (pH) Buffer 4.0 #253583; exp 1/31/25, (pH) buffer 7.0 #256209; exp 1/4/25, (pH) buffer 10.0 #237526; exp 3/2/25, Buffer 2.0 #235664; exp 1/31/25, Buffer 12.45 #229241; exp 8/30/24
Equipment: ATC (pH; AN#023600)
Batch Note: pH result compensated to 25°C, Curve Status (PASS)

		pH at 25°C			
Sample Identification	Client Identification	1st pH reading (s.u.)	2nd pH reading (s.u.)	pH (s.u.)	Temp (C)
4.00	NA	4.00	NA	4.00	21.5
7.00	NA	7.01	NA	7.01	21.5
10.00	NA	10.00	NA	10.00	21.8
ICV ①	NA	9.39	9.43	9.43	21.0
717507	PB-LSC-F1	5.82	5.81	5.81	23.0
717508	PB-LSC-F2	5.63	5.62	5.62	22.9
717509	PB-LSC-F3	5.63	5.65	5.65	22.5
717510	PB-LSC-F4	5.72	5.72	5.72	22.4
717503	PB-Gamma-F1	6.40	6.42	6.42	22.9
717504	PB-Gamma-F2	5.74	5.73	5.73	22.6
717505	PB-Gamma-F3	5.95	6.01	6.01	22.4
717506	PB-Gamma-F4	5.26	5.28	5.28	22.3
717467	708887-LSC-F1	8.46	8.50	8.50	22.6
717468	708887-LSC-F2	8.44	8.45	8.45	22.1
CCV 1 ①	NA	9.40	9.42	9.42	20.4
717469	708887-LSC-F3	8.51	8.52	8.52	21.8
717470	708887-LSC-F4	8.50	8.52	8.52	21.9
717463	708887-Gamma-F1	8.42	8.44	8.44	22.4
717464	708887-Gamma-F2	8.42	8.43	8.43	22.4
717465	708887-Gamma-F3	8.38	8.41	8.41	22.4
717466	708887-Gamma-F4	8.44	8.45	8.45	22.5
717475	708888-LSC-F1	8.55	8.55	8.55	22.4
717476	708888-LSC-F2	8.49	8.50	8.50	22.1
717477	708888-LSC-F3	8.49	8.49	8.49	22.9
717478	708888-LSC-F4	8.50	8.50	8.50	21.8
CCV 2 ①	NA	9.53	9.53	9.53	21.9
717471	708888-Gamma-F1	8.48	8.48	8.48	22.2
717472	708888-Gamma-F2	8.49	8.50	8.50	22.7
717473	708888-Gamma-F3	8.47	8.48	8.48	22.6
717474	708888-Gamma-F4	8.47	8.48	8.48	22.5
717483	708889-LSC-F1	8.51	8.53	8.53	22.4
717484	708889-LSC-F2	8.50	8.52	8.52	22.2
717485	708889-LSC-F3	8.51	8.53	8.53	22.3
717486	708889-LSC-F4	8.52	8.54	8.54	22.4
717479	708889-Gamma-F1	8.43	8.44	8.44	22.5
717480	708889-Gamma-F2	8.44	8.45	8.45	22.4
CCV 3 ①	NA	9.54	9.54	9.54	21.1
717481	708889-Gamma-F3	8.45	8.42	8.42	22.2
717482	708889-Gamma-F4	8.45	8.46	8.46	22.4

U - Result is less than the SwRI Reporting Limit (RL)

Prepared by: NAVA, RAMIRO Date: 02/28/2024

Reviewed by: MOKEN, JAMES Date: 03/13/2024

pH 9040C

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20240229-A008 (Ver. 1)
Status: CONSUMED

Customer: EnergySolutions, LLC
Project: 28282.01.001
SDG: 717463 Final
Task Order: 240229-6
Instrument: Accumet 50 pH
Start Time: 02/28/2024 13:30:00
Analyte Test: pH 9040C
Analysis Method: pH 9040C (TAP: TAP 01-0406-100)
Reagent: (pH) Buffer 4.0 #253583; exp 1/31/25, (pH) buffer 7.0 #256209; exp 1/4/25, (pH) buffer 10.0 #237526; exp 3/2/25, Buffer 2.0 #235664; exp 1/31/25, Buffer 12.45 #229241; exp 8/30/24
Equipment: ATC (pH; AN#023600)
Batch Note: pH result compensated to 25°C, Curve Status (PASS)

		pH at 25°C			
Sample Identification	Client Identification	1st pH reading (s.u.)	2nd pH reading (s.u.)	pH (s.u.)	Temp (C)
CCV 4 ①	NA	9.58	9.57	9.57	21.0
12.45	NA	12.46	NA	12.46	21.7
CCV 5 ①	NA	9.60	9.60	9.60	21.7
717491	711291-LSC-F1	11.15	11.13	11.13	22.2
717492	711291-LSC-F2	11.21	11.20	11.20	22.1
717493	711291-LSC-F3	11.05	11.04	11.04	22.1
717494	711291-LSC-F4	11.19	11.19	11.19	21.9
717487	711291-Gamma-F1	8.80	8.79	8.79	22.9
717488	711291-Gamma-F2	8.69	8.66	8.66	22.2
717489	711291-Gamma-F3	8.71	8.69	8.69	22.2
717490	711291-Gamma-F4	8.92	8.88	8.88	22.1
CCV 6 ①	NA	9.58	9.59	9.59	21.2
717515	Tracer-LSC-F1	8.71	8.70	8.70	21.9
717516	Tracer-LSC-F2	8.67	8.68	8.68	21.9
717517	Tracer-LSC-F3	8.67	8.68	8.68	22.2
717518	Tracer-LSC-F4	8.66	8.67	8.67	22.0
717511	Tracer-Gamma-F1	8.56	8.58	8.58	22.5
717512	Tracer-Gamma-F2	8.55	8.56	8.56	22.2
717513	Tracer-Gamma-F3	8.59	8.59	8.59	22.2
717514	Tracer-Gamma-F4	8.52	8.54	8.54	22.2
717499	LCS-LSC-F1	9.46	9.44	9.44	23.0
717500	LCS-LSC-F2	9.60	9.48	9.48	22.0
CCV 7 ①	NA	9.55	9.46	9.46	20.7
717501	LCS-LSC-F3	9.56	9.45	9.45	21.9
717502	LCS-LSC-F4	9.79	9.76	9.76	21.9
CCV 8 ①	NA	9.53	9.54	9.54	21.0
2.00	NA	2.00	NA	2.00	21.7
CCV 9 ①	NA	9.52	9.52	9.52	21.0
717495	LCS-Gamma-F1	2.18	2.18	2.18	22.0
717496	LCS-Gamma-F2	2.16	2.12	2.12	22.5
717497	LCS-Gamma-F3	2.07	2.08	2.08	22.7
717498	LCS-Gamma-F4	2.08	2.06	2.06	22.0
CCV 10 ①	NA	9.39	9.41	9.41	21.1

U - Result is less than the SwRI Reporting Limit (RL)

Prepared by: NAVA, RAMIRO Date: 02/28/2024

Reviewed by: MOKEN, JAMES Date: 03/13/2024

pH 9040C

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20240229-A008 (Ver. 1)
Status: CONSUMED

Customer: EnergySolutions, LLC
Project: 28282.01.001
SDG: 717463 Final
Task Order: 240229-6
Instrument: Accumet 50 pH
Start Time: 02/28/2024 13:30:00
Analyte Test: pH 9040C
Analysis Method: pH 9040C (TAP: TAP 01-0406-100)
Reagent: (pH) Buffer 4.0 #253583; exp 1/31/25, (pH) buffer 7.0 #256209; exp 1/4/25, (pH) buffer 10.0 #237526; exp 3/2/25, Buffer 2.0 #235664; exp 1/31/25, Buffer 12.45 #229241; exp 8/30/24
Equipment: ATC (pH; AN#023600)
Batch Note: pH result compensated to 25°C, Curve Status (PASS)

		pH at 25°C			
Sample Identification	Client Identification	1st pH reading (s.u.)	2nd pH reading (s.u.)	pH (s.u.)	Temp (C)

① spiked 10 mL of pH Standard - 255670 (Lot# UNDEFINED, Source: UNDEFINED, Exp: 03/23/2026) with pH at 25°C at 9.41 s.u.

Comments:

pH range	Slope	Eff%
2.00 - 4.00	53.68	90.7
4.00 - 7.00	54.86	92.7
7.00 - 10.00	54.16	91.5
10.00 - 12.45	56.37	95.3

Initial calibration curve did not include pH buffers 2.00 and 12.45. See run log for when they were added.

Procedure:
See TAP 01-0406-100 for details.

CGL - 03/18/2024

U - Result is less than the SwRI Reporting Limit (RL)

Prepared by: NAVA, RAMIRO Date: 02/28/2024

Reviewed by: MOKEN, JAMES Date: 03/13/2024

Rad
Standard Logs Certs

Chemical Information Sheet

Carbon-14 130RadSol4

#252627

Grade:	Analytical
Type:	Working Level Solution
CAS:	- No Data -
Lot:	- No Data -
Received:	01/18/2024
Expiration:	01/18/2025
Location:	- No Data -
Current Lab:	Lab 46 Stds Bldg 70
Original Amount:	100 mL
Amount Remaining:	100
Supplier:	- No Data -
Concentration:	1000 uCi
Project:	- No Data -
PO Number:	- No Data -
Internal Lab ID:	- No Data -
Density:	1
Storage Requirement:	Ambient
Measuring Device ID:	- No Data -
Date Disposed:	- No Data -
Notes:	

Rad License:	
Rad License Line:	

Sources Table

ID	Source	Manufacturer	Lot	Amount
251670	Sodium Bicarbonate [Carbon-14]	REVVITY	3240472	1 ml
252626	0.1 M Sodium Hydroxide			10 ml

Solvent Table

ID	Solvent	Manufacturer	Lot	Amount
	DI Water			

Component Table

Compound	Conc/Activity	CAS	Rad License	License Line
Sodium Bicarbonate [Carbon-14]	10 uCi			
Sodium Hydroxide	0.3932 ug/uL	1310-73-2		

*CGL 03/27/2024**

**CGL = Computer Generated Line out*

Created by wnaegeli on 1/18/2024 8:57:46 PM.

--- No Secondary Review ---

SwRI CIMS ID: 251670

Sodium Bicarbonate, [^{14}C]-

Product Number:

NEC086H

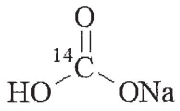
LOT SPECIFIC INFORMATION

Lot Number: 3240472

Specific Activity: 58 mCi/mmol

2146 MBq/mmol

Production Date: 01-DEC-2023



M.W. 84.0
$CHNaO_3$

PACKAGING: 1.0 mCi/ml (37 MBq/ml) steri-packaged in glass ampoules containing aqueous solution, pH 9.5.

STABILITY AND STORAGE: Dilute solutions of sodium bicarbonate, [^{14}C]- in sterile water have been found to be extremely stable when stored at 5°C (not frozen).

SPECIFIC ACTIVITY RANGE: 40-60 mCi/mmol (1480-2220 MBq/mmol)

IMPORTANT: Since the sodium bicarbonate, [^{14}C]- solutions are thermally sensitive, the following procedure for using the product is recommended:

1) Shake ampoule just prior to opening.
2) Gently tap ampoule to remove any solution remaining in the head.
3) Open ampoule while still cold.

FAILURE TO FOLLOW THE ABOVE DIRECTIONS MAY RESULT IN THE INCOMPLETE RECOVERY OF SODIUM BICARBONATE, [^{14}C]-

NOTE: Ensure dilution solvent is basic, and previously degassed with an inert gas. If solution needs to be diluted, the bulk must be stored in an air-tight closed vial under inert gas. Aliquoting the solution into an acidic solvent will result in significant radioactivity loss as gaseous carbon dioxide [^{14}C]-.

HAZARD INFORMATION: WARNING: This product contains a chemical known to the state of California to cause cancer.

SwRI CIMS ID: 251670

SwRI CIMS ID: 251670

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NEC086H-R Rev01

SwRI CIMS ID: 251670
SwRI CIMS ID: 251670
SwRI CIMS ID: 251670

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www.revvity.com

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Chemical Information Sheet

Cesium-137 114RadSol4

#243497

Grade:	Analytical
Type:	Working Level Solution
CAS:	- No Data -
Lot:	- No Data -
Received:	09/19/2023
Expiration:	09/19/2024
Location:	Bldg 70 Lab 55 Std counter
Current Lab:	Lab 46 Stds Bldg 70
Original Amount:	100 mL
Amount Remaining:	100
Supplier:	- No Data -
Concentration:	
Project:	- No Data -
PO Number:	- No Data -
Internal Lab ID:	- No Data -
Density:	1
Storage Requirement:	Ambient
Measuring Device ID:	- No Data -
Date Disposed:	- No Data -
Notes:	

Rad License:	
Rad License Line:	

Sources Table

ID	Source	Manufacturer	Lot	Amount
238819	Hydrochloric Acid Trace Metals	Fisher Scientific	24002385	10 ml
241881	Cesium	Inorganic Ventures	U2-CS732927	1 ml
242064	Cesium-137	Eckert & Ziegler Isotope Product	7137 2389-91-1	5.00054 g

Component Table

Compound	Conc/Activity	CAS	Rad License	License Line
Cesium-137	4.86552542 ug/mL	10045-97-3		
Cesium	10 mg/L	7440-46-2		
Hydrochloric Acid Trace Metals	3.5 %	7647-01-0		

*CGL 03/27/2024**

**CGL = Computer Generated Line out*

Created by wnaegeli on 9/19/2023 4:28:38 PM.

--- No Secondary Review ---

Eckert & Ziegler
Isotope Products

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661 309 1010
Fax 661 257 8303

SwRI CIMS ID: 242064

CERTIFICATE OF CALIBRATION
GAMMA STANDARD SOLUTION

Radionuclide:	Cs-137	**Customer:**	SOUTHWEST RESEARCH INSTITUTE
Half-life:	30.17 ± 0.16 years	**P.O. No.:**	R39915MM
Catalog No.:	7137	**Reference Date:**	1-Sep-23 12:00 PST
Source No.:	2389-91-1	**Contained Radioactivity:**	97.30 **µCi** 3600 **kBq**

Physical Description:

A.	Mass of solution:	5.00054 g in 5 mL flame-sealed ampoule
B.	Chemical form:	CsCl in 0.1M HCl
C.	Carrier content:	10 µg Cs/mL of solution
D.	Density:	0.9996 g/mL @ 20°C

Radioimpurities:

None detected

Radionuclide Concentration: 19.46 µCi/g, 720.0 kBq/g

Method of Calibration:

This source was assayed using a pressurized well type ionization chamber.

Uncertainty of Measurement:

A.	Type A (random) uncertainty:	± 0.2 %
B.	Type B (systematic) uncertainty:	± 3.0 %
C.	Uncertainty in aliquot weighing:	± 0.0 %
D.	Total uncertainty at the 99% confidence level:	± 3.0 %

Notes:

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- This solution has a recommended working life of 5 years.

Daniel James Van Dalsem — Quality Control

17-Aug-23 — Date

EZIP Ref. No.: 2389-91

SwRI CIMS ID: 242064

SwRI CIMS ID: 242064

Chemical Information Sheet

Cobalt-60 128RadSol4

#252625

Grade:	Analytical
Type:	Working Level Solution
CAS:	- No Data -
Lot:	- No Data -
Received:	01/18/2024
Expiration:	01/18/2025
Location:	- No Data -
Current Lab:	Lab 46 Stds Bldg 70
Original Amount:	100 mL
Amount Remaining:	100
Supplier:	- No Data -
Concentration:	99.743 uCi
Project:	- No Data -
PO Number:	- No Data -
Internal Lab ID:	- No Data -
Density:	1
Storage Requirement:	Ambient
Measuring Device ID:	- No Data -
Date Disposed:	- No Data -
Notes:	

Rad License:	
Rad License Line:	

Sources Table

ID	Source	Manufacturer	Lot	Amount
250998	Hydrochloric Acid Trace Metals	Fisher Scientific	24006976	5 ml
251671	Cobalt-60	Eckert & Ziegler Isotope Product	2427-24	5.01980 g

Solvent Table

ID	Solvent	Manufacturer	Lot	Amount
	DI Water			

Component Table

Compound	Conc/Activity	CAS	Rad License	License Line
Cobalt-60	5.00574456 ug/mL			
Hydrochloric Acid Trace Metals	1.75 %	7647-01-0		

*CGL 03/27/2024**

**CGL = Computer Generated Line out*

Created by wnaegeli on 1/18/2024 6:11:33 PM.

--- No Secondary Review ---

Eckert & Ziegler
Isotope Products

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661 309 1010
Fax 661 257 8303

SwRI CIMS ID: 251671

CERTIFICATE OF CALIBRATION
GAMMA STANDARD SOLUTION

Radionuclide:	Co-60	**Customer:**	SOUTHWEST RESEARCH INSTITUTE
Half-life:	5.272 ± 0.001 years	**P.O. No.:**	S39322SS
Catalog No.:	7060	**Reference Date:**	1-Jan-24 12:00 PST
Source No.:	2427-24	**Contained Radioactivity:**	99.72 **µCi** 3.690 **MBq**

Physical Description:

A. Mass of solution:	5.01980 g in 5 mL flame-sealed ampoule
B. Chemical form:	$CoCl_2$ in 0.1M HCl
C. Carrier content:	10 µg Co/mL of solution
D. Density:	0.9996 g/mL @ 20°C

Radioimpurities:

None detected

Radionuclide Concentration: 19.87 µCi/g, 0.7352 MBq/g

Method of Calibration:

This source was assayed using a pressurized well type ionization chamber.

Uncertainty of Measurement:

A. Type A (random) uncertainty:	± 0.2 %
B. Type B (systematic) uncertainty:	± 3.0 %
C. Uncertainty in aliquot weighing:	± 0.0 %
D. Total uncertainty at the 99% confidence level:	± 3.0 %

Notes:

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- This solution has a recommended working life of 5 years.

David James VanDalsem
Quality Control

16-Dec-23
Date

EZIP Ref. No.: 2427-24

SwRI CIMS ID: 251671

SwRI CIMS ID: 251671

Chemical Information Sheet

Europium-152 126RadSol4

#252624

Grade:	Analytical
Type:	Working Level Solution
CAS:	- No Data -
Lot:	- No Data -
Received:	01/18/2024
Expiration:	01/18/2025
Location:	- No Data -
Current Lab:	Lab 46 Stds Bldg 70
Original Amount:	100 mL
Amount Remaining:	100
Supplier:	- No Data -
Concentration:	103.11 uCi
Project:	- No Data -
PO Number:	- No Data -
Internal Lab ID:	- No Data -
Density:	1
Storage Requirement:	Ambient
Measuring Device ID:	- No Data -
Date Disposed:	- No Data -
Notes:	

Rad License:	
Rad License Line:	

Sources Table

ID	Source	Manufacturer	Lot	Amount
250998	Hydrochloric Acid Trace Metals	Fisher Scientific	24006976	5 ml
251672	Europium-152	Eckert & Ziegler Isotope Product	2427-25	5.02733 g

Solvent Table

ID	Solvent	Manufacturer	Lot	Amount
	DI Water			

Component Table

Compound	Conc/Activity	CAS	Rad License	License Line
Europium-152	5.18317723 ug/mL			
Hydrochloric Acid Trace Metals	1.75 %	7647-01-0		

CGL 03/27/2024*

*CGL = Computer Generated Line out

Created by wnaegeli on 1/18/2024 5:56:59 PM.

--- No Secondary Review ---

Eckert & Ziegler
Isotope Products

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661 309 1010
Fax 661 257 8303

SwRI CIMS ID: 251672

CERTIFICATE OF CALIBRATION
GAMMA STANDARD SOLUTION

Radionuclide:	Eu-152	**Customer:**	SOUTHWEST RESEARCH INSTITUTE
Half-life:	4933 ± 11 days	**P.O. No.:**	S39323SS
Catalog No.:	7152	**Reference Date:**	1-Jan-24 12:00 PST
Source No.:	2427-25	**Contained Radioactivity:**	103.1 **µCi** 3.815 **MBq**

Physical Description:

A.	Mass of solution:	5.02733 g in 5 mL flame-sealed ampoule
B.	Chemical form:	$EuCl_3$ in 0.5M HCl
C.	Carrier content:	10 µg Eu/mL of solution
D.	Density:	1.0077 g/mL @ 20°C

Radioimpurities:

Eu-154 = 0.547%; Gd-153 = 0.462% on 1-Jan-24

Radionuclide Concentration: 20.51 µCi/g, 0.7589 MBq/g

Method of Calibration:

This source was prepared from a weighed aliquot of solution whose activity in µCi/g was determined using gamma ray spectrometry.

Peak energy used for integration:	344.3 keV
Branching ratio used:	0.266 gammas per decay

Uncertainty of Measurement:

A.	Type A (random) uncertainty:	± 0.3 %
B.	Type B (systematic) uncertainty:	± 3.0 %
C.	Uncertainty in aliquot weighing:	± 0.2 %
D.	Total uncertainty at the 99% confidence level:	± 3.0 %

Notes:

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- This solution has a recommended working life of 5 years.

Daniel James VanDalsem — Quality Control

16-Dec-23 — Date

EZIP Ref. No.: 2427-25

SwRI CIMS ID: 251672

SwRI CIMS ID: 251672

Chemical Information Sheet

Strontium-85 116RadSol4

#243501

Grade:	Analytical
Type:	Working Level Solution
CAS:	- No Data -
Lot:	- No Data -
Received:	09/19/2023
Expiration:	09/20/2024
Location:	Bldg 70 Lab 55 Std counter
Current Lab:	Lab 46 Stds Bldg 70
Original Amount:	100 mL
Amount Remaining:	100
Supplier:	- No Data -
Concentration:	
Project:	- No Data -
PO Number:	- No Data -
Internal Lab ID:	- No Data -
Density:	1
Storage Requirement:	Ambient
Measuring Device ID:	- No Data -
Date Disposed:	- No Data -
Notes:	

Rad License:	
Rad License Line:	

Sources Table

ID	Source	Manufacturer	Lot	Amount
227019	Sodium	Inorganic Ventures	T2-NA717221	0.01 ml
229190	Rubidium	Inorganic Ventures	T2-RB725288	0.25 ml
229930	Strontium	Inorganic Ventures	T2-Sr724435	0.1 ml
232587	Calcium	Inorganic Ventures	T2-CA724685	0.1 ml
238812	Nitric Acid Trace Metals	Fisher Scientific	24001085	10 ml
241515	Strontium-85	Los Alamos National Laboratory	22-7-1-Sr82 (Sr-85)	0.093 ml

Solvent Table

ID	Solvent	Manufacturer	Lot	Amount
	DI Water			

Component Table

Compound	Conc/Activity	CAS	Rad License	License Line
Strontium-85	79.143 Ci/Kg			
Strontium	10 mg/L	7440-24-6		
Nitric Acid Trace Metals	6.86 %	7697-37-2		
Sodium	1 mg/L	7440-23-5		
Calcium	10 mg/L	7440-70-2		
Rubidium	2.5 mg/L	7440-17-7		

*CGL 03/27/2024**

**CGL = Computer Generated Line out*

Created by wnaegeli on 9/19/2023 5:00:42 PM.

--- No Secondary Review ---

Isotope Production and Application Program
P.O. Box 1663, Mailstop J975
Los Alamos, NM 87545

Certificate of Analysis

Strontium-85

Batch ID: 22-7-1-Sr82 (Sr-85)
Release Date: Friday, August 25, 2023
Retest Date: Monday, October 23, 2023
**All values are calculated to 0800 MST.*

Property	Specification		On Assay Date: 6/15/2023		Decayed to Calibration Date: 8/16/2023	
Chemical Form	Strontium (II) in 0.1 N HCl		Strontium (II) in 0.1 N HCl			
Activity Concentration of Primary Isotope	$[^{85}Sr]$ > 0.05 mCi/mL		1.64	mCi/mL	0.85	mCi/mL
Specific Activity	> 10 mCi/mg		165.2	mCi/mg	85.1	mCi/mg
Radionuclidic Purity	> 99%		98.38	%	99.22	%
Activity concentration of minor isotopes		^{82}Sr	0.023	mCi/mL	0.004	mCi/mL
		^{83}Rb	0.004	mCi/mL	0.002	mCi/mL
		Other Isotopes	ND			

Stable Element Concentrations (µg/mL)						
Sr =	9.93	Al =	ND	Ba =	ND	
Ca =	10.42	Cd =	ND	Co =	ND	
Cr =	ND	Cu =	ND	Fe =	ND	
Mg =	ND	Mn =	ND	Mo =	ND	
Na =	0.81	Ni =	ND	Pb =	ND	
Rb =	2.44					

Comments: In order to reduce evaportion, the product was diluted to a total volume of approximately 100 µL. The numbers on this certificate reflect the numbers of the product as it is in the shipping vial. Dilution factor = 4.02

Quality Unit Signatory: X Christopher Henning Digitally signed by Christopher Henning Date: 2023.08.09 12:05:04 -06'00'

Verifier: X Guy Dutech Digitally signed by Guy Dutech Date: 2023.08.09 12:47:15 -06'00'

SwRI CIMS ID: 241515
SwRI CIMS ID: 241515
SwRI CIMS ID: 241515

ATTACHMENT 4

Revised Pages for FCS LTP Chapters 1, 5, and 6

6 Pages Follow

At the beginning of the Pleistocene period, the Missouri River Valley and its main tributaries were established in their approximate present positions. Subsequently, under successive glacial movements, the valleys were filled and re-opened several times. During this period, the Peorian loess was deposited on the terraces and adjacent uplands. It is probable that only the upper part of the alluvium in the Missouri River Valley is actually of recent age and that deeper deposits are mostly of Pleistocene age.

According to the [5] and [6], unconsolidated sediments at the plant site generally range from 65 to 75 feet in thickness. The soils are typically interstratified and cross-bedded. These soils may be grouped generally into two units:

- an upper fine-grained sandy clay with silt approximately 20 to 50 feet thick
- an underlying fine to coarse sand with some gravel, extending down to the relatively flat-lying carbonate bedrock surface at a depth of approximately 65 to 75 feet below ground surface (bgs).

The upper units represent former river deposits and are not likely continuous, but rather have preferential channels formed by paleo-oxbow deposits.

Pennsylvanian-aged limestone and shale (bedrock) of the Kansas City Formation are encountered below the overburden soils. The bedrock below the site consists of various types of limestone formations.

1.3.6 Hydrology

According to EA12-010, "Post 2011 Flood Geotechnical Assessment" [7], groundwater at the site is in hydraulic communication with the adjacent Missouri River with the water table ranging from 2 to 20 feet bgs depending on the river stage. However, according to the “Review of the Groundwater Protection Program at the Fort Calhoun Nuclear Station” [8], under typical conditions, the depth to groundwater is approximately 15 to 20 feet bgs. Both soil units identified in Section 1.3.5 are water bearing with the deeper unit exhibiting a higher hydraulic conductivity. The hydraulic gradients below the site are relatively flat with relatively slow groundwater velocity.

Water levels taken at the site show that the groundwater gradients are nearly flat with only a gentle slope toward the river about 10 feet below the ground surface. Water levels at the site varied from elevations 993.7 to 992.4 feet, while the river levels recorded during this same period ranged from elevations 993.2 to 992.4 feet. Groundwater levels vary with changes in the river level. The rate of groundwater flow in the alluvial soils varies with the permeability; however, the groundwater flow rate, or velocity, is very slow due to the low gradients. The coefficient of permeability varied from about one-half to three feet per day in the upper sandy silt and silty sand. In the lower fine-to-coarse sands and gravels, coefficients of permeability as high as 20 feet per day were measured.

According to the DSAR, groundwater flow directions have been reported to be both toward the Missouri River (northeasterly) and away from the Missouri River (south-southwesterly). The groundwater in the saturated zone under the site is in strong communication with the stage level

of the Missouri River, i.e., the groundwater flows both towards the river and away from the river depending on whether the river stage is declining or rising. This results in a bank storage effect.

Next to the plant structures, a reverse osmosis (RO) water treatment plant withdrew groundwater to be used at the plant. This groundwater withdrawal caused a cone of depression and altered groundwater flow locally. The extraction well was located at the northwest corner of the old warehouse slab. Testing during the well installation documented that the aquifer may produce approximately 500 gallons per minute (gpm). The production well was in service as of August 2007, continuously pumping about 200 gpm and was subsequently removed from service in 2018. Measurements of groundwater flow indicated that within 600 feet of the RO well, groundwater flow was toward the RO well (i.e., southwest).

A search for active wells was conducted of nearby properties and concentrated in the flood plain approximately 2.5 miles upstream and 4.5 miles downstream from the FCS site. A review of the well databases revealed that there are 31 domestic/private wells, seven geothermal heating wells, 13 irrigation wells, 6 public water wells (for recreation areas), 27 environmental monitoring wells, and 4 commercial/industrial wells within the search area (Haley & Aldrich, Inc. memorandum to Energy*Solutions*, LLC., April 13, 2021) [9].

1.3.7 Surface Waters

The FCS site is bounded on the north by a portion of the Blair Bend of the Missouri River. USACE maintains river structures to prevent further meandering of the channel within the alluvial flood plain; the structures take the form of pile dikes and revetments. There are six dams upstream that control the river flow. The nearest structure to the site is at Gavin's Point, and the most distant structure is Fort Peck. There are no dams, locks, or similar structures on the Missouri River downstream of the plant site.

Fish Creek is an intermittent drainage stream that runs along the west side of the ISFSI and switchyard. This stream discharges into a larger wetland before flowing in the Missouri River.

Two sanitary lagoons are located in the east portion of the site. An application area is located to the south of the lagoons for disposal of lagoon water. Although detectable Cs-137 has been found in the sludge from these lagoons, licensed radioactivity has not been detected in the lagoon water. The FCS site surface water features are shown on Figure 1-5.

The site has been flooded several times, with the most recent events occurring in 2019. The most impactful flooding occurred in 2011, where the river overflowed its banks for several months. The flood stage from that event and its impacts to the site are shown on Figure 1-6.

In 2020, OPPD installed a HESCO barrier around the site to mitigate flooding during decommissioning. The barriers are sand and gravel filled fabric-lined metal cages that range from 5 to 10 feet in height. Approximately 8,000 linear feet of barrier was installed at the locations identified on Figure 1-7. The portion of the barrier that runs between the Intake Structure and Turbine Building will be erected in the future, if necessary. The HESCO barrier will likely be dismantled upon the completion of decommissioning activities.

Potential future groundwater doses due to residual radioactivity left on-site at license termination (e.g., in land areas, basements, etc.) are separately addressed through the modeling and DCGLs established for each respective media remaining on-site.

Identify the Inputs to the Decision – Historical and current groundwater monitoring results will be used to establish groundwater ROCs for FSS and to determine trends in detection.

10% of samples per sampling cycle will be counted for the full initial suite of radionuclides in Table 5-2. If positive results from plant derived radionuclides are identified in these additional analyses, the planning team will evaluate the need for additional groundwater ROCs to be analyzed.

Positive detection of a groundwater ROC is defined as an analytical result above the L_C, with considerations given to identifying false positive detections. Actual analytical results above L_C will be reported. The actual values for analytical results between L_C and MDC will be used for dose calculations.

As stated previously, results below L_C will be considered as zero.

- Define the Boundaries of the Study – The existing set of groundwater monitoring wells will represent the spatial monitoring boundary and will be used to identify existing residual radioactivity in groundwater. The FCS groundwater protection program currently includes 17 on-site groundwater monitoring wells. The program includes the sampling of all wells quarterly. The following is a breakdown of the analyses per the LT/FSS Groundwater Monitoring Program:
    - All seventeen wells are sampled quarterly for gamma emitters (Ce-144, Co-58, Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, and Sb-125), H-3, C-14, Sr-90, Fe-55, and Ni-63.
    - Two wells (10%) are sampled quarterly for the remaining radionuclides from the full list of radionuclides listed in Table 5-2 (Am-241, Cm-243/244, Ni-59, Np-237, Pu-238, Pu-239/240, Pu-241, and Tc-99).
    - One well is selected for duplicate analysis of gamma emitters, C-14, H-3, Sr-90, Fe-55, and Ni-63.

  Monitoring commenced in the 1st quarter of 2024 and will continue through the 3rd quarter of 2026, resulting in a total of 11 quarterly sampling events.
- Develop a Decision Rule – The decision rule is defined as: "If the combined compliance dose calculation, including the dose from the maximum positive groundwater monitoring values and all other media defined in the final compliance equation, results in a dose less than 25 mrem/year to the AMCG, then the site is considered acceptable to be released for unrestricted use."
- Specify Limits on Decision Errors – Groundwater monitoring results will be tracked, and fluctuations or trends over time will be evaluated to demonstrate that residual radioactivity concentrations in water are stable or decreasing. The groundwater ROCs at

(bedrock) of the Kansas City Formation are encountered below the overburden soils. The bedrock below the site consists of various types of limestone formations.

6.2.2 Hydrogeology

From technical support document (TSD) 21-001, "Historical Site Assessment for Fort Calhoun Station" (HSA) [2] and the "Defueled Safety Analysis Report," (DSAR) [3] groundwater at the site is in hydraulic communication with the Missouri River with the water table ranging from 2-20 ft bgs depending on the river stage. Water levels taken in a series of borings drilled during July and August 1966 reveal that the ground water levels at the site varied from elevations 993.7-992.4 ft AMSL while the river levels recorded during this same period ranged from elevations 993.2-992.4 ft . Based on the gauging stations both upriver and downriver, located approximately 25 miles from the plant in each direction, the historical river stage varies widely and is prone to flooding. Water levels collected in June 2020 show that the groundwater elevations ranged from 993.5-995.5 ft, i.e., 10.5-8.5 ft bgs. Based on water level data collected in June 2020 and comparisons to the gage height of the Missouri River, the onsite water table is estimated to vary between approximately 10-15 ft bgs with periods of higher elevations corresponding to river stage.

Groundwater flow directions have been reported to be both toward the Missouri River (northeasterly) and away from the Missouri River (south-southwesterly) depending on the river stage. The groundwater in the saturated zone under the site is in strong communication with the stage level of the Missouri River, i.e., the groundwater flows both towards the river and away from the river depending on whether the river stage is declining or rising. This results in a bank storage effect. Based on the groundwater depth to water data and corresponding groundwater elevation data, groundwater contours are consistent with historical data and flow towards the river.

Horizontal hydraulic gradients at the site are nearly flat with relatively slow groundwater velocity with a gentle slope toward the Missouri River. Shallow and deep aquifer groundwater contours from June 2020 are presented in Figure 6-5 and Figure 6-6. From elevation data collected in June 2020 the approximate average gradient in both the shallow and deeper system was 0.0008 feet/foot.

Based on the classification of fine to medium sands and silts for the shallow soils, expected hydraulic conductivities for the shallow aquifer range from 10^{-5} cm/sec (or 10^{-1} ft per day) to 10^{-1} cm/sec (or 10^{-1} to 100 ft/day). Using the data collected from modified pumping tests and/or slug tests completed in June 2020, calculated hydraulic conductivities ranged from 9.4×10^{-3} to 1.8×10^{-2} cm/sec. The measured values are within the range for these types of soils. The calculated average hydraulic conductivity for the shallow aquifer is 4,352 m/yr. *In situ* falling head tests were completed at seven open borehole locations to determine the field coefficient of permeability (or hydraulic conductivity) of unsaturated soils (i.e., vadose zone). The average hydraulic conductivity of the unsaturated zone is 34.4 m/yr.

Using groundwater contours, horizontal hydraulic gradients, and hydraulic conductivity information, groundwater velocity data for the shallow and deeper aquifers were calculated. Groundwater velocity calculations are estimated from the June 2020 field measurements and contour plans where the flow direction is towards the Missouri River. The resulting velocity

calculations are therefore representative of this flow direction. Based upon the analysis, the groundwater velocities are very similar, with the shallow system ranging from 5.73-34.39 ft/yr and the deeper system ranging from 5.86-35.16 ft/yr.

6.2.3 Area Land Use

Area land use information is summarized from the "Hydrogeological Conceptual Site Model" and DSAR.

The plant site is located on the alluvial plain of the Missouri River in a predominantly agricultural region roughly 10 miles north of the Omaha metropolitan area. There are no residences within one-half mile of the site. An industrial park is located north of the plant property. Industries include a large corn processing facility, agricultural fertilizer storage facilities, and various other light industrial plants.

The DeSoto National Wildlife Refuge occupies approximately 7,821 acres east of the plant site. This area is open to the public for day use year-round. Visitors to the refuge generally use areas from two to five miles from the plant. The State of Nebraska operates the Fort Atkinson State Historic Park five and one-half miles southeast of the plant site. This day-use facility is mostly seasonal. The State of Iowa maintains Wilson Island State Park south of the DeSoto National Wildlife Refuge and four miles southeast of the plant site.

Two private facilities lie to the north of the plant along the Missouri River. The Cottonwood Cove Marina & RV Resort is located approximately four and one-half miles from the plant. River View Park Resort & Marina is a private campground lying directly to the south of Cottonwood Marina and ranging from four to four and one-half miles from the plant.

The nearest municipality is the city of Blair, Nebraska, about three miles northwest, with a population of 7,990 per the 2010 census. Fort Calhoun, Nebraska, is about five miles southeast of FCS. The 2010 census reported a population of 908 in Fort Calhoun and 167 in Kennard Village, about seven miles from the plant site.

The Omaha metropolitan area includes the cities of Omaha, Nebraska, and Council Bluffs, Iowa, and the adjoining areas of Douglas, Washington, and Sarpy Counties, Nebraska, and Pottawattamie County, Iowa. The area lies 10-25 miles southeast of the site, with the main concentration of population beyond 15 miles.

The U.S. Census data shows an increase in population in the Omaha metropolitan area and in most of the nearby cities but a decrease in the rural and farm population. While it is probable that the area around the plant site outside of the Omaha metropolitan area will remain largely agricultural and that the population will increase slowly, a general decline of the rural population will continue, reflecting the movement of people into towns and cities. The expansion of the Omaha metropolitan area has been generally south and westward, coinciding with the interstate highway. It is expected that future growth of the metropolitan area will continue south and west and also northwestward. Thus, it is probable that the area surrounding the plant site will continue to remain largely agricultural.

6.2.4 Area Groundwater Use

A search on the Nebraska Department of Natural Resources Permits & Registrations Division, Groundwater Section database and website and the Iowa Geological Survey website, yielded 31 active domestic/private wells and 13 irrigation wells. The well search was concentrated in the flood plain approximately 2.5 miles upstream and 4.5 miles downstream from the FCS site. There were several additional wells that are used for public water supply (for recreation areas), environmental monitoring, or commercial/industrial operations but these uses are not applicable to the compliance scenario conceptual model of residential farming (see Section 6.4.2).

Fifteen of the thirty-one domestic wells encountered either shale (6 wells between 130-255 ft bgs with an average static water level of approximately 137.7 ft bgs) or limestone (9 between 34-279 ft bgs with an average static water level of approximately 75.2 ft bgs). Each of the 31 screens were installed in sand or straddled a sand/clay interval. Of the 13 irrigation wells that were mainly located in Iowa, six encountered bedrock. The deepest irrigation well encountered shale at approximately 180 ft bgs and was screened in sandy clay from 165-175 ft bgs. The static water level for this well was approximately 148 ft bgs. Five other irrigation wells encountered limestone ranging from approximately 68-110 ft bgs. These wells had an average static water level of approximately 7.4 ft bgs. The bottom of the well screens ranged from 81-110 ft bgs.

6.3 End State at License Termination

The "end state" is defined as the configuration of the remaining below-ground basements, above-ground buildings, piping, and open land areas at the time of license termination. Chapter 3 of this license termination plan (LTP) provides a more detailed discussion of the FCS end state.

Six above-ground buildings will remain at the time of license termination: the Training Building, FLEX Building, Owner Controlled Area (OCA) Entrance Building, Switchyard 3451 Old Building, Switchyard 3451 New Building, and the 1251 Control and Switchgear Building. The Switchyard will also remain untouched by decommissioning. All other structures will be removed to a minimum of three ft below grade (approximately 1,001 ft AMSL). The basements of the Turbine Building, Containment Building, Auxiliary Building, Intake Structure, and Circulating Water Tunnels will remain with all interior walls removed, with the exception of the Turbine Building where the turbine pedestal will remain up to 3 ft below grade. All other structures will be removed in their entirety with the exception of the six above-ground buildings listed above. Once decommissioning activities are completed, as well as subsequent final status survey (FSS), each basement will be backfilled to grade level (approximately 1,004 ft AMSL). The general basement configurations, basement elevations, and surface areas are shown in Figures 6-7 to 6-17.

The end state will also include a range of buried and embedded pipes. The inventory of buried and embedded pipes to remain is provided in Omaha Public Power District (OPPD) calculations and position paper FC-21-002, "Description of Embedded Piping, Penetrations, and Buried Pipe to Remain in Fort Calhoun End State" [4].

OPPD added three rail lines to the rail spur to allow for the direct loading of waste into rail cars. The added rail lines will remain in place after license termination with the exception of the portion of the line that resides within the waste processing structure.